ALEXANDER'S

Fourteenth Edition

CARE OF THE PATIENT IN SURGERY

Jane C. Rothrock

MOSBY
ELSEVIER

evolve
learning system

evolve
learning system

REGISTER TODAY!

To access your Student Resources, visit:

http://evolve.elsevier.com/Rothrock/Alexander

Register today and gain access to:

- Competency Assessments
- Animations
- OR Live Links
- AHRQ Case Study Links
- Flash Cards
- Surgical Instrumentation Photos
- Printable Surgical Pharmacology Tables
- Printable Patient and Family Education Tables
- Content Updates
- Web Links

ELSEVIER

ALEXANDER'S

Fourteenth Edition

CARE OF THE PATIENT IN SURGERY

Jane C. Rothrock, PhD, RN, CNOR, FAAN
Professor and Director, Perioperative Programs
Delaware County Community College
Media, Pennsylvania

Associate Editor
Donna R. McEwen, RN, BSN, CNOR
Senior Educational Instructional Designer
OptumHealth Care Solutions
UnitedHealthcare
San Antonio, Texas

ELSEVIER
MOSBY

ELSEVIER
MOSBY

3251 Riverport Lane
St. Louis, Missouri 63043

ALEXANDER'S CARE OF THE PATIENT IN SURGERY, ed 14 ISBN: 978-0-323-06916-8

Copyright © 2011, 2007, 2003, 1999, 1995, 1991, 1987, 1983, 1978, 1972 by Mosby, Inc., an affiliate of Elsevier Inc.

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Permissions may be sought directly from Elsevier's Right Department: phone:(+1) 215'239 3804 (US) or (+44) 1865 843830 (UK); fax:(+44) 1865 853333; e-mail: healthpermissions@elsevier.com. You may also complete your request on-line via the Elsevier website at http://www.elsevier.com/permissions.

Notice

Knowledge and best practice in this field are constantly changing. As new research and experience broaden our knowledge, changes in practice, treatment, and drug therapy may become necessary or appropriate. Readers are advised to check the most current information provided (i) on procedures featured or (ii) by the manufacturer of each product to be administered, to verify the recommended dose or formula, the method and duration of administration, and contraindications. It is the responsibility of practitioners, relying on their own experience and knowledge of the patient, to make diagnoses, to determine dosages and the best treatment for each individual patient, and to take all appropriate safety precautions. To the fullest extent of the law, neither the Publisher nor the Author assumes any liability for any injury and/or damage to persons or property arising out of or related to any use of the material contained in this book.

The Publisher

Library of Congress Cataloging-in-Publication Data

Alexander's care of the patient in surgery.-- 14th ed./[edited by] Jane Rothrock; associate editor, Donna McEwen.
p. ; cm.
Other title: Care of the patient in surgery.
Includes bibliographical references and index.
ISBN 978-0-323-06916-8 (hardcover : alk. Paper) 1. Surgical nursing. 2.Therapeutics, Surgical. I. Alexander, Edythe Louise. II. Rothrock, Jane C., 1948- III. McEwen, Donna R. IV. Title: Care of the patient in surgery.
[DNLM: 1. Perioperative Nursing. 2. Nursing Care. 3. Operating Room Nursing. 4. Surgical Procedures, Operative -- nursing,WY 161 A3756 2011]
RD99.M387 2011
617'.0231–dc22 2010010606

Nursing Diagnoses—Definitions and Classifications 2009-2111 © 2009, 2007, 2005, 2003, 2001, 1998, 1996, 1994 Nanda International. Used by arrangement with Wiley-Blackwell Publishing, a company of John Wiley and Sons, Inc.

Acquisition Editor: Tamara Myers
Developmental Editor: Laura Selkirk
Design Direction: Karen Pauls
Cover Image: BSIP/PhototakeUSA.com

Printed in the United States of America
Last digit is the print number: 9 8 7 6 5 4 3 2

Working together to grow libraries in developing countries
www.elsevier.com | www.bookaid.org | www.sabre.org
ELSEVIER BOOK AID International Sabre Foundation

Contributors

Sheila L. Allen, RN, BSN, CNOR, CRNFA(E)
Self-Employed Educator, Consultant
Meeker, Colorado
Chapter 26: Geriatric Surgery

Gregory J. Artz, MD
Assistant Professor
Department of Otolaryngology—Head and Neck Surgery
Thomas Jefferson University
Philadelphia, Pennsylvania
Chapter 18: Otorhinolaryngologic Surgery

Kay A. Ball, PhD, RN, CNOR, FAAN
Perioperative Consultant/Educator
K&D Medical Inc.
Lewis Center, Ohio
Chapter 7: Surgical Modalities

Brian Blanchard, MSN, CRNP
Cardiothoracic Nurse Practitioner
Pennsylvania Hospital
Philadelphia, Pennsylvania
Chapter 22: Thoracic Surgery

Barbara A. Bowen, RN, MSN, CRNP, CRNFA
President
Perioperative Consulting & Surgical Services, LLC
Collegeville, Pennsylvania
Chapter 19: Orthopedic Surgery

Maya N. Clark, ACNP-BC
General Surgery Nurse Practitioner
Pennsylvania Hospital
Philadelphia, Pennsylvania
Chapter 12: Repair of Hernias

Susan M. Craig, RN, BSN, CNOR, RCT
Perioperative Nurse Educator
Seattle, Washington
Chapter 29: Integrated Health Practices: Complementary and Alternative Therapies

Linda M. DeLamar, CRNA, MSN, MS
Independent Contractor
Mount Laurel, New Jersey
Chapter 4: Anesthesia

Troy J. DeRose, CRNP, RNFA
Certified Registered Nurse Practitioner, RN First Assistant
Department of Otolaryngology
Thomas Jefferson University Hospital
Philadelphia, Pennsylvania
Chapter 18: Otorhinolaryngologic Surgery

Leigh Ann DiFusco, MSN, RN, CNOR
Clinical Nurse Specialist
The Children's Hospital of Philadelphia
Philadelphia, Pennsylvania
Chapter 25: Pediatric Surgery

Victoria Dreger, MSN, RN, MA, CNOR
Staff Nurse/Nurse Clinician III, Surgery Department
Advocate Christ Medical Center
Oak Lawn, Illinois
Chapter 17: Ophthalmic Surgery
Chapter 21: Plastic and Reconstructive Surgery

Kathleen A. Gross, MSN, RN, BC, CRN
Owings Mills, Maryland
Chapter 28: Interventional Radiology

Charlotte L. Guglielmi, RN, BSN, CNOR
Perioperative Nurse Specialist/Educator
Beth Israel Deaconess Medical Center
Boston, Massachusetts
Chapter 6: Sutures, Needles, and Instruments

Pauline Anne Heizenroth, RN, MSN, CNOR
Perioperative Nurse/Clinical Nurse Educator
Bryn Mawr Hospital Surgicenter
Bryn Mawr, Pennsylvania
Chapter 5: Positioning the Patient for Surgery

Diane L. Ferrara-Hoffman, MSN, CRNP, RNFA, APRN, BC
Nurse Practitioner, RN First Assistant for Neurosurgery
Thomas Jefferson University Hospital
Philadelphia, Pennsylvania
Chapter 20: Neurosurgery

Sheila Hunter, RN, MSN, CNOR
Unit-Based Educator—Perioperative Services
Beth Israel Deaconess Medical Center
Boston, Massachusetts
Chapter 6: Sutures, Needles, and Instruments

Sarah J. Krizman, RN, BSN, CNOR
OR Staff Nurse
Thomas Jefferson University Hospital
Philadelphia, Pennsylvania
Chapter 20: Neurosurgery

Helene Korey Marley, RN, CNOR, CRNFA
Clinical Service Coordinator, Urology
Pennsylvania Hospital
Philadelphia, Pennsylvania
Chapter 14: Genitourinary Surgery

Donna R. McEwen, RN, BSN, CNOR
Senior Educational Instructional Designer
OptumHealth Care Solutions
UnitedHealthcare
San Antonio, Texas
Chapter 8: Wound Healing, Dressings, and Drains
Chapter 13: Gynecologic and Obstetric Surgery

Ellen K. Murphy, MS, JD, FAAN
Professor Emerita, Milwaukee College of Nursing
University of Wisconsin
Milwaukee, Wisconsin
Chapter 2: Patient Safety and Risk Management

Janice A. Neil, RN, PhD
Associate Professor
East Carolina University
Greenville, North Carolina
Chapter 11: Surgery of the Liver, Biliary Tract, Pancreas, and Spleen

Lillian H. Nicolette, RN, MSN, CNOR
Sales Development Manager, Edwards Lifesciences
Faculty, Perioperative Nursing
Delaware County Community College
Media, Pennsylvania
Chapter 3: Infection Prevention and Control in the Perioperative Setting

Jan Odom-Forren, PhD, MS, RN, CPAN, FAAN
Perianesthesia Nursing Consultant
Louisville, Kentucky
Chapter 9: Postoperative Patient Care and Pain Management

Rebecca M. Patton, MSN, RN, CNOR
President
American Nurses Association
Silver Spring, Maryland
Chapter 30: Workplace Issues and Staff Safety

Elizabeth B. Pearsall, RN, BSN, CNOR, RNFA
Staff Nurse
Taylor Hospital
Ridley Park, Pennsylvania
Chapter 16: Breast Surgery

Jane C. Rothrock, PhD, RN, CNOR, FAAN
Professor and Director, Perioperative Programs
Delaware County Community College
Media, Pennsylvania
Chapter 12: Repair of Hernias

Diane Catherine Saullo, RN, MSN, CNOR, BC
Manager Professional Development
New Hanover Regional Medical Center
Wilmington, North Carolina
Chapter 27: Trauma Surgery

Patricia C. Seifert, RN, MSN, CNOR, CRNFA, FAAN
Education Coordinator, Cardiovascular Operating Room
Inova Heart and Vascular Institute
Editor-in-Chief, *AORN Journal*
Falls Church, Virginia
Chapter 24: Cardiac Surgery

Christine E. Smith, RN, MSN, CNOR
Perioperative Clinical Nurse Specialist
Lucile Packard Children's Hospital at Stanford
Palo Alto, California
Chapter 10: Gastrointestinal Surgery

Victoria M. Steelman, PhD, RN, CNOR, FAAN
Advanced Practice Nurse
Department of Nursing
University of Iowa Hospitals & Clinics
Iowa City, Iowa
Chapter 1: Concepts Basic to Perioperative Nursing

Joanne C. Wentzell, RN, MSN, CNOR, CRNFA
Certified RN First Assistant
Gibbsboro, New Jersey
Chapter 15: Thyroid and Parathyroid Surgery

Patricia Wieczorek, MSN, RN, CNOR
Nurse Manager
The Johns Hopkins Hospital
Baltimore, Maryland
Chapter 23: Vascular Surgery

Clinical Consultants

D. Greg Anderson, MD
Associate Professor of Orthopaedic Surgery
Thomas Jefferson University
Philadelphia, Pennsylvania

Nicole Armstrong, RN, BSN, CMSRN
Registered Nurse
Thomas Jefferson University Hospital
Philadelphia, Pennsylvania

Larry L. Asplin, RN, MSN, CNOR
Clinical Director, Surgery and Sterile Processing
St. Cloud Hospital
St. Cloud, Minnesota

Kristine Biggie, RN, MSN, CRNP, CCRN
Pediatric Trauma Nurse Practitioner, Pediatric Trauma Program
The Children's Hospital of Philadelphia
Philadelphia, Pennsylvania

James W. Collins, PhD, MSME
Associate Director for Science
Division of Safety Research, National Institute for Occupational Safety and Health
Centers for Disease Control and Prevention
Morgantown, West Virginia

Debra Coston, RN, CCRN
Coordinator AHA Program, Staff Nurse STICU
New Hanover Regional Medical Center
Wilmington, North Carolina

Cynthia L. Danko, RN, MSN
Director, Surgical Services
Hillcrest Hospital
Mayfield Heights, Ohio

Beth Fitzgerald, RN, MSN, CNOR
Perioperative Nurse Internship Manager
Christiana Care Health System
Wilmington, Delaware

Allen S. Gabroy, MD, FACS
Chairman, Department of Surgery
Taylor Hospital
Ridley Park, Pennsylvania

Jerome B. Goldstein, MD, FACOG
Senior Attending, OB/GYN Department
Crozer-Keystone Health System
Upland, Pennsylvania

Ahmed Gomad, MD, ScD, MSPH
Medical Officer, Surveillance Branch
Division of Surveillance Hazard Evaluation and Health Studies
National Institute for Occupational Safety and Health
Centers for Disease Control and Prevention
Cincinnati, Ohio

Paula Graling, RN, MSN, CNS, CNOR
Clinical Nurse Specialist, Perioperative Services
Inova Fairfax Hospital
Past President of Association of periOperative Registered Nurses
Falls Church, Virginia

Joseph F. Harryhill, MD, FACS
Assistant Clinical Professor of Urology
Penn Urology at Pennsylvania Hospital
Philadelphia, Pennsylvania

Vesna Milica Hess, BSN, MSN, CRNP, CRNFA
Acute Care Nurse Practitioner
Certified Registered Nurse First Assistant
Thomas Jefferson University Hospital
CEO, Certified Perioperative Services, LLC
Philadelphia, Pennsylvania

Nancy L. Hughes, MS, RN
Director, Center for Occupational and Environmental Health
American Nurses Association
Silver Spring, Maryland

Rama D. Jager, MD
Assistant Professor, Department of Surgery
University of Illinois Chicago
Chicago, Illinois

Janine Jagger, MPH, PhD
Professor of Medicine
Director, International Healthcare Worker Safety Center
University of Virginia Health System
Charlottesville, Virginia

Ramasamy Kalimuthu, MD, FACS
Visiting Professor and Section Chief, Microsurgery Plastic Division
University of Illinois Chicago
Chicago, Illinois
Chief, Division of Plastic Surgery
Advocate Christ Medical Center
Oak Lawn, Illinois

Susan N. Kamerling, RN, MSN, BC
Family Services Coordinator, Perioperative Services
The Children's Hospital of Philadelphia
Philadelphia, Pennsylvania

Amy L. Kennedy, RN, MSN, CNOR
Surgical Technology Program Director
Harrisburg Area Community College
Harrisburg, Pennsylvania

Joy C. Kerr, RNFA, BSN, CNOR
RNFA—Division of Urology
The Children's Hospital of Philadelphia
Philadelphia, Pennsylvania

Mary Lou Kubu, RN, BSN, CNOR
Perioperative Education Coordinator
University Hospitals Case Medical Center
Cleveland, Ohio

Ivy Fenton Kuhn, PNP-BC, CNOR
Nurse Practitioner, Division of Ophthalmology
The Children's Hospital of Pennsylvania
Philadelphia, Pennsylvania

Linda Cunningham Lawler, RN, BSN
Family Services Coordinator
The Children's Hospital of Philadelphia
Philadelphia, Pennsylvania

Maureen Lewis, RN, BSN, CNOR, RNFA
RN First Assistant for Orthopedics
Riddle Memorial Hospital
Media, Pennsylvania
Adjunct Faculty
Delaware County Community College
Media, Pennsylvania

Patrick J. Loynd, DNP, CRNA
Associate Program Director, School of Nurse Anesthesiology
Nazareth Hospital
Philadelphia, Pennsylvania

Maureen Murphy, RN
Perioperative RN
Thomas Jefferson University Hospital
Philadelphia, Pennsylvania

Audrey L. Nelson, PhD, RN, FAAN
Director, HSR&D REAP
James A. Haley VA Medical Center
Tampa, Florida

Cheryl Osmian, CCLS
Child Life Specialist
The Children's Hospital of Philadelphia
Philadelphia, Pennsylvania

Roni L. Robinson, RN, MSN, CRNP
Nurse Practitioner
Philadelphia, Pennsylvania

Thomas R. Saullo, MD
Third Year Resident, Physical Medical Rehab
Cornell/Columbia Presbyterian Hospital
New York, New York

Beverly B. Schuler, RN, BSN
Patient Care Manager
Lucile Packard Children's Hospital
Palo Alto, California

Mary Jean Schumann, MSN, MBA, RN, CPNP
Chief Programs Officer
American Nurses Association
Silver Spring, Maryland

Susan Scully, RN, BSN, CNOR
General, Thoracic, and Fetal Surgery Specialty Nurse, Clinical Level IV
Children's Hospital of Philadelphia
Philadelphia, Pennsylvania

Katie Elaine Slavin, MS, RN
Senior Staff Specialist, Center for Occupational and Environmental Health
American Nurses Association
Silver Spring, Maryland

Benjamin H. Ticho, MD
Eye & Ear Infirmary
University of Illinois
Chicago, Illinois

Raj K. Verma, RN
Ophthalmology Specialty Nurse
The Children's Hospital of Philadelphia
Philadelphia, Pennsylvania

Thomas R. Waters, PhD, CPE
Research Safety Engineer
National Institute for Occupational Safety and Health
Cincinnati, Ohio

Mitchell Winter, RN, BSN
Operating Room Staff Nurse, Neurosurgery
Thomas Jefferson University Hospital
Philadelphia, Pennsylvania

Reviewers

Mike Aldridge, MSN, RN, CCRN, CNS
Instructor of Clinical Nursing, School of Nursing
The University of Texas
Austin, Texas

Alice Erskine, RN, MSN, CNOR
Professor, Surgical Technology Program
Science, Math & Technology Department
Skyline Community College
San Bruno, California

Rachel Hottel, MSN, RN, CNOR
Advanced Practice Nurse, Perioperative Division
University of Iowa Hospitals & Clinics
Iowa City, Iowa

Christina Keels, CST, RN
Surgical Technology Program Director
Central Carolina Technical College
Sumter, South Carolina

Tom Lescarbeau, BS, CFA, CST
Program Coordinator, Surgical Technology
McCann Technical School
North Adams, Massachusetts

Elizabeth A. Matos, PhD, MSN, BSN, CNE
Assistant Professor, Department of Nursing
West Texas A & M University
Canyon, Texas

Jill E. Roofner, CST, RN, CNOR
Clinical Coordinator, Surgical Technology Program
Durham Community Technical College
Durham, North Carolina

Victoria M. Steelman, PhD, RN, CNOR, FAAN
Advanced Practice Nurse, Department of Nursing
University of Iowa Hospitals & Clinics
Iowa City, Iowa

Herman Young, BS, BM, CST/CFA
Program Director Surgical Technology, Health Professions
Oakland Community College
Southfield, Michigan

About the Author

JANE C. ROTHROCK, PhD, RN, CNOR, FAAN

To Alan,
partner and good friend,
for whom I have much love and gratitude.
Thank you seems so inadequate,
but I'll say it anyway:
thank you, thank you, thank you
for your love, support,
encouragement, and patience.
I'm so grateful for the affection, respect,
loyalty, and sense of humor we share.
May Mary-Mom smile down
on us as we grow even closer
over the coming years.

Dr. Jane Rothrock has practiced and taught perioperative nursing since 1969. In 1979 she joined the faculty of Delaware County Community College, where she is now Professor and Director of Perioperative Programs. Her responsibilities include entry-level, postbasic RN education for perioperative nursing and advanced skill preparation for RN first assistants. These courses are offered both in Pennsylvania and at various sites nationally, within host institutions. During her 30-year tenure at the college, Jane has helped to educate more than 3600 registered nurses in the professional practice of perioperative patient care.

Jane's decades of experience include not only as a faculty member but also as an author and speaker. She has taught at the University of Pennsylvania, been an OR Director, and served as the preceptor for many graduate students. She has authored 5 perioperative nursing textbooks, published more than 50 articles, and presented a host of topics to nursing audiences across the United States and internationally. Jane is an AORN past president, served in 1996-1997 as the Chair of the AORN Project Team on Professional Practice Issues, chaired the AORN Project Team on a Professional Practice Model for Perioperative Nursing in 1998-1999, and chaired the Perioperative Academic Curriculum Task Force in 2006. She has received a number of distinguished awards, and is very active in both nursing and community organizations. Jane is a past vice chair of NOLF, a past member of the ANCC Magnet Commission, a past president of the ASPAN Foundation, and a past president of the AORN Foundation Board of Trustees. She served on ASPAN's first National Clinical Guideline Panel to develop a Guideline on Prevention of Unplanned Hypothermia in Adult Surgical Patients. In 2000 Jane became a Fellow of the American Academy of Nursing (FAAN). She currently serves as an "Ask the Expert" for Medscape Nursing, and is a co-editor of *Tea & Toast for the Perioperative Nurse's Spirit*, a book of inspirational stories published in 2006.

Jane began her nursing education with a diploma from Bryn Mawr School of Nursing. She received her BSN and MSN from the University of Pennsylvania and was the first recipient of a doctoral degree from Widener University in suburban Philadelphia, earning her PhD in nursing in 1987.

Preface

The fourteenth edition of *Alexander's Care of the Patient in Surgery* has been updated to reflect new concepts in perioperative nursing practice and increased sophistication and complexity of surgical procedures. The multimedia resource, first introduced in the thirteenth edition, enhances the elemental goal of this textbook: to provide a comprehensive basic reference that will assist perioperative practitioners to meet the needs of the patients they care for safely, cost-effectively, and efficiently during surgical interventions.

The standard in perioperative nursing for more than 50 years, *Alexander's Care of the Patient in Surgery* is written primarily for professional perioperative nurses, but it is also useful for nursing students, surgical technologists, healthcare industry representatives, medical students, interns, residents, and government officials concerned with healthcare issues. Perioperative nurses, RN first assistants, clinical nurse specialists, nurse practitioners, surgeons, surgical technologists, and educators from many geographic areas of the United States have served as contributors and reviewers for this text, providing a vast range of perioperative nursing knowledge and procedural information.

This thoroughly revised edition highlights current techniques and innovations in surgery. Hundreds of illustrations, including many new photographs and drawings, help familiarize the reader with new procedures, methods, and equipment. Classic illustrations, particularly of surgical anatomy, have been preserved to enhance the text. New to this edition, clinical chapters now include Ambulatory Surgical Considerations, Risk Reduction Strategies, and Rapid Response Team applications. Best Practices, featured in previous editions, have been updated, and retitled Evidence for Practice.

As with previous editions, there are updated Research Highlights, Sample Plans of Care, Patient and Family Education features, Surgical Pharmacology features, Patient Safety features, and History boxes in each clinical chapter, so that readers can look back, as well as forward, as they explore perioperative patient care.

Enhanced in the fourteenth edition is the *Evolve web site*. With its learner resources, readers are now able to access content updates, surgical instrumentation photos, printable surgical pharmacology tables, printable patient and family education materials, resources for surgical technology students, and web links to surgical procedure videos.

Also improved in the fourteenth edition are resources for instructors and clinical educators. In addition to the learner resources listed previously, there are instructor resources containing a lesson plan for each chapter with the following elements: a pretest, suggested background assessment of learners, critical thinking questions, learning objectives, suggested content for lectures and class activities, PowerPoint lecture slides, an image collection of more than 950 images, and animations to use in teaching. Instructors and clinical educators will also find a test bank with 800 questions as well as more than 50 competency assessments for use in clinical settings or simulation laboratories as learners practice new perioperative nursing skills and techniques. Overall, this textbook imparts state-of-the-art information and resources that reflect contemporary practice and promotes the delivery of comprehensive perioperative patient care.

Unit I, *Foundations for Practice*, provides information on basic principles and patient care requisites deemed essential to the care of all recipients of perioperative patient care. The nursing process, a model for developing therapeutic nursing interventional knowledge, reflects a six-step process that includes the identification of desired patient outcomes. Interest in patient outcomes and their improvement continues to be an essential element of nursing. The collection of health data requires clear identification of contributions to patient outcomes and quantification of these contributions. Perioperative nurses must continue to link their interventions to outcomes. This relationship is presented in Chapter 1 and explicated in each Sample Plan of Care throughout the text. Research Highlights continue to be included in every chapter, reflecting the steady increase in the amount and quality of research relevant to perioperative patient care. As current findings of new research are important to use in clinical practice, the editors and authors of *Alexander's Care of the Patient in Surgery* are committed to supporting this research-practice relationship. The Research Highlights will help perioperative nurses implement research findings in their practice and patient care activities. Chapter 1 also sets the stage for an emphasis on patient and family education and discharge planning throughout the text. Chapters in Units II and III address specific patient and family education and discharge planning relevant for patients undergoing one or more of the respective specialty surgical procedures. As the responsibilities of perioperative nurses become greater with regard to those important care components, it is imperative that we effectively educate patients and families. With the length of stay in healthcare facilities continuing to decrease, patients and families must be informed and prepared to deal appropriately with postoperative needs after discharge. Pain management, addressed in Chapter 9, is also reflected in many of the chapters on surgical specialties, as all perioperative nurses recognize its importance in patient discharge planning.

Chapter 2 has been refocused on both patient safety and risk management. New chapters have been added on interventional radiology and workplace safety. As perioperative nurses and surgical technologists face increasing workloads and workplace stress, this fourteenth edition emphasizes the need for workplace safety. When pressure in the surgical suite mounts, nurses and surgical technologists may feel the need to work faster, even if it means taking shortcuts. The chapter on workplace safety stresses the need for personal safety at work.

The chapters within Unit II, *Surgical Interventions*, include more than 400 contemporary and traditional specialty surgical interventions, with descriptions of both minimally invasive surgical procedures and robotic-assisted surgery. Each chapter provides a helpful review of pertinent anatomy and details the steps of surgical procedures. Perioperative nursing considerations are again presented within the nursing process framework. Current NANDA International–approved nursing diagnoses and Sample Plans of Care for each surgical specialty aim to help perioperative nurses plan, implement, and evaluate individualized perioperative patient care. Each of these chapters also provides an example of Evidence for Practice related to the surgical specialty. In 2010 and beyond, perioperative nurses can expect to find a continuing emphasis on evidence-based nursing as a means to provide care that is effective and yields improved outcomes. The integration of evidence-based practice with the perioperative nurse's individual clinical expertise leads to optimal care provision, the foundation of perioperative patient care. Improving the quality of patient care and effecting safe outcomes are at the heart of all of our efforts to achieve excellence in whatever setting we encounter the patient undergoing an operative or other invasive procedure.

Incorporation of Surgical Pharmacology in the fourteenth edition continues to reflect the ongoing emphasis on medication safety in the United States. *Alexander's Care of the Patient in Surgery* joins the nationwide health professional education campaign aimed at reducing the number of common but preventable sources of medication errors. Providing information about select medications used in surgical specialties, the Surgical Pharmacology features are intended to promote safe medication practices among perioperative practitioners to help avoid serious, even potentially fatal, consequences of medication errors. Medication errors can occur anywhere in the medication-use system, from prescribing to administering a drug. Other areas covered in the Surgical Pharmacology feature address the use of written medication orders, recommendations for read-back and repeat-back reports, and suggestions for proper labeling of medications on and off the sterile field, as well as uses, dosages, and other information regarding perioperative medications.

To further facilitate the perioperative nurse's focus on safe patient care, Patient Safety features in each chapter succinctly review a practice to assist perioperative practitioners in developing a core body of knowledge about safe patient care. We intend this feature not only to raise awareness about patient safety applications but also simultaneously to foster communication and ongoing dialogue in perioperative practice settings regarding application of recommended patient safety strategies and use of robust process improvement initiatives, all to improve quality and safety.

The unique needs of pediatric, geriatric, and trauma surgery patients are presented in Unit III, *Special Considerations*. The chapter *Integrated Health Practices: Complementary and Alternative Therapies* was introduced in the twelfth edition. Perioperative nurses frequently encounter patients who use such therapies, some of which are nonpharmacologic and some of which involve medications. This chapter explores alternative medical systems, mind-body interventions, biologically based therapies, manipulative and body-based methods, and energy therapies. Numerous treatments and systems within each category are discussed.

Many expert perioperative practitioners, RN first assistants, clinical nurse specialists, and educators have contributed to this fourteenth edition, and I owe a debt of gratitude to all of them for sharing their expertise in the development of this text. I give special thanks to my partner, Alan Zulick, for his help during copy-edits and page proofs. I also acknowledge the valuable assistance of editors, reviewers, photographers, and illustrators who have contributed their time and expertise to the revision of this text. The team I had the privilege of working with at Elsevier is talented and eager to support perioperative practitioners in their commitment to excellence in patient care.

Alexander's Care of the Patient in Surgery is written by and for perioperative nurses. Its premise is underscored by the clear understanding that perioperative nursing is a caring and intellectual endeavor, requiring critical thinking, technical acumen, and clinical decision-making to improving patient outcomes. With the multimedia package accompanying this fourteenth edition, *Alexander's Care of the Patient in Surgery* invites you to walk with us as we meet the challenges and opportunities of perioperative nursing in this new decade of the twenty-first century.

Jane C. Rothrock

Contents

Unit I: Foundations for Practice

1 Concepts Basic to Perioperative Nursing, 1

Overview of Perioperative Nursing Practice, 1
Standards of Perioperative Nursing Practice, 3
Evidence-Based Practice, 12
Performance Improvement, 13
Perioperative Nursing Roles, 15

2 Patient Safety and Risk Management, 18

Safety As an Individual Responsibility, 18
Concentrated Emphasis on Systems, 18
Major Association Safety Activities, 19
Perioperative Nursing Safety Issues, 23
Patient Rights, 45

3 Infection Prevention and Control in the Perioperative Setting, 48

Causes of Infection, 48
Controlling Infection, 57
Aseptic Practices to Control Infection, 85

4 Anesthesia, 111

History of Anesthesia, 111
Anesthesia Providers, 111
Patient Safety, 113
Environmental Noise, 113
Awareness During Anesthesia, 113
Preoperative Preparation, 114
Types of Anesthesia Care, 117
Perioperative Monitoring, 118
Anesthesia Machines and Anesthetic Gases, 121
General Anesthesia, 123
Regional Anesthesia, 133
Monitored Anesthesia Care (MAC), 137
Conscious Sedation/Analgesia, 137
Local Anesthesia, 138
Pain Management, 138
Temperature Control, 139
Malignant Hyperthermia (MH), 140
Perioperative Nursing Considerations, 141

5 Positioning the Patient for Surgery, 144

Overview, 144
Anatomic and Physiologic Considerations, 144
PERIOPERATIVE NURSING CONSIDERATIONS, 158
OR Beds, 160
Standard Surgical Positions, 162

6 Sutures, Needles, and Instruments, 174

Suture Materials, 174
Surgical Needles, 180
Packaging, Storage, and Selection of Sutures, 182
Suturing Techniques/Wound Closures, 183
Hemostasis, 185
Perioperative Nursing Considerations, 188
Instruments, 193

7 Surgical Modalities, 204

Minimally Invasive Surgery Overview, 204
Video Technology, 217
Practices and Potential Risks During MIS, 224
Energies Used During Surgery, 226

8 Wound Healing, Dressings, and Drains, 250

Anatomy, 250
Etiology of Wounds, 250
Types of Wound Closure, 250
Phases of Healing, 251
Factors Affecting Wound Healing, 253
Wound Classification, 254
Antimicrobial Prophylaxis, 257
Nursing Diagnoses, 257
Patient and Family Education and Discharge Planning, 258
Wound Management, 258
Dressings, 263
Drains, 265

9 Postoperative Patient Care and Pain Management, 267

Perianesthesia Considerations, 267
Discharge from the PACU, 286
Admission to the Surgical or Short Procedure Unit, 286
Postoperative Nursing Considerations, 286
Patient and Family Education and Discharge Planning, 292

Unit II: Surgical Interventions

10 Gastrointestinal Surgery, 295

SURGICAL ANATOMY, 295
PERIOPERATIVE NURSING CONSIDERATIONS, 299

SURGICAL INTERVENTIONS, 311
Abdominal Incisions, 311
Laparotomy, 315
Laparoscopy, 317
Intraoperative Intraperitoneal Chemotherapy, 320
Endoscopic Procedures, 320
Surgery of the Esophagus, 323
Surgery of the Stomach, 327
Bariatric Surgery, 336
Surgery of the Small Bowel, 338
Surgery of the Colon, 342
Surgery of the Rectum, 352

11 Surgery of the Liver, Biliary Tract, Pancreas, and Spleen, 357
SURGICAL ANATOMY, 357
PERIOPERATIVE NURSING CONSIDERATIONS, 361
SURGICAL INTERVENTIONS, 371
Surgery of the Biliary Tract, 371
Surgery of the Pancreas, 381
Surgery of the Liver, 387
Surgery of the Spleen, 393

12 Repair of Hernias, 396
SURGICAL ANATOMY, 396
PERIOPERATIVE NURSING CONSIDERATIONS, 400
SURGICAL INTERVENTIONS, 406
Surgery for Repair of Groin Hernias, 406
Surgery for Repair of Hernias of the Anterior Abdominal Wall, 415

13 Gynecologic and Obstetric Surgery, 419
SURGICAL ANATOMY, 419
Female External Genital Organs (Vulva), 419
Pelvic Cavity, 419
Bony Pelvis, 422
Pelvic Floor, 423
PERIOPERATIVE NURSING CONSIDERATIONS, 423
Lasers in Gynecologic Surgery, 431
SURGICAL INTERVENTIONS, 433
Vulvar Surgery, 433
Gynecologic Surgery Using Vaginal Approach, 435
Gynecologic Surgery Using Minimally Invasive Techniques, 448
Gynecologic Surgery Using Abdominal Approach, 455
Surgery for Conditions That Affect Fertility, 462
Assisted Reproductive Therapies for Infertility, 466
Obstetric Surgery, 467
Abdominal Surgery During Pregnancy, 473

14 Genitourinary Surgery, 478
SURGICAL ANATOMY, 478
PERIOPERATIVE NURSING CONSIDERATIONS, 482
SURGICAL INTERVENTIONS, 493
Interventional Uroradiology, 493
Diagnostic and Endoscopic Procedures, 495
Surgery of the Penis and the Urethra, 499
Surgery of the Scrotum and Testicles, 506
Surgery of the Prostate Gland, 511
Surgery of the Bladder, 535
Surgery of the Ureters and Kidneys, 551

15 Thyroid and Parathyroid Surgery, 566
SURGICAL ANATOMY, 566
PERIOPERATIVE NURSING CONSIDERATIONS, 567
SURGICAL INTERVENTIONS, 577
Unilateral Thyroid Lobectomy, Subtotal Lobectomy, Bilateral Subtotal Lobectomy, Near-Total Thyroidectomy, and Total Thyroidectomy, 577
Substernal or Intrathoracic Thyroidectomy, 582
Minimally Invasive Thyroidectomy, 582
Thyroglossal Duct Cystectomy, 583
Neck Dissection, 584
Parathyroidectomy, 585

16 Breast Surgery, 588
SURGICAL ANATOMY, 588
Benign Lesions of the Breast, 588
Breast Cancer, 589
Screening Technologies, 592
Diagnostic Techniques, 593
Surgical Treatment Options, 594
PERIOPERATIVE NURSING CONSIDERATIONS, 597
SURGICAL INTERVENTIONS, 602
Biopsy of Breast Tissue, 602
Incision and Drainage for Abscess, 603
Lumpectomy (Segmental Resection), 603
Sentinel Lymph Node (SLN) Biopsy, 603
Axillary Node Dissection, 605
Subcutaneous Mastectomy, 606
Simple Mastectomy, 606
Modified Radical Mastectomy, 606

17 Ophthalmic Surgery, 610
SURGICAL ANATOMY, 610
PERIOPERATIVE NURSING CONSIDERATIONS, 614
SURGICAL INTERVENTIONS, 628
Surgery of the Globe and Orbit, 628
Surgery of the Lacrimal Gland and Apparatus, 631
Surgery of the Eyelids, 633
Surgery of the Conjunctiva, 637
Surgery of the Cornea, 637

Surgery of the Lens, 641
Surgery for Glaucoma, 645
Vitreoretinal Surgery, 647
Laser Treatment in Diabetic Retinopathy, 649
Vitrectomy, 649

18 Otorhinolaryngologic Surgery, 657
SURGICAL ANATOMY, 657
External, Middle, and Inner Ear, 657
Nasal Anatomy, 659
Throat Anatomy, 660
Proximal Structures, 664
PERIOPERATIVE NURSING CONSIDERATIONS, 664
SURGICAL INTERVENTIONS, 680
Otologic Procedures, 680
Rhinologic (Nasal) Procedures, 692
Oral Cavity/Laryngologic/Neck Procedures, 699
Endoscopic Procedures, 705
Open Neck and Laryngeal Procedures, 707

19 Orthopedic Surgery, 719
SURGICAL ANATOMY, 719
PERIOPERATIVE NURSING CONSIDERATIONS, 728
SURGICAL INTERVENTIONS, 743
Allografts/Autografts, 743
Electrical Stimulation, 744
Fractures and Dislocations, 745
Surgery of the Shoulder, 750
Surgery of the Humerus, Radius, and Ulna, 754
Surgery of the Hand, 760
Surgery of the Hip and Lower Extremity, 761
Surgery of the Lower Leg (Distal Femur, Tibia, and Fibula), 768
Surgery of the Ankle and Foot, 776
Pelvic Fracture and Disruption, 780
Total Joint Arthroplasty, 781
Arthroscopy, 800
Surgery of the Spine, 809

20 Neurosurgery, 818
SURGICAL ANATOMY, 818
Brain and Adjacent Structures, 818
Spine, Spinal Cord, and Adjacent Structures, 835
PERIOPERATIVE NURSING CONSIDERATIONS, 844
SURGICAL INTERVENTIONS, 861
Minimally Invasive and Specialized Neurosurgery Techniques, 861
Surgical Approaches to the Brain, 864
Surgery of the Brain and Cranium, 865
Surgery of the Spine, 875
Peripheral Nerve Surgery, 882

21 Plastic and Reconstructive Surgery, 885
SURGICAL ANATOMY, 885
PERIOPERATIVE NURSING CONSIDERATIONS, 886
SURGICAL INTERVENTIONS, 897
Removal of Skin Cancers, 897
Burn Surgery, 899
Excisional Debridement, 902
Treatment of Pressure Ulcers, 902
Diabetic Foot Conditions, 903
Skin and Tissue Grafting, 904
Reconstructive Breast Surgery, 907
Microsurgery, 911
Reconstructive Maxillofacial Surgery, 914
Gender Reassignment, 918
Aesthetic Surgery, 918

22 Thoracic Surgery, 936
SURGICAL ANATOMY, 936
PERIOPERATIVE NURSING CONSIDERATIONS, 938
SURGICAL INTERVENTIONS, 947
Endoscopy (Diagnostic or Therapeutic), 947
Lung Surgery, 956

23 Vascular Surgery, 969
SURGICAL ANATOMY, 969
Arterial Disease, 971
Venous Disease, 975
PERIOPERATIVE NURSING CONSIDERATIONS, 976
SURGICAL INTERVENTIONS, 985
Abdominal Aortic Aneurysm Resection, 985
Endovascular Abdominal Aortic Aneurysm Repair, 987
Percutaneous Transluminal Angioplasty, 989
Femoral-Popliteal and Femoral-Tibial Bypass, 990
Femoral-Popliteal Bypass in situ, 991
Femorofemoral Bypass, 991
Arterial Embolectomy, 992
Amputation, 992
Carotid Endarterectomy (CEA), 994
Carotid Endarterectomy with Shunt, 995
Arteriovenous Fistula, 996
Vena Cava Filter Insertion, 998
Varicose Vein Excision and Stripping, 998

24 Cardiac Surgery, 1002
SURGICAL ANATOMY, 1002
PERIOPERATIVE NURSING CONSIDERATIONS, 1008
SURGICAL INTERVENTIONS, 1047
Extracorporeal Circulation Procedures, 1047
Pericardiectomy, 1051
Surgery for Coronary Artery Disease, 1051
Surgery for Heart Failure, 1058

Surgery for the Mitral Valve, 1058
Surgery for the Tricuspid Valve, 1063
Surgery for the Pulmonary Valve, 1065
Surgery for the Aortic Valve, 1065
Surgery for the Thoracic Aorta, 1066
Assisted Circulation, 1072
Heart and Heart-Lung Transplantation, 1076
Surgery for Conduction Disturbances, 1077

Unit III: Special Considerations

25 Pediatric Surgery, 1085
Pediatric Surgical Anatomy, 1085
Psychologic Development, 1086
PERIOPERATIVE NURSING CONSIDERATIONS, 1086
SURGICAL INTERVENTIONS, 1096
Vascular Access, 1096
Minimally Invasive Surgery, 1097
Bariatric Surgery, 1100
General Surgery—Gastrointestinal Procedures, 1101
General Surgery—Hernias, 1108
General Surgery—Abdominal Procedures, 1111
General Surgery—Resection of Tumors, 1113
Genitourinary Surgery, 1115
Otorhinolaryngologic Procedures, 1125
Neurosurgical Procedures, 1127
Orthopedic Procedures, 1129
Plastic and Reconstructive Surgery, 1131
Trauma, 1141
Surgery for Congenital Heart Disease, 1145

26 Geriatric Surgery, 1157
PERIOPERATIVE NURSING CONSIDERATIONS, 1158
SURGICAL INTERVENTIONS, 1177
Common Surgical Procedures in Geriatric Patients, 1177
Additional Considerations, 1180

27 Trauma Surgery, 1182
PERIOPERATIVE NURSING CONSIDERATIONS, 1184
SURGICAL INTERVENTIONS, 1204
Damage Control Surgery, 1204
Injuries of the Head and Spinal Column, 1205
Injuries of the Face, 1209
Injuries of the Eye, 1209
Injuries of the Neck, 1209
Injuries of the Chest and Heart, 1209
Injuries of the Abdomen, 1211
Injuries of the Genitourinary System, 1212
Skeletal Injuries, 1213
Hypothermia, 1214
Thermal Injuries, 1214
Organ and Tissue Procurement, 1215

28 Interventional Radiology, 1216
Radiology Nursing, 1216

29 Integrated Health Practices: Complementary and Alternative Therapies, 1240
History and Background, 1240
Major Categories of Complementary and Alternative Medicine, 1240
Complementary and Alternative Medicine Use and Surgery, 1243

30 Workplace Issues and Staff Safety, 1258
Ergonomics, 1258
Safe Patient Handling and Movement, 1258
Slips, Trips, and Falls, 1261
Sharps Safety and Bloodborne Pathogens, 1263
Personal Protective Equipment, 1265
Blunt Suture Needles, 1265
Responding to Exposure, 1265
A Culture of Safety, 1267
Waste Anesthetic Gases, 1267
Chemicals, 1273
Universal and Standard Precautions, 1274
Immunizations and Infectious Disease Exposure, 1276
Radiation Safety, 1277
Latex Allergy, 1278
Workplace Violence, 1279

Illustration Credits, 1283

Pharmacology Index, 1288

Index, 1290

UNIT I FOUNDATIONS FOR PRACTICE

CHAPTER 1

Concepts Basic to Perioperative Nursing

VICTORIA M. STEELMAN

OVERVIEW OF PERIOPERATIVE NURSING PRACTICE

Perioperative nursing is the nursing care provided to patients before, during, and after surgical and invasive procedures. Nurses practice this specialty in surgical suites, ambulatory surgery centers, endoscopy suites, laser centers, interventional radiology departments, mobile surgical units, and physicians' offices across the United States and the world. Perioperative nursing includes a broad array of cutting-edge innovations, such as remote surgery, virtual endoscopy, robotics, computerized navigation systems for neurosurgery, electronic medical records (EMR), transplanted tissue and organs, biologic materials that are absorbed to replace worn-out body parts, and radiofrequency identification (RFID). In this high-tech era, perioperative patient care is very different than it was in the past.

In the past, the term *operating room (OR)* nursing was used to describe the care of patients in the immediate preoperative, intraoperative, and postoperative phases of the surgical experience (Figure 1-1). This term implied that nursing care activities were circumscribed to the physical confines of the surgical suite. The term may have contributed to stereotypic images of the OR nurse who took care of the operating room and its equipment, but who had little if any interaction or nursing responsibility for medicated and anesthetized patients in the surgical suite. With such an image, nurses practicing outside the OR had difficulty crediting important elements of the nursing process and patient care accountability to the nurse who practiced "behind the double doors" of the surgical suite. Today, perioperative nursing implies the delivery of comprehensive patient care within the preoperative, intraoperative, and postoperative periods of the patient's experience during operative and other invasive procedures, using the framework of the nursing process. In doing so the perioperative nurse assesses the patient—collects, organizes, and prioritizes patient data; establishes nursing diagnoses; identifies desired patient outcomes; develops and implements a plan of nursing care; and evaluates that care in terms of outcomes achieved by and for the patient (Figure 1-2). Throughout, the perioperative nurse functions both independently and interdependently. Like nurses in other specialties, the perioperative nurse collaborates with other healthcare professionals, makes appropriate nursing referrals, and delegates and supervises other personnel in providing safe and efficient patient care (Patient Safety).

When nurses practice perioperative nursing in its broadest scope, care may begin in the patient's home, a clinic, a physician's office, the patient care unit, the presurgical care unit, or the holding area. After the surgical or invasive procedure, care may continue in the perianesthesia care unit (PACU) and evaluation of patient outcomes may extend onto the patient care unit, in the physician's office, in the patient's home, in a clinic, or through written or telephone patient surveys.

When nurses practice perioperative nursing in its most limited sense, patient care activities may be confined to the common areas of the surgical suite. Assessment and data collection may take place in the holding area while evaluation may take place on discharge from the OR. Regardless of the way nurses practice perioperative nursing in a healthcare setting, it remains founded on the nursing process and professional nursing practice.

The perioperative nurse also functions as a patient advocate during times of vulnerability. This specialty requires a broad knowledge base, instant recall of nursing science, the intuitive ability to be guided by nursing experience, and diversity of thought and action, as well as both great stamina and flexibility. Whether a generalist or a specialist, the perioperative nurse depends on knowledge of surgical anatomy, physiologic alterations and their consequences for the patient, intraoperative risk factors, potentials for and prevention of patient injury, and psychosocial implications of surgery for the patient and family. This knowledge enables the perioperative nurse to anticipate needs of the patient and surgical team and to initiate safe and appropriate nursing interventions rapidly. This too is part of patient advocacy—that is, doing for the patient what needs to be done to provide a safe and caring environment. The Association of periOperative Registered Nurses (AORN, 2006) has asserted the significance of such safety by affirming that staffing of healthcare personnel must ensure that patients undergoing surgical and invasive procedures have a perioperative nurse as circulator in the OR, and also that the core activities of perioperative nursing care (assessment, diagnosis, outcome identification, planning, and evaluation) be completed by a perioperative nurse.

A significant part of perioperative nursing is the delivery of scientifically based care. Such care implies understanding the rationale for certain activities and interventions, knowledge of how and when to implement them, and the skills to evaluate safety, cost-effectiveness, and outcomes of the care delivered. Knowledge of anatomy, surgical procedures, instruments, and

PATIENT SAFETY

Never Events

The term "never event" was first introduced in 2001 by Ken Kizer, MD, former CEO of the National Quality Forum (NQF), to describe tragic medical errors, such as wrong-site surgery, that should never occur. The NQF initially defined 27 of these events. Over time, the list has been expanded to describe adverse events that are clearly identifiable and measurable, result in death or significant disability, and are usually preventable.

Healthcare facilities are under increasing pressure to eliminate these preventable medical errors completely. In August 2007 the Centers for Medicare & Medicaid Services (CMS) announced that Medicare would no longer pay for the treatment of *never events*. Many states have now mandated reporting of these events when they occur, and additional states mandate reporting of serious adverse events, including many of the NQF *never events*. Healthcare facilities are accountable for investigating and correcting the system problems that contribute to these events. Some states require that a review called a "root cause analysis" be performed after an event and results reported.

Perioperative nurses play a key role in prevention of many *never events*, including:

- Surgery performed on the wrong body part
- Surgery performed on the wrong patient
- Wrong surgical procedure performed on a patient
- Unintended retention of a foreign object in a patient after surgery or other procedure
- Intraoperative or immediately postoperative death in an American Society of Anesthesiologists Class I patient
- Patient death or serious disability associated with the use of contaminated drugs, devices, or biologics provided by the healthcare facility
- Patient death or serious disability associated with the use or function of a device in patient care, in which the device is used for functions other than as intended
- Patient death or serious disability associated with intravascular air embolism that occurs while receiving care in a healthcare facility
- Patient death or serious disability associated with a medication error (e.g., errors involving the wrong drug, wrong dose, wrong patient, wrong time, wrong rate, wrong preparation, or wrong route of administration)
- Patient death or serious disability associated with a hemolytic reaction attributable to the administration of ABO/HLA-incompatible blood or blood products
- Stage 3 or 4 pressure ulcers acquired after admission to a healthcare facility
- Any incident in which a line designated for oxygen or other gas to be delivered to a patient contains the wrong gas or is contaminated by toxic substances
- Patient death or serious disability associated with a burn incurred from any source while receiving care in a healthcare facility
- Patient death or serious disability associated with a fall while receiving care in a healthcare facility

From U.S. Department of Health & Human Services, Agency for Healthcare Research & Quality: *Never events,* available at www.psnet.ahrq.gov/primer.aspx?primerID=3. Accessed March 5, 2009; National Quality Forum: *Serious reportable events in healthcare 2006 update: a consensus report,* available at www.psnet.ahrq.gov/resource.aspx?resourceID=5363. Accessed March 5, 2009; National Quality Forum (NQF): *Safe practices for better healthcare—2009 update: a consensus report,* Washington, DC, 2009, Author; Medicare says it won't cover hospital errors, *New York Times,* August 19, 2007, available at www.nytimes.com/2007/08/19/washington/19hospital.html?_r=1. Accessed March 5, 2009.

FIGURE 1-1 Thomas Eakins, *The Agnew Clinic,* 1889. In this painting, reforms and advancements in surgical techniques and procedures are apparent. Surgeons wear gowns, instruments are sterilized, ether is used, and the patient is covered. An OR nurse is a prominent member of the team.

equipment is essential when implementing nursing care. This knowledge empowers the perioperative nurse to anticipate and prepare for the next steps of the surgical procedure and understand their concomitant implications for the patient and for the surgical team. Scientific nursing interventions and caring, comforting behaviors are at the heart of perioperative nursing. Unit II focuses on surgical procedures common to inpatient and ambulatory settings. Each chapter in Unit II contains a *Sample Plan of Care* with suggested nursing interventions. A fundamental assumption throughout this textbook is that perioperative nursing is a blend of technical and behavioral care and that critical thinking is the underpinning for doing and caring for patients professionally. Good clinical judgment derives from critical thinking (Fesler-Birch, 2005). Critical thinking requires purposeful, outcomes-directed thought and is driven by patient need. It is based on the nursing process and nursing science. Further, critical thinking requires knowledge, skills, and experience, guided by professional standards and ethics and grounded in constant reevaluation, self-correction, and continual striving to improve.

Perioperative Patient Focused Model

The AORN has developed a model to describe the important relationship between the patient and the perioperative nursing care provided. The *Perioperative Patient Focused Model* (AORN, 2009a) (Figure 1-3) consists of domains or areas of nursing

Assessment…	Review medical record, validate important findings, corroborate with patient. Analyze, interpret, and prioritize information.
Nursing Diagnosis…	Synthesize data collected; then label clinical judgment about the patient as a nursing diagnosis. Can be actual or risk for. Based on patient assessment and perioperative nurse's clinical judgment.
Outcome Identification…	Because perioperative nursing is largely preventive, generic outcomes have been identified that apply to all patients undergoing an operative or other invasive procedure. Additional outcomes are identified based on individual patient assessment and nursing diagnosis. Some outcomes are mutually formulated by the nurse and patient. Guide implementation of nursing interventions. Should be specific, realistic, and measurable.
Planning…	Incorporate information into a plan for the patient's care. Identify nursing interventions to achieve identified outcomes.
Implementation…	Carry out nursing plan of care. Gather equipment and supplies; participate in/guide/supervise patient preparation, transfer to OR bed, anesthesia induction, antimicrobial skin preparation, draping, patient positioning, monitoring of physiologic alterations during surgery, and patient discharge (transfer from OR bed, discharge to postanesthesia or postoperative unit).
Evaluation…	Determine whether outcomes were met; use outcome statements. Incorporate outcomes that have been met and those that are pending in report to nurse in postanesthesia care unit/ discharge area.

FIGURE 1-2 The steps of the nursing process are interrelated, forming a continuous cycle of thought and action.

concern: nursing diagnoses, nursing interventions, and patient outcomes. These domains are in continuous interaction with the health system that encircles the focus of perioperative nursing practice—the patient (AORN, 2007a).

Three of these domains—behavioral responses, patient safety, and physiologic responses—reflect phenomena of concern to perioperative nurses and comprise the nursing diagnoses, interventions, and outcomes that surgical patients or their families experience. The fourth domain, the health system, comprises the structural data elements and focuses on clinical processes and outcomes. When looking at the model, note the heavy line that indicates a differentiation between the health system and the patient.

The model as a whole illustrates the dynamic nature of the perioperative patient experience and the nursing presence throughout that process. Working in a collaborative manner with other members of the healthcare team and the patient, the nurse establishes outcomes, identifies nursing diagnoses, and provides nursing care. The nurse intervenes within the context of the healthcare system to help the patient achieve the highest attainable health outcomes (physiologic, behavioral, and safety) throughout the perioperative experience.

The *Perioperative Patient Focused Model* (AORN, 2009a) emphasizes the outcomes-driven nature of perioperative patient care. Perioperative nurses possess a unique understanding of desired outcomes that apply to all patients. In contrast to some nursing specialties in which nursing diagnoses are derived from signs and symptoms of a condition, much of perioperative nursing care is preventive in nature, based upon knowledge of inherent risks to patients undergoing surgical and invasive procedures. Perioperative nurses identify these risks and potential problems in advance and direct nursing interventions toward prevention of undesirable outcomes, such as injury and infection. Based upon an individual patient assessment, the nurse identifies relevant nursing diagnoses. This information guides the nursing interventions for each patient. From admission through discharge and home follow-up, the perioperative nurse plays a major role in managing the patient's care. Research based upon the *Perioperative Patient Focused Model* (AORN, 2009a) continues to test and validate the contributions of perioperative nurses to patient outcomes in the variety of settings in which the specialty is practiced.

STANDARDS OF PERIOPERATIVE NURSING PRACTICE

Perioperative nursing is a systematic, planned process—a series of integrated steps. For professional nursing, national standards establish the full expectations of the professional role within which the nurse practices. In the 1960s the American Nurses Association (ANA) engaged in standards development. First published in 1973, these standards have helped to shape nursing practice. Specialty nursing organizations, including the AORN, have worked with the ANA to develop their own standards and guidelines using the ANA framework. This collaboration has resulted in the use of common language and a consistent format for the profession.

Perioperative Nursing Practice Standards

The AORN (2009b) has developed a set of standards for perioperative nursing care (Box 1-1). These standards are authoritative statements that describe the responsibilities for which perioperative nurses are accountable. The standards represent a comprehensive approach to meeting the healthcare needs of surgical patients.

AORN's nursing standards are categorized within three overarching elements: structure, process, and outcome. The AORN (2009b) *Standards of Perioperative Administrative Practice* are *structure* standards that describe organizational characteristics, administrative and fiscal accountabilities, personnel qualifications, and facilities and environmental requirements. These standards provide authoritative guidance for professionals in

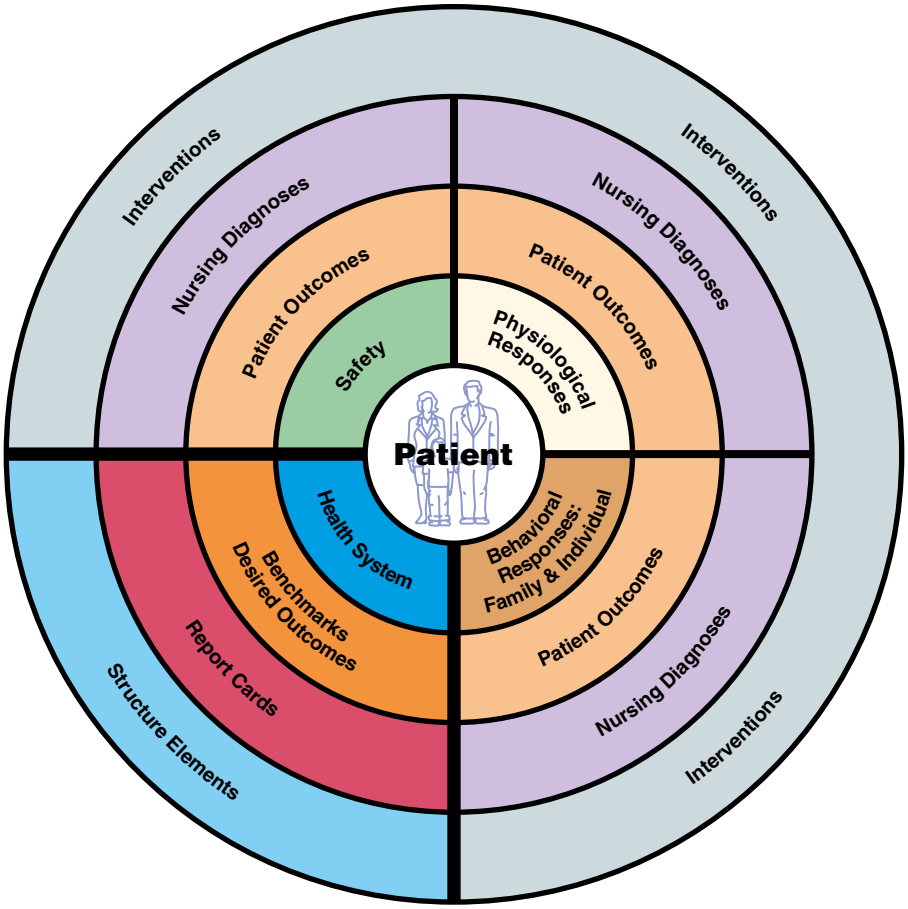


FIGURE 1-3 The AORN Perioperative Patient Focused Model.©

BOX 1-1

Standards of Perioperative Nursing Practice

Standards of Perioperative Administrative Practice
Standards of Perioperative Clinical Practice
Standards of Perioperative Professional Practice
Quality and Performance Improvement Standards for Perioperative Nursing
Perioperative Patient Outcomes

Association of periOperative Registered Nurses: *Perioperative standards and recommended practices,* Denver, 2009d, The Association.

administrative roles and provide the structure within which perioperative patient care should be provided.

Process standards relate to nursing activities, interventions, and interactions. They are used to explicate clinical, professional, and quality objectives in perioperative nursing. The AORN (2009b) process standards are the *Standards of Perioperative Clinical Practice, Standards of Perioperative Professional Practice,* and *Quality and Performance Improvement Standards for Perioperative Nursing.*

Standards of Perioperative Clinical Practice comprise the standards of care and professional performance (AORN, 2009b). The standards of care are based on and describe the application of the nursing process in perioperative nursing. The standards include the collection and analysis of health data, identification of expected outcomes, the planning and implementation of patient care, and evaluation of the effect of this care on patient outcomes.

The AORN (2009b) *Standards of Professional Practice* mandate, in part, that the perioperative nurse evaluate the effectiveness of nursing practice and the quality of that practice. Professional practice standards also require that perioperative nurses evaluate their own practice in relation to AORN's professional practice standards. Achieving certification (Certified Nurse, Operating Room [CNOR]), pursuing lifelong learning, and maintaining competency and current knowledge in perioperative nursing are the hallmarks of the professional. One of the standards focuses on the importance of evidence-based practice and participation in the generation of new knowledge through research. The pace and complexity of advances in surgical procedures, minimally invasive surgery, new technologies, professional nursing issues, ongoing healthcare reform measures, continuing changes in recommended practices, and the burgeoning body of nursing research and best practice guidelines demand constant professional education and development. Perioperative professionals must continue to research patient outcomes tenaciously, to link nursing interventions to outcomes, and to determine methods that conserve resources when implementing interventions. Other

standards of professional practice address ethics, collaboration, and collegiality.

The third set of *process* standards, The AORN (2009b) *Quality and Performance Improvement Standards for Perioperative Nursing,* delineate perioperative nurses' responsibilities to evaluate the patient care provided and make improvement to optimize patient outcomes. This standard underscores the importance of using data to improve patient care.

Outcome standards identify desirable and measurable physiologic and psychologic responses of patients to nursing interventions. Patient outcomes are an essential indicator of the quality of care. The AORN (2009b) *Perioperative Patient Outcomes* provide outcome statements, interpretations, and criteria guidelines for measuring patient responses. The common goal of standards is quality care for the surgical patient.

Nursing Process

Looking at nursing as a process can bring it into perspective as a system of critical thinking that provides the foundation for nursing actions. The focus of the nursing process is the patient, and prescribed nursing interventions are those that meet patient needs. Given the setting and the nature of the work, perioperative nursing is particularly vulnerable to being seen as only an accumulation of mechanical techniques and the execution of surgeon orders. By using the nursing process, however, perioperative nurses can focus on the patient and, at the same time, use skills and knowledge to care for patients and to make independent judgments and clinical decisions. Use of the nursing process, nursing plans of care, clinical pathways, and best practices (discussed later in this chapter) has become an integral part of patient care.

In its simplest form, the nursing process defined by the ANA consists of the following six steps: assessment, nursing diagnosis, outcome identification, planning, implementation, and evaluation (see Figure 1-2). The process is dynamic and continuous. Also, in all areas of nursing practice, certain responsibilities are inherent in the nursing process: (1) providing culturally and ethnically sensitive, age-appropriate care; (2) maintaining a safe environment; (3) educating patients and their families; (4) ensuring continuity and coordination of care through discharge planning and referrals; and (5) communicating information.

Assessment. *Assessment* is the collection of relevant health data about the patient. Sources of data may be a preoperative interview (History box) with the patient and the patient's family; review of the planned surgical or invasive procedure; review of the patient's medical record; examination of the results of diagnostic tests; and consultation with the surgeon and anesthesia provider, unit nurses, or other personnel. Data collection focuses on these major elements: (1) the patient's current diagnosis, physical status, and psychosocial status (including literacy, language skills, and spiritual, ethnic, cultural, and lifestyle information relevant to the delivery of patient-specific care); (2) previous hospitalizations or surgical interventions, and serious illnesses; and (3) the planned surgical or invasive procedure and the patient's understanding of this plan. Implementing patient-centered care requires the perioperative nurse to encourage the patient's active involvement in his or her care as part of patient safety (The Joint Commission [TJC], 2009b). Of primary importance are the patient's and family's understanding of the scheduled procedure and the patient's participation in activities such as marking the surgical site (Patient Safety) (the Universal Protocol for correct site surgery is discussed in Chapter 2) (TJC, 2009b). The perioperative nurse also assesses risk factors that may contribute to negative outcomes (Evidence for Practice). Communication with other members of the healthcare team is essential. The perioperative nurse proactively reports any concerns (e.g., abnormal laboratory values, or issues related to the patient's lack of understanding of the planned procedure) to the surgeon. The nurse should document all data collected and note any referrals that he or she makes.

The assessment format varies from institution to institution but always includes the physiologic and psychosocial aspects of the patient. In some settings, the assessment is done in stages by one or more perioperative nurses. A perioperative nurse may perform an assessment in the presurgical care unit or by telephone before the day of surgical admission. In such cases, the nurse in the OR may verify parts of the assessment previously done and complete the remainder. For a perioperative nurse caring for a healthy patient, assessment may mean only a thoughtful, brief review of the assessments previously done, a short patient interview, review of the medical record

HISTORY

Nurses' Responsibilities to Their Patients

Although theoretic perspectives regarding patient outcomes have been described by nursing scholars, a recognition and appreciation of the contributions and legacy of the past should not be disregarded. Early in our nursing history, the foundation was clearly laid for nurses' responsibility and accountability to their patients.

- The Order of St. John (1000s) had as its mission the relief of sickness, suffering, distress, and danger.
- Florence Nightingale (1800s) analyzed healthcare conditions and patient outcomes related to morbidity and mortality in the Crimean War.
- Clara Weeks-Shaw (1900s) described in some detail the measures perioperative nurses should take when surgery was being done in the patient's home, noting actions to alleviate anxiety and provide for patient comfort.
- Dorothy Johnson (1950s) introduced the concepts of internal and interpersonal equilibrium to relieve discomfort and tension in patients.
- Virginia Henderson (1970s) described nursing as a substitute for self-care, assisting in the outcome of bringing the patient toward independence.
- Dorothy Orem (1970s) identified self-care needs of patients and nursing measures to support them: partially compensatory, wholly compensatory, and supportive-educative. Perioperative nurses act therapeutically in all three ways with their surgical patients.
- Imogene King (1980s) noted the interconnections between nurse and patient, identifying goal-related decisions to attain, maintain, or restore health or to die with dignity.
- Jean Watson (1980s) introduced the science of caring, wherein nurses applied caring factors to promote health, prevent illness, care for the sick, and restore health.
- Patricia Benner and Judith Wrubel (1980s) suggested that caring is central to the essence of nursing, enabling connection and concern.

PATIENT SAFETY

Involving Patients in Marking the Surgical Site

Perioperative nurses collectively value patient safety. One way to facilitate this goal is to improve involvement by patients in their care through information and education. The Joint Commission (TJC) Speak Up™ campaigns are safety initiatives that encourage patients to take an active role in their healthcare. *Help Avoid Mistakes in Your Surgery* offers a patient the following information about marking the surgical site and the time-out:

- A healthcare professional will mark the spot on your body where the surgeon will operate. Make sure that only the correct part and nowhere else is marked. This helps avoid mistakes.
- Marking usually happens when you are awake. Sometimes you cannot be awake for the marking. If this happens, a family member or friend or another healthcare worker can watch the marking. They can make sure that your correct body part is marked.
- Your neck, upper back, or lower back will be marked if you are having spine surgery. The surgeon will check the exact place on your spine in the OR after you are asleep.
- Ask your surgeon if they will take a "time out" just before your surgery. This is done to make sure they are doing the right surgery on the right body part on the right person.

TJC also offers surgery patients these "tips" to further encourage their active involvement:

- You and your surgeon should agree on exactly what will be done during the operation.
- Ask to have the surgical site marked with a permanent marker and to be involved in marking the site. This means that the site cannot be easily overlooked or confused (for example, surgery on the right knee instead of the left knee).
- Ask questions. You should speak up if you have concerns. It is okay to ask questions and expect answers that you understand.
- Think of yourself as an active participant in the safety and quality of your healthcare. Studies show that patients who are actively involved in making decisions about their care are more likely to have good outcomes.

Modified from The Joint Commission: *Help avoid mistakes in your surgery,* www.jointcommission.org/GeneralPublic/Speak+Up/wss_tips.htm. Accessed April 17, 2009; The Joint Commission: *Tips for patients to prevent wrong-site surgery,* on-line at www.jointcommission.org/GeneralPublic/Speak+Up/wss_tips.htm. Accessed April 17, 2009.

EVIDENCE FOR PRACTICE

The Risk of Hypothermia

Unplanned hypothermia (core temperature less than 36° C) is among the most common complications of surgery. It results from impaired thermoregulation caused by anesthesia and heat lost into the surgical environment. Shortly after induction of anesthesia, body heat rapidly shifts from the body's core to its periphery. This redistribution results in a core temperature drop of about 1.6° C (2.7° F) during the first hour after induction of anesthesia (Matsukawa et al, 1995a, 1995b). This initial temperature drop is followed by a slow, linear decrease during the second hour of anesthesia, in which heat loss exceeds the body's ability to metabolically produce heat. After 3 to 5 hours of anesthesia, the patient's core temperature usually plateaus and is characterized by a constant core body temperature (Kurz, 2008). All anesthetized surgical patients are at risk of hypothermia, and the risk increases as the anesthesia duration increases (Matsukawa et al, 1995a, 1995b; Sessler, 2000; Kurz et al, 1993). The risk of hypothermia is greater in some patients, including neonates (Tander et al, 2005), trauma patients, and patients with extensive burns (Caldwell et al, 1994).

Mild hypothermia increases the risk of negative patient outcomes. Kurz and colleagues (1996) studied 200 patients undergoing colon surgery. Subjects were randomly assigned to either standard care (resulting in hypothermia) or intraoperative warming (resulting in normothermia). Surgical site infection occurred in 19% of subjects who received no warming compared to only 6% of those who received warming. Sutures were removed 1 day later in the patients assigned to standard care and hospitalization was prolonged by 2.6 days more than the normothermia group.

Frank and colleagues (1993) studied 100 patients undergoing lower extremity vascular reconstruction. These researchers found that patients with postoperative temperatures less than 35° C experienced a higher rate of myocardial ischemia, angina, and lower oxygen saturation during the early postoperative period.

When patients become hypothermic, platelet activation is inhibited, resulting in increased blood loss (Michelson et al, 1994). Mild hypothermia also alters medication metabolism and increases the duration of muscle relaxant action, which results in an extended postanesthesia recovery time and may prolong hospitalization. Based upon these and similar studies, warming patients using both active and passive methods in the OR has become a standard, evidence-based practice.

Caldwell FT, Jr et al: The effect of wound management on the interaction of burn size, heat production, and rectal temperature, *J Burn Care Rehabil* 15:121–129, 1994.
Frank SM et al: Unintentional hypothermia is associated with postoperative myocardial ischemia. The Perioperative Ischemia Randomized Anesthesia Trial Study Group, *Anesthesiology* 78:468–476, 1993.
Kurz A: Physiology of thermoregulation, *Best Pract Res Clin Anaesthesiol* 22:627–644, 2008.
Kurz A et al: The threshold for thermoregulatory vasoconstriction during nitrous oxide/isoflurane anesthesia is lower in elderly than in young patients, *Anesthesiology* 79:465–469, 1993.
Kurz A et al: Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. Study of Wound Infection and Temperature Group, *Engl J Med* 334:1209–1215, 1996.
Matsukawa T et al: Heat flow and distribution during epidural anesthesia, *Anesthesiology* 83:961–967, 1995a.
Matsukawa T et al: Heat flow and distribution during induction of general anesthesia, *Anesthesiology* 82:662–673, 1995b.
Michelson AD et al: Reversible inhibition of human platelet activation by hypothermia in vivo and in vitro, *Thromb Haemost* 71:633–640, 1994.
Sessler DI: Perioperative heat balance, *Anesthesiology* 92:578–596, 2000.
Tander B et al: Risk factors influencing inadvertent hypothermia in infants and neonates during anesthesia, *Paediatr Anaesth* 15:574–579, 2005.

and surgical procedure, and a mental rehearsal of the resources and knowledge necessary to guide the patient successfully through an operative course. At other times, the perioperative nurse must assess all aspects of the patient and the patient's condition thoroughly, along with preoperative and postoperative reviews.

When developing guidelines for preoperative assessment, patient and family education, and discharge planning, the perioperative nurse should consider the following:

- Is relevant, concise patient information already available to the perioperative nursing staff?
- Is enough information available to allow perioperative nurses to consider patient care needs when setting up the room (e.g., special equipment, accessory items, instruments, sutures)?
- Is sufficient time available to initiate a meaningful perioperative nurse-patient interaction?
- Are surgical patients satisfied with their perioperative nursing care (do they express feelings of comfort and satisfaction regarding their care in the surgical setting) and do they have knowledge of the perioperative nurse's role?
- Is there continuity of care between the perioperative unit and other nursing care units?

Being able to exchange information about their patients in face-to-face meetings, by telephone, or by written messages is helpful for unit and perioperative nurses. A thorough assessment made and recorded by the preoperative nurse can accompany patients to the OR and serve as a guide for the perioperative nurse, who then completes a more focused preoperative patient assessment. With the burgeoning number of ambulatory surgery procedures, preoperative assessment is often integrated in preadmission testing. Some institutions hold group preoperative sessions. These not only help nurses get to know the patients, but also permit nurses to impart information on common routines, reactions, sensations, and nursing procedures that will take place preoperatively, intraoperatively, and postoperatively. The perioperative setting determines the type of interaction that may occur. The use of preoperative phone calls and on-line questionnaires has also gained wide acceptance. Soliciting information before the patient's arrival in the perioperative setting can affect patient outcomes. The important point is that some form of assessment, patient and family education, and discharge planning must be done. The particular facility and nursing staff determine how to accomplish it.

Assessment is knowing and understanding the patient as a feeling, thinking, and responsible individual who is a candidate for a surgical or invasive procedure. Data identified through assessment help the perioperative nurse meet unique patient needs throughout the surgical intervention. Based on the data collected, recorded, and interpreted during patient assessment, the perioperative nurse then formulates a nursing diagnosis.

Nursing Diagnosis. *Nursing diagnosis* is the process of identifying and classifying data collected in the assessment in a way that provides a focus to plan nursing care. Nursing diagnoses have evolved since they were first introduced in the 1950s. Today, they are identified, named, and classified according to human response patterns and functional health patterns. The organization responsible for delineating the accepted list of nursing diagnoses is the North American Nursing Diagnosis Association International (NANDA-I) (Box 1-2). Each NANDA-I–approved nursing diagnosis has a set of components, as follows: a definition (i.e., the meaning of the diagnostic term); its defining characteristics (i.e., the requisite pattern of signs and symptoms or cues that make the meaning of the diagnosis clear); and its related or risk factors (i.e., causative or contributing factors that are useful in determining whether the diagnosis applies to a particular patient). For perioperative patients, many nursing diagnoses are "risk" diagnoses, meaning that they are not evidenced by signs or symptoms because the problem has yet to occur and nursing interventions are directed at prevention.

BOX 1-2

Selected Perioperative Nursing Diagnoses

Ineffective **A**irway clearance
Anxiety
Risk for **A**spiration
Risk for imbalanced **B**ody temperature
Readiness for enhanced **C**omfort
Ineffective **C**oping
Risk for imbalanced **F**luid volume
Impaired **G**as exchange
Hyperthermia
Hypothermia
Risk for **I**nfection
Risk for **I**njury
Risk for perioperative positioning **I**njury
Deficient **K**nowledge
Acute **P**ain
Risk for impaired **S**kin integrity
Delayed **S**urgical recovery
Ineffective **T**issue perfusion
Impaired **U**rinary elimination

NANDA International: *NANDA nursing diagnoses: definition and classification 2009-2011,* Philadelphia, 2009, Author.

Not all patient problems encountered in the perioperative setting can be described by the list of accepted NANDA-I nursing diagnoses. Perioperative nurses must participate in describing and naming new nursing diagnoses that characterize unique perioperative patient problems. NANDA-I has established a "to be developed" category to designate nursing diagnoses that are partially developed and deemed useful to the nursing profession; perioperative nurses may develop unique diagnostic labels and definitions and work to develop and validate them further through this process. This constructive process becomes even more important as healthcare moves toward the use of information systems to document nursing practice.

Outcome Identification. *Outcome identification* describes the desired or favorable patient condition that can be achieved through nursing interventions (Box 1-3). The study of patient outcomes is not new (see History box). To be useful for assessing the effectiveness of nursing care, patient outcomes should be "nursing-sensitive"; that is, they should be influenced by nursing and describe a patient state that can be measured and quantified. Nursing-sensitive patient outcomes derive from nursing diagnoses and direct the interventions that resolve the nursing diagnoses. They are the standards or criteria by which

BOX 1-3

Selected PNDS Desired Patient Outcomes

- 2 The patient is free from signs and symptoms of injury caused by extraneous objects.
- 3 The patient is free from signs and symptoms of chemical injury.
- 4 The patient is free from signs and symptoms of electrical injury.
- 5 The patient is free from signs and symptoms of injury related to positioning.
- 8 The patient is free from signs and symptoms of injury related to transfer/transport.
- 9 The patient receives appropriate medication(s), safely administered during the perioperative period.
- 10 The patient is free from signs and symptoms of infection.
- 11 The patient has wound/tissue perfusion consistent with or improved from baseline levels established preoperatively.
- 12 The patient is at or returning to normothermia at the conclusion of the procedure.
- 13 The patient's fluid, electrolyte, and acid-base balance is consistent with or improved from baseline levels established preoperatively.
- 14 The patient's respiratory status is consistent with or improved from baseline levels established preoperatively.
- 15 The patient's cardiac function is consistent with or improved from baseline levels established preoperatively.
- 16 The patient demonstrates knowledge of the physiologic responses to the operative or other invasive procedure.
- 17 The patient demonstrates knowledge of the psychologic responses to the operative or other invasive procedure.
- 23 The patient participates in decisions affecting his or her perioperative plan of care.
- 24 The patient's care is consistent with the perioperative plan of care.
- 25 The patient's right to privacy is maintained.
- 28 The patient's value system, lifestyle, ethnicity, and culture are considered, respected, and incorporated in the perioperative plan of care as appropriate. The plan of care reflects the patient's level of function and ability during the perioperative period.

Association of periOperative Registered Nurses: *PNDS—Perioperative nursing data set,* ed 2, Denver, 2007a, The Association.

the effectiveness of interventions is measured. Outcomes are stated in terms of expected or desired patient behavior and must be specific and measurable. The appropriate time to measure perioperative nursing-sensitive outcomes varies.

Some outcomes from intraoperative nursing interventions can be evaluated immediately. Others occur over a longer period. In this textbook, the use of "the patient will" indicates an outcome that is expected to occur over time. Identification of expected and desired outcomes unique to the surgical patient provides the opportunity to prioritize care, becomes a basis for continuity of care, and directs evaluation (outcomes research). In this type of research, the relationship between patient characteristics, the processes of care (i.e., what the perioperative nurse does, described under Implementation), and the outcomes of that care are studied, enhancing the perioperative nurse's ability to improve care. In many instances, outcomes research results in the identification of a "best practice" to improve patient care (Whittemore, 2005).

Planning. After collecting and interpreting patient data, identifying appropriate nursing diagnoses, and establishing desired outcomes, the perioperative nurse begins *planning* the nursing care for the patient. Planning requires use of nursing knowledge and information about the patient and the intended surgical or invasive procedure in order to prepare the surgical environment and to plan patient care. Perioperative nurses check equipment for proper functioning, have requisite supplies and positioning devices available, and use their knowledge of anatomy to have proper instruments and sutures on hand for the procedure to be performed. They also modify routines based upon unique patient information, such as allergies, transmissible infections, and risk of hypothermia, deep vein thrombosis (Risk Reduction Strategies), infection, or pressure injury. They know the sequence of steps in the operative or other invasive procedure and use surgeons' preference cards, nursing care guides, and other resources such as computerized data sheets to prepare the room and equipment for the patient.

RISK REDUCTION STRATEGIES

Preventing Deep Vein Thrombosis (DVT)

In August 2008 the Centers for Medicare & Medicaid Services (CMS) added DVT and pulmonary embolism to its list of hospital-associated conditions of *never events* when either occurs following total knee arthroplasty or total hip arthroplasty. DVT is considered a preventable condition, and perioperative nurses can take the following measures to reduce its risk of occurrence:

- Review the medical record for risk factors that predispose the patient to developing DVT. These include age older than 50; history of varicose veins, myocardial infarction, cancer, atrial fibrillation, ischemic stroke, or previous DVT; obesity; paralysis; inhibitor deficiency state; or diabetes mellitus (Dipaola, 2008).
- As part of the plan of care for the patient with DVT risk, implement use of mechanical prophylaxis such as sequential compression devices (SCDs), graduated compression stockings, or foot pumps.
- When graduated compression stockings are used, ensure that they are applied properly (smoothly, no wrinkles, heel in pocket) and are the correct size (Patterson, 2009).
- Use safe medication practices if administering pharmacologic prophylaxis (low-molecular-weight heparin, fondaparinux, or warfarin) (Streiff and Haut, 2009).

Adapted from Dipaola CA: Preventing deep vein thrombosis: a perioperative nursing imperative, *AORN J* 88(2):283-285, 2008; Patterson P: Are staff using compression hose correctly? *OR Manager* 25(3):16-17, 2009; Streiff MB, Haut ER: The CMS ruling on venous thromboembolism after total knee or hip arthroplasty, *JAMA* 301(10):1063-1065, 2009.

Planning is preparing in advance for what will or may happen and determining the priorities for care. Planning based on patient assessment results in knowing the patient and the patient's unique needs so that alterations in events such as positioning requirements or the surgical process are anticipated and readily accommodated. Planning also requires knowledge of the patient's psychosocial state and feelings about the proposed operation so that the perioperative nurse can provide explanation, comfort, or emotional support.

BOX 1-4

Selected PNDS Perioperative Nursing Interventions

- I26 Confirms identity before the operative or invasive procedure.
- I143 Verifies operative procedure, surgical site, and laterality.
- I76 Implements protective measures to prevent skin or tissue injury caused by thermal sources.
- I93 Performs required counts.
- I84 Manages specimen handling and disposition.
- I11 Applies safety devices.
- I96 Positions the patient.
- I38 Evaluates for signs and symptoms of injury as a result of positioning.
- I118 Transports according to individual needs.
- I8 Administers prescribed medications and solutions.
- I51 Evaluates response to medications.
- I70 Implements aseptic technique.
- I98 Protects from cross-contamination.
- I94 Performs skin preparation.
- I131 Assesses risk for inadvertent hypothermia.
- I78 Implements thermoregulation measures.
- I86 Monitors body temperature.
- I55 Evaluates response to thermoregulation measures.
- I97 Preserves and protects the patient's autonomy, dignity, and human rights.
- I109 Provides status reports.

Association of periOperative Registered Nurses: *PNDS—Perioperative nursing data set,* ed 2, Denver, 2007a, The Association.

Implementation. *Implementation* is performing the nursing care activities and interventions that were planned and responding with critical thinking and orderly action as changes in the surgical procedure or patient's condition or emergencies occur (Box 1-4). Implementation employs established standards of nursing care, recommended practices, and clinical practice guidelines and best practices, developed and maintained by the nursing profession. During this phase of the nursing process, the perioperative nurse continues to assess the patient to determine the appropriateness of selected interventions and to alter the intervention as necessary to achieve desired outcomes of care. Nursing interventions are the "work of nursing." The study of nursing interventions links nursing diagnoses with interventions and outcomes and leads to the validation of selected interventions or the development of new ones. Likewise, clinical practice, decision making, and evidence-based practice are enhanced by their study. Finally, the study of nursing interventions also assists in the delivery of cost-effective care by quantifying resource allocation.

Implementation also means being the patient's advocate by recognizing and acknowledging the patient's concerns or unmet needs. Advocacy is part of nurse-caring and it encompasses caring behaviors that promote emotional and physical comfort. Caring behaviors include establishing a "connection" with the patient, responding to each patient's individuality, and meeting patient and family expectations (Research Highlight). The role of patient advocate is especially important in surgical settings when patients are sedated or unconscious and unable to speak for themselves. Perioperative nurses as caring patient advocates advance the best interests of their patients (Beyea, 2005).

RESEARCH HIGHLIGHT

Clinical Decision Making: Caring and Advocacy

Clinical judgment and decision making are hallmarks of professional nursing. In one qualitative study, Parker and colleagues asked the question, "What are the processes used by expert perioperative nurses in clinical decision making?" A structured interview guide was used with six perioperative nurses who had a minimum of 5 years of experience and considered themselves expert circulating nurses. After in-depth interviews, four levels of data analysis were used to sort and interpret findings. The single, overriding pattern for these expert nurses was captured as *seeing the big picture: engendered through caring*. Three themes emerged as essential to the expert decision making of the study participants: (1) connecting with patients (subthemes were the use of touch, conducting a perioperative interview, and humanizing the patient's care), (2) advocating for patients, and (3) embodied knowing (knowing through personal experience and through the experience of similar situations).

Another study by Boyle explored perioperative nurses' definition of, role in, and personal experiences with advocacy. A sample of 33 perioperative nurses participated in tape-recorded interviews. Four overarching themes of advocating for surgical patients emerged: protection, communication/giving voice, doing, and comfort and caring.

Seeing the big picture through connecting to and advocating for the patient and depending on one's own experience embody essential elements of critical thinking. Expert perioperative nurses actively and skillfully conceptualize, analyze, synthesize, and evaluate information gathered from and generated by observation, experience, reflection, and intellectual reasoning as a guide to their belief about their practice and the actions they take with patients. Advocacy, as reflected in both of these studies, underscores the perioperative nurse's acts in informing and supporting patients they care for and taking action to achieve goals on behalf of those patients. The pattern, themes, and subthemes identified in these studies support the cognitive, psychomotor, and affective skills used by perioperative nurses as they make decisions about patient care.

Modified from Parker CB et al: Clinical decision-making processes in perioperative nursing, *AORN J* 70(1):45-62, 1999; Boyle HJ: Patient advocacy in the perioperative setting, *AORN J* 82(2):250-262, 2005.

DELEGATION. A team delivers perioperative patient care and different categories of personnel assist in various direct and indirect patient care activities. The surgical team usually consists of a surgeon and assistants (e.g., residents, interns, physician assistant [PA], RN first assistant [RNFA], nurse practitioner [NP], or certified first assistant [CFA]), an anesthesia provider, a circulating nurse, and a scrub person, who may be either a surgical technologist or an RN. Other members of the healthcare team, such as nursing assistants, orderlies, environmental services, and patient care technicians, support the surgical team. During the implementation of patient care, the perioperative nurse may delegate certain nursing activities to these personnel, often called *unlicensed assistive personnel (UAP)*. These healthcare workers emerged during the nursing shortages of World War I and World War II and became part of a team model of delivering patient care. In the 1980s delivery models shifted the skill mix away from assistive personnel; RNs were the principal caregivers in primary nursing models. During

the fiscally constrained 1990s, however, healthcare facilities began to reintroduce assistive personnel, who have less training and receive lower salaries than nurses. Instead of using UAP in narrowly defined job categories (e.g., clerical, housekeeping, orderly, patient transport), the trend in the late 1990s was to create a set of multiskilled assistive personnel who could assist nurses in multiple activities rather than in just a single area.

As the use of UAP quickly grew in the 1990s, questions and concerns arose about the proper scope of delegated activities that nurses had formerly performed. Each state's board of nursing defines the scope of practice for registered nurses, based on the nursing process. Further, each state's nurse practice act—a state law that protects the health and safety of the public—establishes legal qualifications for who can practice nursing. Implementation of the plan of care and the interventions to accomplish it is part of the nursing process. Therefore guidelines for proper delegation of some of these interventions became necessary. Delegation transfers to a competent person the authority to perform a selected nursing task in a selected situation according to the five "rights" of delegation (Box 1-5). When the perioperative nurse delegates a task, he or she retains accountability for that delegation. Nursing functions of performing assessments, determining nursing diagnoses, establishing patient outcomes, developing the plan of care, and evaluating patient outcomes as well as nursing interventions that require independent nursing knowledge, skills, or judgment cannot be delegated (Cherry and Jacob, 2005). Perioperative nurses need to understand that institutional policy cannot contradict the nurse practice act of their state. Although tasks and procedures may be delegated to unlicensed members of the surgical team, the perioperative nurse is responsible for supervising care; supervision cannot be delegated. The perioperative nurse must assess the patient and the competency level of personnel to determine which team member has the skill to provide the necessary care. Using unlicensed personnel appropriately assists the profession of perioperative nursing to be better prepared for the challenge of maintaining high quality in patient care services even when nurse shortages occur.

DOCUMENTING INTERVENTIONS. Accurate documentation of nursing care is an integral part of all phases of the nursing process, especially implementation of the plan of care. A description of the patient, nursing diagnoses and desired patient outcomes, nursing care given, and the patient's response to care (outcomes) should be included in the patient's record (Chapter 2 has a more comprehensive review of documentation). Documentation of the nursing care given should include more than the technical aspects of care, such as the sponge count or the application of the electrosurgical dispersive pad. Nursing care documentation should be associated with the assessment and nursing diagnoses, with preestablished outcomes against which the appropriateness and effectiveness of care may be judged. The form for this documentation may include standardized protocols and interventions as noted on clinical pathways; space should be provided to write in interventions that are unique to individual patients or to describe variances in care. Documentation should require little time to complete, be specific to the perioperative setting, and provide continuity across the various areas in surgery, from presurgical holding areas to the PACU. Many facilities have incorporated computerized documentation systems to allow the data entered to be more readily retrievable. This trend and the need for electronic data are rapidly escalating, with federal requirements for electronic records by 2014 (Gunn, 2008).

BOX 1-5

The Five Rights of Delegation

1. **The Right task.** The perioperative nurse determines that this task is one that is delegable for a specific patient, taking into consideration such factors as potential for harm, the complexity of the task, necessary problem solving, and the predictability of the outcome. Routine tasks that are performed according to a standardized procedure and that have predictable outcomes are the safest to delegate.
2. **The Right circumstances.** The perioperative nurse considers the patient care setting, the resources available, and other relevant factors. Tasks delegated must be ones that do not require independent nursing judgment.
3. **The Right person.** The perioperative nurse is the right person to delegate the right task to the right person to be performed on the right patient. The perioperative nurse must be familiar with the job description of the UAP along with the person's capabilities, knowledge and skill level, and learning needs to ensure that safe, quality patient care is provided. In this way, the nurse matches tasks to the UAP's skills, qualifications, and competence.
4. **The Right communication and direction.** The perioperative nurse provides a clear, specific, and concise description of the task, with key information relating to its objectives, rationale, limits, and expectations. There should be an opportunity for questions and clarifying instructions. Information the perioperative nurse needs to know from the person performing the task must be identified. Communication should be direct and not provided through others.
5. **The Right supervision and evaluation.** The perioperative nurse appropriately monitors the task or person performing it, evaluates the results or patient outcomes or both, intervenes if necessary, and provides feedback. Providing immediate feedback or identifying a problem with performance as it occurs is essential to upholding standards of care and performance expectations.

Perioperative nurses must be involved actively in providing the assessment, evaluation, and judgment needed to coordinate and supervise perioperative patient care. When delegating care activities, the perioperative nurse retains accountability for analyzing and evaluating the outcome of the delegated task. Activities that rely on the nursing process, such as performing assessments, making nursing diagnoses, establishing plans of care, providing extensive patient and family education, and planning for patient discharge, cannot be delegated.

Modified from the National Council of State Boards of Nursing Response to the PEW Taskforce Principles and Vision for Health Care Workforce Regulation, Chicago, 1996, The Council, pp 4-5; Cherry B, Jacob SR: *Contemporary nursing: issues, trends and management,* St Louis, 2005, Mosby; Standing TS, Anthony, MK: Delegation: what it means to acute care nurses, *Appl Nurs Res* 21:8-14, 2008.

PERIOPERATIVE NURSING DATA SET. In 1993 the AORN recognized the need to describe and define the unique contributions of perioperative nurses to patient outcomes. After 6 years of research and validation, the Perioperative Nursing Data Set (PNDS) was recognized as a specialty nursing language, providing a uniform and systematic method to collect and document the basic elements of perioperative nursing care. Similar to the *Perioperative Patient Focused Model* (AORN, 2009a), the PNDS begins with patient outcomes (Figure 1-4). Each outcome is defined and interpreted, and presents criteria by which to measure

Patient outcome. →

OUTCOME 0.110
Patient is free from signs and symptoms of radiation injury.

Definition provides further explanation of the outcome. →

OUTCOME DEFINITION
Patient is free from observable signs or reportable symptoms of radiation injury.

Interpretive statement describes the scope of the current problem or need. →

INTERPRETIVE STATEMENT
Prevention of radiation injury requires the application of principles of physics and radiologic safety standards. Policies addressing education, credentialing, and radiologic safety and maintenance must be in accordance with national regulatory standards and manufacturers' documented instructions. Preexisting patient conditions (e.g., length of and/or previous exposure) can influence the patient's susceptibility to radiologic injury. Radiation exposure is limited to the target site.

Outcome indicators are derived from assessment data and provide a framework for evaluating the patient's progress or a clinical standard. *(This is not intended to be an all-inclusive list.)* →

OUTCOME INDICATORS
- Skin condition (general): smooth, intact, and free from unexplained edema, redness, blistering, or tenderness in nontargeted areas.
- Cognition: responds appropriately to questioning; memory intact.

Examples of interim outcome statements provide outcomes that reflect a patient or patient's family member's* status at a specific point and time across the surgical continuum. *(This is not intended to be an all-inclusive list.)* →

EXAMPLES OF INTERIM OUTCOME STATEMENTS
- The patient's skin remains smooth, intact, free from unexplained redness, blistering, or tenderness in targeted areas between admission and discharge from the perioperative setting.

Nursing diagnoses are linked to each outcome and provide possible human responses linked with surgical experiences. *(This is not intended to be an all-inclusive list.)* →

POTENTIALLY APPLICABLE NURSING DIAGNOSES
- Risk of impaired skin integrity (00047)
- Impaired skin integrity (00046)
- Acute confusion (00128)

Nursing interventions include assessments, implementations, and evaluation statements and are in bold print; each has a definition and a unique identifier. →

Assesses history of previous radiation exposure (A.240.1)
- Ensures that premenopausal women are aware of radiation risks associated with pregnancy.
- Delays, if possible, surgical procedure for 24 hours after radioactive diagnostic studies.
- Recognizes risk of compromised wound healing in patients who have received radiation in large doses preoperatively.

Activity statements are the bulleted points under interventions. Activities support interventions, but do not necessarily need to be documented. *(This is not intended to be an all-inclusive list.)*

Implements protective measures to prevent injury due to radiation sources. (Im.110)
- Assembles proper protective equipment.
- Limits exposure to radiation to therapeutic levels (e.g., fluoroscope is off when not in use, radioactive elements remain in lead-lined containers until ready for implantation).
- Implements measures to protect the patient from direct and scatter radiation.
- Provides shields to protect body areas from scatter radiation or focused beam whenever possible (e.g., fetus/gonadal shields).

Evaluates for signs and symptoms of physical injury to skin and tissue (E.10)
- Assesses the patient's skin and adjacent tissue for discoloration and reddened, raised, or painful areas around the surgical site and compares to preoperative skin assessment and medical record review.
- Assesses for complaints of pain or discomfort in areas other than surgical incision.

* Family member—AORN defines *family* as the person or people that the patient identifies as his or her family or designated support person.

FIGURE 1-4 An explanation of the layout of the Perioperative Nursing Data Set (PNDS).

outcome achievement. Subsequently, nursing interventions to achieve the desired patient outcomes are noted, along with suggested nursing activities to support the interventions. Of special import is the opportunity for perioperative nurses to use the PNDS to support standardized documentation. When this is accomplished, databases enable streamlined comparison of clinical outcomes from large patient populations within an institution and even across institutions. The databases can be used to guide research, develop best practices and practice guidelines, and support the work of evidence-based practice (EBP).

Performance improvement activities, notably by monitoring important aspects of care, problem identification, problem solving, and peer review, may be part of overall system evaluation. Often referred to as *quality improvement (QI) programs,* interdisciplinary teams address areas for improvement in patient care, identify problems, propose solutions, and monitor and evaluate the effectiveness of improvements. This topic is discussed in more detail later.

Evaluation. *Evaluation* is checking, observing, and appraising the results of what was done. Although evaluation is traditionally listed as the last phase of the nursing process, it is an integral, systematic, and ongoing component of providing safe, effective—and good—perioperative patient care. Evaluation focuses on the patient's progress in attaining identified outcomes. When feasible and appropriate, the patient and family should participate in the evaluation process. The attainment of outcomes, any revisions to nursing diagnoses or desired outcomes, and the plan of care are documented. Because perioperative patient care processes and interventions often are interdisciplinary, healthcare facilities may need to use additional evaluation methods.

Institutional Standards of Care

Healthcare facilities have developed additional standards to communicate expectations of performance. Perioperative departments have responsibility, delegated through the administrative governance of the institution, to develop policies and procedures, often called *surgical services standards of care.* Policies are written statements that outline responsibilities and appropriate actions in specific circumstances. To be effective, a policy should be consistent with national and state practice standards, be realistic and achievable, be consistently followed except where prior approval has been obtained, be based on evidence and reasoned and rational thinking, and be related to the long-term intent of the surgical services department.

Procedures are guides to implementing policies. They describe detailed chronologic sequences of activities as they relate to particular policies. Policies and procedures are usually combined into a manual that is kept readily available as a perioperative care resource in departments where operative or other invasive procedures are performed. Many facilities have moved to an on-line manual as well, to provide easy access in multiple patient care locations. Participation of staff members in policy and procedure development increases their knowledge of the subject matter and generates a sense of ownership. This results in meaningful and authoritative interpretation of approved policy and procedure to peers and furthers successful implementation.

Clinical Pathways. Another expectation in the AORN *Standards of Perioperative Nursing Practice* (2009b) is that the nurse will use the best available evidence, preferably research data, in planning patient care and will participate in research activities. Clinical pathways (also referred to as *care maps* or *care protocols*) lead to improvement in patient care because they are based on research and outcomes. In general, clinical pathways are interdisciplinary practice guidelines that allow one to recommend key resources and activities within targeted time frames during all phases of a patient's care. Their intent is to improve quality of care, enhance patient and family satisfaction, and reduce or control costs.

EVIDENCE-BASED PRACTICE

Perioperative nursing has been built upon a strong foundation of traditions designed to provide excellent patient care. These traditions include many aspects of direct patient care as well as control of the environment in which the care is provided. Perioperative nurses have an ethical responsibility to review practices and to modify them, based upon the best available scientific evidence. Using research and other forms of evidence to guide practice is called evidence-based practice (EBP). This process can be used proactively to evaluate alternative ways of providing care, such as using different patient positioning surfaces or developing patient education materials. It can also be used for problem solving, as when investigating a serious adverse event or other clinical problem, such as hypothermia, a pressure injury, or a retained surgical sponge. Regardless of the issue, the underlying evidence should always be examined and used to guide decision making to improve perioperative patient care (Steelman, 2006).

Evidence-based practice is a systematic, thorough process by which to identify an issue, to collect and evaluate the best evidence to design and implement a practice change, and to evaluate the process (Carey et al, 2009). The change may be how patients are assessed for risk (Research Highlight), an intervention, staff education, or a change in supplies or equipment. Some changes that have been implemented through this process are double-gloving to reduce sharps injuries (Stebral and Steelman, 2006), having patients shower preoperatively twice with chlorhexidine gluconate showers (Pottinger et al, 2006), administering antibiotics within 60 minutes before the surgical incision (Spalter and Wyatt, 2006), and using forced-air warming devices to prevent perioperative hypothermia (Wagner, 2006). When there is not enough evidence to guide practice, perioperative nurses should collaborate with a nurse researcher in a research study to address the clinical issue. For example, such collaboration was done to evaluate the best patient positioning surface in one hospital (King and Bridges, 2006). One model used in many healthcare facilities is the Iowa Model of Evidence-Based Practice to Promote Quality Patient Care (Figure 1-5).

Evidence-based practice has become an integral part of many national quality initiatives. One such initiative, the Surgical Care Improvement Project (SCIP), is a national quality partnership endorsed by many organizations and focused on improving care of surgical patients by using EBP to significantly reduce surgical complications. Endorsing organizations include the American College of Surgeons (ACS), American Society of Anesthesiologists (ASA), AORN, Centers for Disease Control and Prevention (CDC), and The Joint Commission (TJC, 2009a). The goal of SCIP is to reduce surgical complications nationally by 25% by 2010. Some core measures of SCIP address prophylactic antibiotics, normothermia, prevention of deep vein thrombosis (DVT), and blood glucose control (TJC,

RESEARCH HIGHLIGHT

Development of a Surgical Apgar Score

Surgical teams lack routine, objective criteria to evaluate a patient's condition after surgery to guide prognosis and clinical communication. This can be of significance in the hand-off report provided to the PACU, ICU, or another area where the patient is being transferred. In this study, researchers at Harvard, Brigham and Women's Hospital and at the Massachusetts General Hospital, Boston, developed a 10-point Surgical Apgar Score based on information routinely available during surgery—estimated blood loss (EBL), lowest recorded intraoperative heart rate (HR), and lowest recorded intraoperative mean arterial pressure (MAP)—to rate outcomes in surgery patients. Next, the Surgical Apgar Score was validated with 4119 general and vascular surgery patients. The main outcome measure examined was incidence of major postoperative complications and/or death within 30 days of surgery. The analysis showed a consistent trend toward worse outcomes with lower scores. Patients with scores of 9 or 10 had only a 5.0% incidence of major complications and a 0.1% incidence of death. On the other hand, patients with scores of 4 or less had a 56.3% incidence of major complications and a 19.5% incidence of death.

Based on these findings, the researchers concluded that the 10-point Surgical Apgar Score successfully identifies patients at higher-than-average and lower-than-average risk of major complications and death after surgery. Based on this research, the three areas of EBL, HR, and MAP may become important elements included in postsurgical hand-off reports.

Adapted from Regenbogen SE et al: Utility of the surgical Apgar score: validation in 4119 patients, *Arch Surg* 144(1):30-36, 2009.

2008). The Centers for Medicare & Medicaid Services (CMS) now require that healthcare facilities receiving reimbursement by Medicare report their level of compliance with these core measures (U.S. Department of Health and Human Services, CMS, 2008). In the future, CMS plans to reduce reimbursement for noncompliance with these core measures.

PERFORMANCE IMPROVEMENT

Recent and continuing trends in healthcare have seen increased control of costs, more efficient use of resources and supplies, decreased length of stay for surgical patients, and a shift of many surgical procedures from inpatient to ambulatory care settings (Ambulatory Surgery Considerations). Concomitantly, there is a keen awareness of the need for continued improvement in the provision of perioperative patient care. TJC has taken a strong position on the need for continuously monitoring and evaluating the quality and appropriateness of care delivery to resolve any identified problems, while striving constantly to improve delivery systems and processes. In 1994 TJC instituted performance assessment, measurement, and improvement as the core of its standards. This represented an evolution from quality assurance, to continuous quality improvement, and finally to performance improvement (PI). Such a transition was underscored by the belief that measuring outcomes and improving care are the essential purposes of healthcare delivery. Performance improvement efforts encompass improvements in quality and effectiveness, based on ethical and economic perspectives.

AMBULATORY SURGERY CONSIDERATIONS

The Functional Recovery Index (FRI) for Ambulatory Surgery Patients

Ambulatory surgery centers perform complex procedures on higher risk patients. It becomes important not only to determine patients' readiness for discharge from the ambulatory surgery center but also to determine how well patients fare in their recovery and rehabilitation after their discharge. Researchers in Toronto developed a research tool to evaluate recovery after ambulatory surgery, focusing on functional abilities after discharge. The research instrument, called the Functional Recovery Index (FRI), takes about 4 to 5 minutes to complete. There are 14 items that are answered on a scale of 0 (no difficulty with activity) to 10 (extreme difficulty with activity). The items are grouped according to important recovery activities such as pain, social activity, lower limb activity, and general physical activity. The responses are summed, and the lower the score, the more superior the patient's recovery. The summation of the items can be adjusted if there is an item that is not applicable or that the patient did not answer. As is usual during development of a research tool, tests were undertaken for validity and reliability. In the Functional Recovery Index, internal consistency for the three factors was Cronbach α = 0.90, 0.89, and 0.86, respectively. Interrater reliability as assessed in 264 patients was 0.99, indicating high reliability. Convergent validity testing for FRI compared to a verbal rating scale pain score was 0.76. Discriminant validity testing showed that the type of surgery was significant and that both intermediate surgery and major surgery were associated with higher FRI scores than minor surgery, not an unusual finding. The tool developers concluded that the FRI has excellent reliability, good validity, responsiveness, and acceptability.

Data from Wong J et al: Development of the Functional Recovery Index for ambulatory surgery and anesthesia, *Anesthesiology* 110(3):596-602, 2009.

A surgical services PI program should be based on established standards of care. The intent of each standard should be reflected in realistic and measurable outcomes. A plan to measure and improve care, including the scope of care and important aspects of that care, should be in place. Specific quality indicators should be identified that reflect all important aspects of care. Thresholds that identify the level of acceptable variance for each indicator are then established. Measurement methods include retrospective or concurrent review of medical records, review of adverse event reports, utilization review, patient surveys and interviews, and peer review. Emphasis has evolved from process auditing to the current emphasis on structure, process, and outcome indicators. Some facilities have implemented programs used in industry, such as Six Sigma and Lean Sigma, to assess and refine processes to improve efficiency. These efforts underscore nursing's commitment to improving processes and outcomes of care.

A performance measurement and improvement approach facilitates the delivery of safe, high-quality perioperative patient care. When processes are understood, they can be improved through a systematic plan of action. Involvement on teams that perform surgical services performance assessments and create improvement plans can strengthen the staff's commitment to meet standards and enhance program effectiveness. TJC supports the evolution to an information technology infrastructure

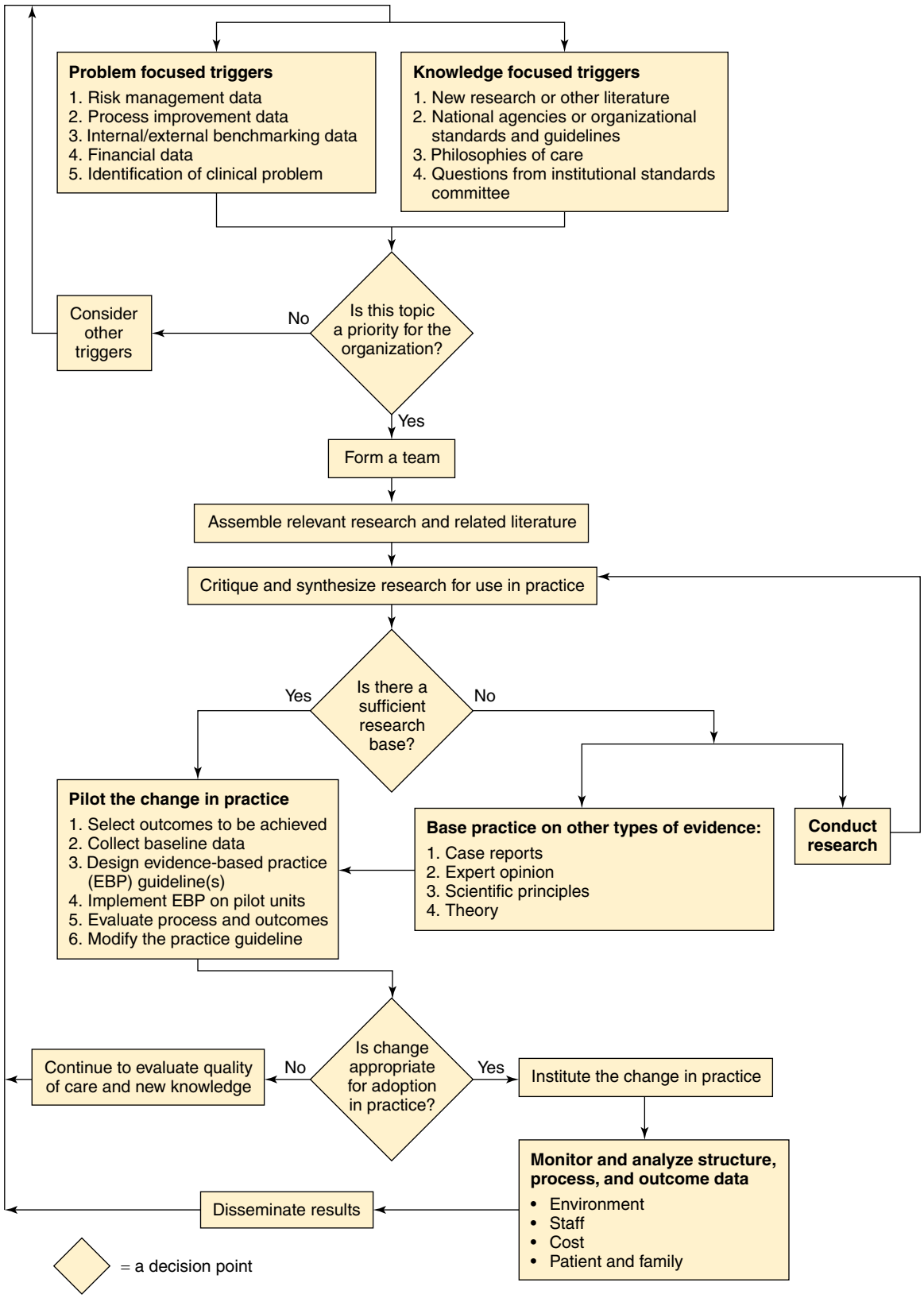


FIGURE 1-5 The Iowa Model of Evidence-Based Practice to Promote Quality Patient Care is one model used in some healthcare settings to identify opportunities to improve care, evaluate the evidence, and design, implement, and evaluate evidence-based practice changes.

(i.e., electronic health records [EHR]) in which performance measurement becomes a natural part of the care delivery process. As current uses of data expand and improve, objectives still will include the use of data for research activities directed at improving the quality of care and identifying and disseminating evidence-based practices. Perioperative nurses can anticipate that measurement requirements and performance expectations will change over time to reflect new technologies and care practices as they affect the quality and safety of care. TJC also is expected to add measurement of patient perception of care to its required set of core measures over the next several years. The objectives of future TJC activities are likely to focus on the following:

- Continuing expansion and coordination of nationally standardized core measurement capabilities
- Increasing the use of measurement data for quality improvement, benchmarking, accountability, decision making, accreditation, and research

PERIOPERATIVE NURSING ROLES

The nursing profession and the healthcare culture in the United States continue to change rapidly in response to many elements. An aging population, with the over-65 population already topping 40 million, will continue to create a significant increase in demand for health services. As baby boomers turn 65, the over-85 segment of the population is projected to triple by 2050. Referred to as the "longevity revolution," in 2030 it is anticipated that one in five residents in the United States will be over 85. New ambulatory settings for the delivery of health services, including operative and other invasive procedures, will continue to develop, as will community-based clinics, school-linked clinics, mobile clinics, and drive-in health centers. Healthcare organizations that are able to respond quickly to change will have an edge in the healthcare industry of the future. Perioperative nurses who understand the need for clinical and service quality, cost-effectiveness, information management, coordinated patient-centered care, efficiency, special needs of an aging surgical population, and the importance of patient satisfaction will be able to anticipate and position themselves for this future. Roles in case management, care coordination, informatics, the healthcare industry, consulting, management, advanced practice nursing, and research are all possibilities for perioperative nurses.

Traditional Perioperative Roles

There are two traditional perioperative nursing roles: the circulating nurse and the scrub nurse. The circulating nurse remains "non-scrubbed" and uses the nursing process to assess the patient, identify desired outcomes, formulate nursing diagnoses, implement interventions, and evaluate the outcome of the care provided. Among many other responsibilities, the circulating nurse manages patient positioning, antimicrobial skin preparation, medications, implants, specimens, warming devices, and the surgical count. The AORN (2006) has published a position statement advocating the requirement that there be a registered nurse circulator for every patient undergoing surgery or an invasive procedure, and that this person manage the care of only one patient at a time.

The scrub person assembles needed instruments and supplies in a manner to maximize safety and efficiency. This role requires an in-depth knowledge of each step of the surgical procedure, and the certain ability to anticipate each and every instrument and supply that will be needed. Many instruments are complex and require assembly. Instruments are positioned on the sterile table so that the scrub person can prepare each instrument as it will be used and quickly transfer it to the surgeon, often without being asked. This role is highly technical and either a registered nurse or a surgical technologist (ST) may assume it. The ST who functions as the scrub person may be certified (CST). The certifying agency for STs is the National Board of Surgical Technology and Surgical Assisting (the NBSTSA, formerly the LCC-ST). Surgical technology students who graduate from an accredited surgical technology program are eligible to take the certification exam. Many of these programs result in an associate degree. The ST and circulating nurse form an important partnership in ensuring patient safety. They work closely and effectively together throughout the procedure. Close teamwork keeps communication open, minimizes the risk of errors, and promotes the cost-effective utilization of supplies. Based upon mutual respect, teamwork enhances quality in the workplace. It is so essential that the National Quality Forum (NQF) has identified the establishment of team-based care and team-led performance improvements as a "safe practice for better health care" to reduce preventable patient harm (NQF, 2009).

Certification in perioperative nursing (CNOR) is available to perioperative nurses who function in traditional or nontraditional roles. This credential represents demonstrated knowledge of clinical practices and standards as well as a marked level of professional achievement. It also demonstrates proficiency in support of quality patient care and sets a standard of commitment to the profession of OR nursing (Competency and Credentialing Institute, 2009).

Registered Nurse First Assistant

The role of the perioperative registered nurse first assistant (RNFA) in surgery is an expanded perioperative nursing role that requires formal academic education (Welter, 2007). In 1984 the AORN approved an official statement on the RNFA and has revised the statement regularly to reflect changes in the RNFA's role. The RNFA works collaboratively with the surgeon (and the patient and surgical team) by handling and cutting tissue, using instruments and medical devices, providing exposure and hemostasis, and suturing, all as components of assisting-at-surgery behaviors. The AORN has developed standards for RNFA educational programs (AORN, 2009c) and certification is available for this role (CRNFA) (Competency and Credentialing Institute, 2009). Many experienced perioperative nurses have prepared for this role by obtaining this education. Performing as an RNFA allows an experienced perioperative nurse to expand clinical knowledge and skills and to assume additional responsibility for preoperative and postoperative patient management, while still remaining directly involved with intraoperative patient care. The RNFA has gained wide acceptance as a highly skilled member of the surgical team and is only one way perioperative nurses can develop professionally to meet the changing needs of healthcare delivery.

Advanced Practice Nurse

Advanced practice nurses (APNs) include nurse practitioners (NPs), certified registered nurse anesthetists (CRNAs), and clinical nurse specialists (CNSs); they are valuable members of

the perioperative team in many healthcare settings (Steelman, 2009). The AORN (2007b) has identified six facets of the advanced perioperative practice role: clinical practice, education, consultation, leadership, management, and research. NPs and CRNAs usually focus on clinical practice, providing licensed independent care to individual patients, one at a time.

Acute-care NPs have begun to fill the gap in providing care for patients who are more acutely ill and whose medical-surgical problems are more complex. NPs are now employed in acute care hospitals and ambulatory surgery centers across the country (Watson, 2007). Some NPs have focused primarily on the preoperative phase of patient care, using their advanced knowledge to assess patients and order preoperative medications and treatment. Other NPs have combined this role with that of the RNFA, to allow them to utilize their advanced practice skills throughout the perioperative care continuum. Some CNSs also provide licensed independent care to individual patients. However, the traditional role of the CNS involves primarily indirect care within the perioperative leadership team. As part of the management team, the CNS provides support for the care of groups of patients through leadership, education, consultation, management, and research. CNSs have assumed a significant leadership role in the implementation of evidence-based practice changes in healthcare settings (Steelman, 2009).

APNs must have graduate nursing education (at least a master's degree). In 2004, however, the American Association of Colleges of Nursing (AACN) published a position statement advocating for the Doctor of Nursing Practice degree as the minimum educational preparation for APNs. These educational programs are now available across the country and have a standardized core curriculum.

As a result of the Balanced Budget Act of 1997, APNs receive Medicare reimbursement in a variety of settings. This legislation provides for Medicare reimbursement for the NP or CNS who also functions as an RNFA.

Emerging Roles

As the needs of patients change and technology advances, new perioperative nursing roles develop to meet these needs. Some of these roles include care coordinator, family liaison, robotics coordinator, and informatics specialist. Some healthcare organizations have established the role of care coordinator in specific programs such as trauma, bariatrics, cardiac care, and organ transplant to meet the unique challenges and complexities of these patient populations. The role of care coordinator provides an opportunity for the perioperative nurse to develop more in-depth skills to meet the needs of a specific population of surgical patients.

In the late 1990s the perioperative nursing role of family or surgical liaison evolved to serve as a communication link between the OR and the family during surgery. The liaison translates information from the surgical team to the family, often serving to clarify issues and answer questions that require an understanding of events in the OR. Some hospitals and ambulatory surgery centers have implemented this perioperative nursing role with the goal of enhanced patient and family satisfaction.

Another emerging role in perioperative nursing is that of robotics coordinator. Both the number and the types of procedures performed with surgical robots have increased dramatically. Robots are now commonly used for general, cardiovascular, pediatric, and urologic surgery. The complexity of the equipment and troubleshooting require additional skills. The evolution of robotic technology and rapid expansion of its use have created many challenges for the perioperative team. Some healthcare facilities have developed a new role, the robotics coordinator, to coordinate this technology, provide complex troubleshooting, and train personnel (Francis, 2006). The robotics coordinator may also serve as a liaison to the public by providing marketing and public educational opportunities about the robotics surgery program.

Informatics is another specialty in which some perioperative nurses are focusing. Pressures for more efficient management of fiscal, material, and human resources have stimulated the development of electronic information systems for diverse functions in perioperative patient care settings (Roeder, 2009). A well-designed information system can synthesize large volumes of data efficiently into meaningful reports to support decision making. Newer nursing applications include point-of-care clinical systems, electronic health and medical records, internet-based patient education, research, and telemedicine and telenursing. The growing field of nursing informatics is an interaction of cognitive science, computer science, and informatics, all of which are based on a foundation of nursing science (Ozbolt and Saba, 2008). Perioperative nurse informatics specialists have the opportunity to develop clinical nursing systems that incorporate nursing care protocols, critical paths, best practices, the PNDS, and patient education materials that track patients over time. Such systems allow sharing information across wide networks as patients access healthcare at different points and times over a continuum of care. Future technology systems may include interactive computer/television, by which perioperative nurses can communicate with their patients over phone or a cable line, allowing the perioperative nurse to "view" the patient's wound or "discuss" recovery and rehabilitation from surgery.

Perioperative nursing is an exciting, ever-changing specialty. The opportunities for continuous learning and challenges are endless. As we move into the future, these opportunities will continue to grow and evolve. Perioperative nurses need to identify their professional goals and develop strategic plans to accomplish these goals, including enhancing their skill sets and education. This strategy will position the perioperative nurse well for exciting roles in the future.

REFERENCES

American Association of Colleges of Nursing: Position statement on the practice doctorate in nursing, October 2004.

Association of periOperative Registered Nurses: *One Perioperative Registered Nurse Circulator Dedicated to Every Patient Undergoing a Surgical or Other Invasive Procedure*, Denver, 2006, The Association, available at www.aorn.org/PracticeResources/AORNPositionStatements/Position_RegisteredNurseCirculator/. Accessed March 4, 2009.

Association of periOperative Registered Nurses (AORN): PNDS—Perioperative nursing data set, 2nd ed., Denver, 2007a, The Association.

Association of periOperative Registered Nurses (AORN): Position statement: Perioperative advanced practice nurse, Denver, 2007b, The Association.

Association of periOperative Registered Nurses (AORN): Perioperative Patient Focused Model. In *Perioperative standards and recommended practices,* Denver, 2009a, The Association.

Association of periOperative Registered Nurses (AORN): Standards of perioperative nursing practice. In *Perioperative standards and recommended practices,* Denver, 2009b, The Association.

Association of periOperative Registered Nurses (AORN): Standards for RN first assistant education programs. In *Perioperative standards and recommended practices,* Denver, 2009c, The Association.

Association of periOperative Registered Nurse (AORN): In *Perioperative standards and recommended practices,* Denver, 2009d, The Association.

Beyea SC: Patient advocacy—nurses keeping patients safe, *AORN J* 81:1046–1047, 2005.

Carey M, Buchan H, Sanson-Fisher R: The cycle of change: implementing best-evidence clinical practice, *Int J Qual Health Care* 21(1):37–43, 2009.

Cherry B, Jacob SR: *Contemporary nursing: issues, trends and management*, St Louis, 2005, Mosby.

Competency and Credentialing Institute: Certification and assessment, available at www.cc-institute.org/cert.aspx. Accessed March 5, 2009.

Fesler-Birch D: Critical thinking and patient outcomes: a review, *Nurs Outlook* 53:59–65, 2005.

Francis P: The evolution of robotics in surgery and implementing a perioperative robotics nurse specialist role, *AORN J* 83:629–650, 2006.

Gunn M: Standardized perioperative record: a bold step forward, *AORN J* 88(S2):S66–67, 2008.

King CA, Bridges E: Comparison of pressure relief properties of OR surfaces, *Periop Nurs Clin* 1:261–266, 2006.

National Quality Forum (NQF): *Safe Practices for Better Healthcare-2009 Update: a Consensus Report*, Washington, DC: NQF, 2009.

Ozbolt JG, Saba VK: A brief history of nursing informatics in the United States of America, *Nurs Outlook* 56:199–205, 2008.

Pottinger J et al: Skin preparation, *Periop Nurs Clin* 1:203–210, 2006.

Roeder JA: The electronic medical record in the surgical setting, *AORN J* 89(4):677–686, 2009.

Spalter AW, Wyatt DA: Antibiotic prophylaxis and surgical site infection: are we doing enough to ensure quality? *Periop Nurs Clin* 1:211–222, 2006.

Stebral LL, Steelman VM: Double gloving for surgical procedures: an evidence-based practice project, *Periop Nurs Clin* 1:251–260, 2006.

Steelman VM: Evidence-based practice, *Periop Nurs Clin* 1(3):viii–xiv, 2006.

Steelman VM: The advanced practice nurse: an essential part of the perioperative leadership team, *Periop Nurs Clin* 4:51–56, 2009.

The Joint Commission: Surgical Care Improvement Project core measure set November 2008, 2008, available at www.jointcommission.org/PerformanceMeasurement/PerformanceMeasurement/SCIP+Core+Measure+Set.htm. Accessed March 5, 2009.

The Joint Commission: Developing culturally competent patient-centered care standards, 2009a, available at www.jointcommission.org/PatientSafety/HLC/HLC_Develop_Culturally_Competent_Pt_Centered_Stds.htm. Accessed March 5, 2009.

The Joint Commission: Updated Universal Protocol, 2009b, available at www.jointcommission.org/PatientSafety/UniversalProtocol/. Accessed March 5, 2009.

U.S. Department of Health and Human Services, Centers for Medicare and Medicaid Services: Medicare Program; Changes to the hospital inpatient prospective payment systems and fiscal year 2009; Rates; payments for graduate medical education in certain emergency situations; changes to disclosure of physician ownership in hospitals and physician self-referral rules; Updates to the long-term care prospective payment system; Updates to certain IPPS-excluded hospitals; and collection of information regarding financial relationships between hospitals; Final rule, Federal Register 73: 48433–49083, August 19, 2008.

Wagner D: Unplanned perioperative hypothermia and surgical complications: evidence for prevention, *Periop Nurs Clin* 1:267–282, 2006.

Watson DS: The multidimensional role of the perioperative nurse practitioner, *Periop Nurs Clin* 2:19–21, 2007.

Welter CJ: Registered nurse first assistant: an expanded role, *Periop Nurs Clin* 2:9–18, 2007.

Whittemore R: Combining evidence in nursing research, *Nurs Res* 54: 56–61, 2005.

CHAPTER 2

Patient Safety and Risk Management

ELLEN K. MURPHY

Patient safety is and has long been a primary concern of members of the surgical team. "Primum non nocere" or "First, do no harm," is an imperative for physicians and nurses. As early as 1924, an OR nursing textbook included counting sponges among nursing duties (Smith, 1924). Perioperative nursing textbooks and curricula continued to include substantial content on infection control, positioning, safe medication practices, and counts through World War II. The first edition of this very textbook by Edythe Alexander (1943) included content on asepsis, the importance of correct side surgery, proper blood handling, and proper tourniquet application. Alexander (1943, p. 7) did not use the word "safety," but she described the purpose of "perfecting every detail…to insure that patients…have every chance to overcome the disease or injury with which they are afflicted."

Nursing publications accelerated their patient safety content after World War II. The American Nurses Association (ANA) published the *Code for Nurses,* which included provisions on patient safety and privacy, and the Association of Operating Room Nurses (now called the Association of periOperative Registered Nurses [AORN]) began organizing in the early 1950s. AORN's conferences and publications were replete with patient safety information. Its first conference in 1954 included programs on methods improvement, explosion prevention, bacteria destruction, the surgeon-nurse relationship, and positioning (Glass and Murphy, 2002). AORN published its first *"Standards of Operating Room Practice"* in 1974. *"Technical Standards"* soon followed, and by the 1980s AORN published and regularly updated its *Recommended Practices* (RPs) (Glass and Murphy, 2002, p. 116).

SAFETY AS AN INDIVIDUAL RESPONSIBILITY

Through the 1980s, healthcare professionals' errors and their effects on patient safety continued to be seen primarily as the individual practitioner's responsibility. This attitude was reinforced by the legal and professional licensure systems; the finding of negligence required that at least one individual failed to do what a similarly situated, reasonable, and prudent professional would have done under similar circumstances.

In 1991 authors such as Brennan, Leape, and others proposed that despite individual best efforts by professionals, mistakes continued and were, in fact, more common than previously thought (Brennan et al, 1991). Their findings, combined with James Reason's influential 1990 book *Human Error*, spawned a plethora of research and literature based on the role of systems and their relationship to human error in healthcare (Reason, 1990). Human error leading to patient injuries began to be recognized not so much as an individual's shortcoming, deserving of blame or punishment, but more as a result of failures of systems in patient care areas such as the OR. Leape (1994), Cook and Woods (1994), and others urged that the legal and professional licensure systems' continued focus on individual error was misplaced if adverse patient events were to be prevented. They urged an emphasis on transparent systems that required open reporting, investigation, innovation, and dissemination. The aviation and nuclear systems' parallel examination of human factors served as models for ideas that led to relative success in preventing injury attributable to human error.

In 1943 Edythe Alexander also noted "to get the best result from a surgical operation, the surgeon and his assistants, the operating room nurse and the entire staff must work as a team" (Alexander, 1943, p. 8). Despite AORN and its partner professional association's emphasis on safety and teamwork, patient injuries caused by human error in perioperative settings continue (Pronovost and Colantuoni, 2009).

CONCENTRATED EMPHASIS ON SYSTEMS

In 1999 the landmark Institute of Medicine (IOM) report spurred major additional safety initiatives when it reported that at least 44,000, and perhaps as many as 98,000, patients died in U.S. hospitals every year as a result of preventable adverse events (IOM, 1999). Even the lower figure exceeded the number of deaths resulting from motor vehicle accidents, breast cancer, or AIDS. The IOM report did not focus solely on perioperative errors. However, it did note James Reason's theory that complex, tightly coupled systems are most prone to accidents, and specified the surgical suite, along with emergency departments and intensive care units, as examples of complex, tightly coupled systems (Reason, 1990). Moreover, when one considers highly invasive surgical procedures juxtaposed with anesthetized patients who are unable to detect pain or otherwise defend themselves, patient vulnerability and the consequent need for protection by all team members is strikingly apparent.

Brennan and colleagues (1991) studied 30,121 randomly selected hospital records, found adverse events occurred in 3.7% of hospitalizations, and concluded that substantial

numbers of patient injuries resulted from substandard care. In Part II of that study, Leape and collegues (1991) found that nearly half (48%) of adverse events were associated with an operation. Their results were consistent with those of earlier investigators who found half of all hospital-based potentially compensable events (i.e., injuries from substandard care) arose from treatment in the OR. The Joint Commission's (TJC, 2005) collected findings from sentinel event reports over the last 2 decades are consistent with those findings, demonstrating that individual efforts of the best nurses, surgeons and anesthesia providers, combined with a recognized need for teamwork, are not sufficient—and especially not sufficient in the perioperative setting.

MAJOR ASSOCIATION SAFETY ACTIVITIES

The Joint Commission (TJC)

Like individual surgical team members, TJC has long been involved with quality and safety. TJC began in 1951 as the Joint Commission for the Accreditation of Hospitals. It sharpened its systems-based safety focus in the mid-1990s when it established its Sentinel Event Policy. That policy first encouraged and then required self-reporting of medical errors and root cause analysis of the error. Based on cumulative data, TJC published its first *National Patient Safety Goals* (NPSGs) in 2003; recognized the need for standardized methods of patient identification; and established the Universal Protocol (discussed later in this chapter) in 2004. By 2005, the World Health Organization formed the Collaborative Centre for Patient Safety Solutions, which is comprised of TJC and TJC-International.

Sentinel Events. Sentinel events are unexpected occurrences involving death or risk of serious physical or psychologic injuries. TJC chose the word "sentinel" to indicate that these events signal the need for immediate investigation and response through root cause analysis.

ROOT CAUSE ANALYSIS. Root cause analysis is a systematized process to identify variations in performance that cause or could cause a sentinel event. Suggested steps in such an analysis are briefly summarized in the Patient Safety box.

TJC has categorized errors reported to it and published their frequencies. Examples of perioperative care errors are those that are: related to anesthesia; caused by medical equipment; result in infection, fires, and transfusion reactions; are operative or postoperative; or give rise to unintended retention of foreign objects (RFOs) or wrong site surgery.

National Patient Safety Goals (NPSGs). NPSGs for hospitals and office-based surgery, derived from reported sentinel events, evolve and are reviewed, updated, or retired each year. The Patient Safety boxes on pp. 20 and 21 present the 2009 NPSGs for hospitals and office-based surgery.

Goals for patients in both settings are quite similar. Even though patients in office-based surgery settings are of healthier American Society of Anesthesiologists (ASA) physical status classification (see Chapter 4), one could argue that error prevention procedures in office-based surgery facilities must be even more rigorous than in inpatient settings because the array of emergency or corrective equipment and personnel is likely less available in these facilities. In addition, office-based and ambulatory perioperative staff provide most patient and family discharge education and preparation, unlike inpatient care settings (Ambulatory Surgery Considerations).

PATIENT SAFETY

Root Cause Analysis

Root cause analysis typically asks the following questions:

1. What happened?
2. Why did that happen?
   - What systems and processes underlie the proximate factors?
     - Information and management issues
     - Environmental issues
     - Leadership issues
     - Uncontrollable factors
3. What are the most proximate factors?
   - Human
   - Equipment
   - Controllable environmental
   - Uncontrollable external factors
4. What other factors are involved?
   - Are there other factors that directly influenced the outcome?
   - What other areas or services are impacted?

The next phase of root cause analysis moves to "what can be done to prevent this" questions that flow from the "why" questions, and ultimately result in an action plan. Root cause analysis concentrates on systems and processes, not individuals.

Modified from *Frameworks for conducting a root cause analysis and action plan*, available at www.jointcommission.org/NR/rdonlyres/C8CE68F6-85D7-4EA4-B3E0-895FC1075EE6/0/rcawordframework.doc. Accessed September 20, 2009.

Universal Protocol. A required safety practice of TJC is the Universal Protocol. Key features of the Universal Protocol for perioperative patient care are performing a preoperative verification process, marking the operative site, and conducting a "time out" immediately before starting the procedure. A properly performed "time out" includes information about the patient and procedure (Dillon, 2008). This is discussed in more detail later in the chapter.

Rapid Response Teams (RRTs). When a patient exhibits signs of clinical deterioration, a rapid response team (RRT) may be called to the bedside immediately to assess and treat the patient. The creation of such teams was initially included in the Institute of Healthcare Improvement's "100,000 Lives Campaign" in 2005 (Wachter and Pronovost, 2006). By 2008 TJC required accredited hospitals to have a mechanism for requesting additional assistance when a patient's condition appeared to worsen. That led to widespread implementation of RRTs. In some instances, such teams arise following a sentinel event. The Rapid Response Team box presents the implementation of a RRT in one OR following a sentinel event and root cause analysis. Many of the chapters in the remainder of this book have RRT scenarios/information.

Centers for Medicare & Medicaid Services (CMS)

CMS, formerly the Healthcare Financing Administration (HCFA), is the federal agency charged with administration (including regulations for payment) of the Medicare, Medicaid, and State Children's Health Insurance Programs. It also administers the Health Insurance Portability and Accountability

PATIENT SAFETY

Hospital-Based Surgery National Patient Safety Goals

Identify patients correctly.
- Use at least two ways to identify patients. For example, use the patient's name and date of birth.

Make sure that the correct patient gets the correct blood type when receiving a blood transfusion.
- Improve staff communication.
- Read back spoken (verbal) or phone orders to the person who gave the order.
- Create a list of abbreviations and symbols that are not to be used.
- Quickly hand-off important test results to the right staff person.
- Create steps for staff to follow during patient hand-off. Make sure there is time to ask and answer questions. Eliminate distractions during hand-off reports.

Use medicines safely.
- Create a list of medicines with names that look alike or sound alike. Update the list every year.
- Label all medicines that are not already labeled (e.g., medicines in syringes, cups, and basins, both on and off the sterile field).
- Take extra care with patients who take anticoagulants.

Prevent infection (refers to reducing the risk of healthcare-associated infections).
- Use the hand cleaning guidelines from the World Health Organization or Centers for Disease Control and Prevention (CDC).
- Report patient death or injury from infections acquired in hospitals.
- Use proven guidelines to prevent infections that are difficult to treat.
- Use proven guidelines to prevent infection of the blood.
- Use safe practices to treat the part of the body where surgery was performed.

Check patient medicines.
- Find out what medicines each patient is taking. Make sure that it is acceptable for the patient to take any new medicines with the patient's current medicines.
- Give a list of the patient's medicines to the patient's next caregiver or to the primary care physician before the patient is discharged home (medication reconciliation) to prevent discharge medicine discrepancies.
- Give a list of the patient's medicines to the patient and the patient's family before the patient is discharged home. Explain the list. Have the patient or family member repeat back or teach back important considerations in taking these medicines. Document education provided about discharge medicines.

Prevent patients from falling.
- Find out which patients are most likely to fall. For example, is the patient taking any medicines that might make the patient weak, dizzy, or sleepy? Take action to prevent falls for these patients.

Help patients to be involved in their care.
- Educate patients and family members about treatment, services, safety issues, and concerns about care.
- Tell each patient and their family members how to report their complaints about safety.
- Educate patients about hand hygiene, respiratory hygiene practices, and contact precautions (according to patient condition).
- Provide information about the hospital's measures to prevent adverse events.

Identify patient safety risks.
- Find out which patients are most likely to attempt to commit suicide.
- Watch patients closely for changes in their health and respond quickly if they need help.
- Create ways to obtain help from specially trained staff when a patient's health appears to deteriorate (e.g., rapid response teams [RRTs] or clinical triggers [Moldenhauer et al, 2009]).

Prevent errors in surgery.
- Create steps for staff to follow so that all documents needed for surgery are on hand before surgery starts.
- Mark the part of the body where the surgery will be done. Involve the patient in this step.

Adapted from *2009 Hospital National Patient Safety Goals,* available at www.jointcommission.org/NR/rdonlyres/40A7233C-C4F7-4680-9861-80CDFD5F62C6/0/09_NPSG_HAP_gp.pdf. Accessed July 15, 2009; Watson DS: National patient safety goals and implementation, *AORN J* 90(1):123-127, 2009; Wong JD et al: Medication reconciliation at hospital discharge: evaluating discrepancies, *Ann Pharmacother* 42(10):1373-1379, 2008.

Act (HIPAA) (discussed later) and several other health-related federal programs. A brief review of the hundreds of FAQs on its website provides an idea of the breadth and specificity of its activities. Significant to patient safety is the decision by CMS to impose financial disincentives for selected unsafe patient care outcomes by refusing to pay for the extra cost of treating those outcomes. Conversely stated, the agency responsible for paying Medicare claims now provides a financial incentive for safe patient care.

The original list of no longer reimbursable facility-acquired claims includes the following:
- Pressure ulcer stages III and IV
- Falls and trauma
- Surgical site infection after bariatric surgery for obesity, certain orthopedic procedures, and coronary artery bypass surgery (mediastinitis)
- Vascular catheter-associated infection
- Catheter-associated urinary tract infection
- Administration of incompatible blood
- Air embolism
- Foreign object unintentionally retained after surgery (RFO)
- Wrong site surgery
- Deep vein thrombosis (DVT)
- Pulmonary emboli associated with knee and hip replacements
- Certain manifestations of poor glycemic control

CMS cautions that no inference may be drawn that it considers these listed patient safety concerns more important than others. Rather, it has chosen them to emphasize that the financial cost of insufficient patient safety controls will be directly borne by facilities deemed responsible. Furthermore, CMS regulations prohibit as a matter of law passing these costs on to patients. Most private insurance companies have adopted similar provisions. Thus, from a purely risk management standpoint, in addition to potential indirect costs arising from negligence awards and settlements, facilities now incur direct costs to remedy the listed conditions.

PATIENT SAFETY

Office-Based Surgery National Patient Safety Goals

Identify patients correctly.
- Use at least two ways to identify patients. For example, use the patient's name and date of birth.

Make sure that the correct patient gets the correct blood type when receiving a blood transfusion.
- Improve staff communication.
- Read back spoken (verbal) or phone orders to the person who gave the order.
- Create a list of abbreviations and symbols that are not to be used.
- Quickly hand-off important test results to the right staff person.
- Create steps for staff to follow during hand-offs. Make sure there is time to ask and answer questions. Eliminate distractions during hand-off reports.

Use medicines safely.
- Create a list of medicines with names that look alike or sound alike. Update the list every year.
- Label all medicines that are not already labeled (e.g., medicines in syringes, cups, and basins, both on and off the sterile field).

Prevent infection.
- Use the hand cleaning guidelines from the World Health Organization or Centers for Disease Control and Prevention (CDC).
- Report patient death or injury from infections acquired in the facility.
- Use safe practices to treat the part of the body where surgery was performed.

Check patient medicines.
- Find out what medicines each patient is taking. Make sure that the patient is allowed to take any new medicines with current medicines.
- Give a list of the patient's medicines to the patient's next caregiver. Give the list to the patient's primary care physician before the patient is discharged home (medication reconciliation).
- Give a list of the patient's medicines to the patient and the patient's family before the patient is discharged home. Explain the list. Have the patient or the family member repeat back or teach back important considerations in taking these medications.

Prevent fires during surgery.
- Remind staff about the dangers of fire during surgery.
- Fire can be caused by lasers and other heated equipment.
- Some fluids and gases can catch fire. Ask staff to use less oxygen under sheets and blankets around the patient. Use appropriate patient skin preparation practices.

Help patients to be involved in their care.
- Tell each patient and the patient's family how to report complaints about safety.

Adapted from *2009 Office-based Surgery National Patient Safety Goals*, available at www.jointcommission.org/NR/rdonlyres/89440B8D-6FCC-4372-B2FA-02DA564D022E/0/09_NPSG_OBS_gp.pdf. Accessed July 15, 2009.

AMBULATORY SURGERY CONSIDERATIONS

Postoperative Telephone Calls

Office-based and ambulatory perioperative staff provide most patient and family discharge education and preparation, unlike inpatient care settings. Commonly, they also contact patients postoperatively to determine whether there are any problems or concerns. In reviewing the timing for such postoperative phone calls, Flanagan's research explored themes of postoperative patient calls at different time periods and discovered the following:
- At 12 hours postoperatively, patients expressed relief that their procedure was completed. Their primary symptom was nausea.
- At 24 hours postoperatively, patients expressed feelings of being unprepared and unable to manage by themselves. They needed resources to help with their care; they had symptoms of pain, nausea, and fatigue and reported decreased mobility.
- By 72 hours postoperatively, patients were more able to function on their own and continued to experience fatigue, but felt "abandoned." They did not yet feel "back to normal" and had concerns about missing work and their inability to manage other role functions and activities. However, they were now able to ask more questions and felt more comfortable expressing their concerns over the phone.

Patient and family education and preparation for discharge are critical to the well-being of surgery patients. Each of the chapters in this book that reviews a surgical specialty has a discussion of this critical aspect of perioperative nursing care in order to assist both the nurse and the patient in discussing and anticipating what will be needed during the postoperative recovery and convalescence period.

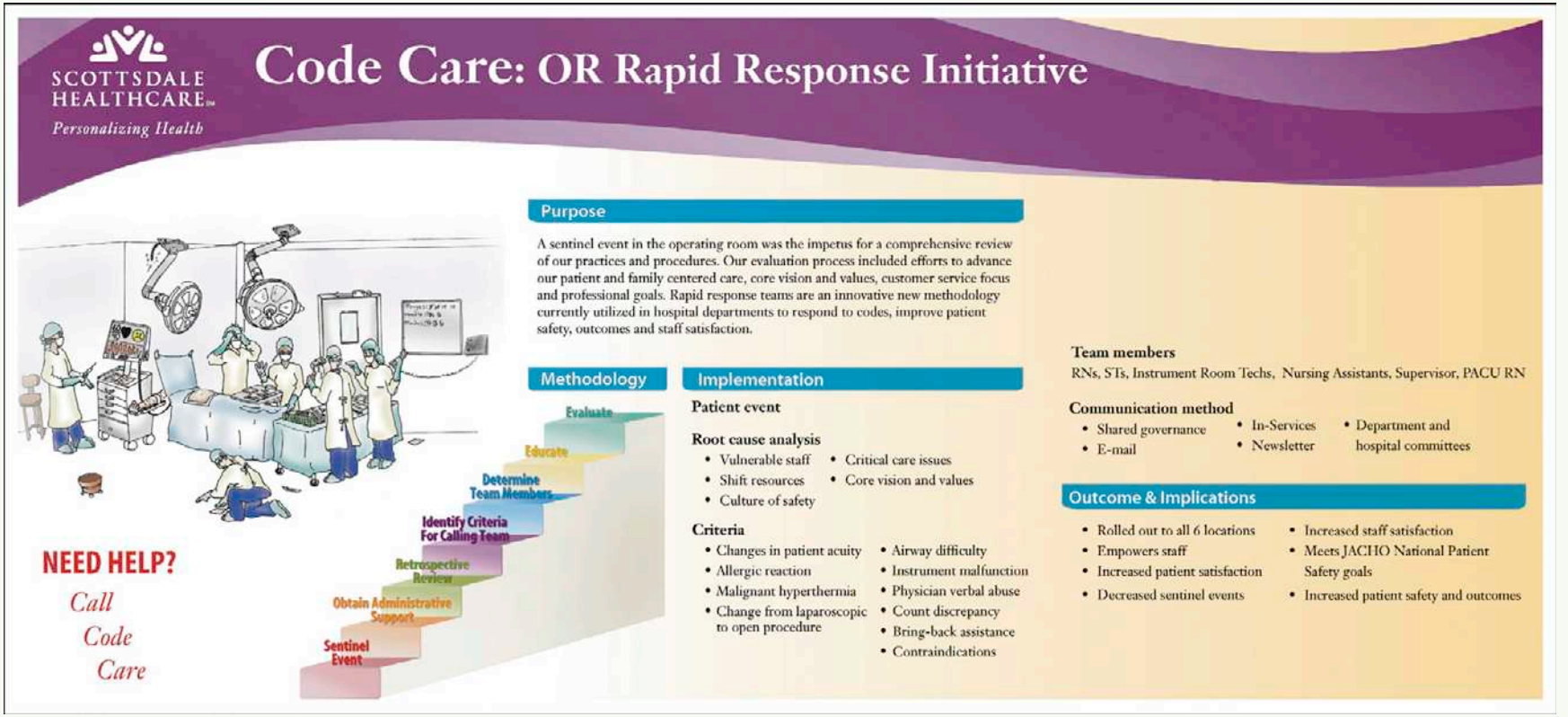
Modified from Flanagan J: Postoperative telephone calls: timing is everything, *AORN J* 90(1):41-51, 2009.

The World Health Organization (WHO)

WHO was created by and functions within the United Nations (UN) as the directing and coordinating authority for health throughout UN member nations. In October 2004 WHO launched the World Alliance on Patient Safety, which began to examine patient safety in acute as well as primary care settings relevant to all WHO member nations. Its action initiatives include "Clean Care is Safer Care" and "Safe Surgery Saves Lives." The focus of the "Clean Care" campaign is hand hygiene (also referenced in TJC's NPSGs), which resulted in release of a 2009 WHO guideline for surgical hand preparation (Evidence for Practice, p. 23). Salient points in "Surgical Hand Preparation" include discussion of the length of preoperative hand antisepsis, encouragement of brushless hand scrubs, and review of hand scrub preparations.

The "Safe Surgery Saves Lives" initiative published its Surgical Safety Checklist (Evidence for Practice, p. 24) in June 2008. Similar in content to TJC's Universal Protocol, it added a third phase following the time-out. The WHO checklist adds a "Sign Out" phase that includes team reviews of outcomes and concerns to be included in the handover (international term for "hand-off") to postanesthesia recovery caregivers. Haynes and colleagues (2009) hypothesized that implementation of the *WHO Surgical Safety Checklist* would reduce complications and deaths associated with surgery. They compared outcomes of surgical patients in eight countries representing widely diverse economic circumstances and patient populations, and found a 1.5% pre-checklist rate of death declined to 0.8% ($p = 0.003$) with use of the checklist. They also found inpatient complications occurred in 11% of patients before the checklist was

RAPID RESPONSE TEAM



Courtesy Scottsdale Healthcare

EVIDENCE FOR PRACTICE

WHO Guidelines on Surgical Hand Preparation

Steps before starting surgical hand scrubs:

KEY STEPS

- Keep nails short and pay attention to them when washing your hands—most microbes on hands come from beneath the fingernails.
- Do not wear artificial nails or nail polish.
- Remove all jewelry (rings, watches, bracelets) before entering the OR.
- Wash hands and arms with a nonmedicated soap before entering the OR and/or if hands are visibly soiled.
- Clean under the nails with a nail file. Nail brushes should not be used as they may damage the skin and encourage shedding of cells. If used, nail brushes must be sterile and used once only (single use). Reusable nail brushes are available that may be resterilized for each use.

PROCEDURAL STEPS

- Start timing. Scrub each side of each finger, between the fingers, and the back and front of the hand for 2 minutes.
- Proceed to scrub the arms, keeping the hand higher than the arm at all times. This helps to avoid recontamination of the hands by water from the elbows and prevents bacteria-laden soap and water from contaminating the hands.
- Wash each side of the arm from wrist to elbow for 1 minute.
- Repeat the process on the other hand and arm, keeping hands above elbows at all times. If the hand touches anything at any time, the scrub must be lengthened by 1 minute for the area that has been contaminated.
- Rinse hands and arms by passing them through the water in one direction only, from fingertips to elbow. Do not move the arm back and forth through the water.
- Proceed to the OR holding hands above elbows.
- At all times during the scrub procedure, care should be taken not to splash water onto surgical attire.
- Once in the OR, hands and arms should be dried using a sterile towel and aseptic technique before donning gown and gloves.

Modified from *WHO guidelines on hand hygiene in health care,* available at http://whqlibdoc.who.int/publications/2009/9789241597906_eng.pdf. Accessed July 15, 2009.

implemented and in 7.0% after introduction of the checklist. Thus tangible improvements in safety outcomes were confirmed following implementation of the checklist. Notable about WHO's entry into surgical patient safety is recognition that perioperative adverse events causing complications before, during, and after surgery is a public health problem.

The Association of periOperative Registered Nurses (AORN)

AORN has a nearly 60-year history of addressing perioperative patient safety issues. It represents perioperative patients and perioperative nurses in multiple policy settings, participating with TJC, WHO, other nursing associations and surgical alliances, and many safety coalitions to formulate safety statements that impact perioperative patient care. AORN provides an array of standards, RPs, guidelines, publications, videos and toolkits specifically addressing patient safety from the perioperative team's point of view. Toolkit subjects include fire safety, correct site surgery, safe medication administration, hand-off communication, and culture and human factors. RPs and toolkits are evidence-based to the extent possible. These AORN undertakings aim to distill, review, and suggest strategies for implementing perioperative patient care practices. Along with TJC and WHO recommendations, AORN recommendations should be reflected and adopted within institutional policies and procedures and educational curricula for perioperative nursing to the extent possible.

Other Patient Safety Groups/Coalitions/Companies

Major professional associations that represent other perioperative team members (e.g., American College of Surgeons [ACS], American Society of Anesthesiologists [ASA], American Association of Nurse Anesthetists [AANA], Association of Surgical Technologists [AST]) have also issued position statements and clinical recommendations related to patient safety. Additionally, many coalitions with similar patient safety interests have emerged as not-for-profit entities to gather and disseminate data, guidelines, protocols, and goals, for example. For-profit groups are also included in what may fairly be called a "patient safety industry." A partial listing of these groups is found in Box 2-1.

PERIOPERATIVE NURSING SAFETY ISSUES

Communication

Communication underpins many patient safety issues (Research Highlight). Implementation of both the Universal Protocol and the WHO checklist requires enhanced communication. More recent initiatives such as hand-off/handover protocols have joined the traditional clinical written documentation record to further improve communication in perioperative settings.

Ultimately, improved communication is imbedded in human factors, culture, and social systems, all of which are more complex than checklists, mnemonics, and acronyms (Leape and Berwick, 2005; Leonard et al, 2004; Moorman, 2007; Mills et al, 2008).

Clinical Documentation

The historical mainstay of communicating perioperative patient information is the written clinical record. Evidence suggests that a written record is inadequate as the sole perioperative communication tool. More recent enhanced communication initiatives such as preoperative briefings have augmented the written record. Nonetheless, whether written or documented electronically, the clinical record remains a key component in assuring a safer patient experience in all perioperative communication systems.

Institutions in which operative and other invasive procedures are performed maintain records of each operation, including preoperative diagnosis, surgery performed, a description of findings, specimens removed, postoperative diagnosis, and names of all individuals participating in intraoperative care. A sample intraoperative record may be found in Figure 2-1. This operative record is a permanent part of the patient's medical record. AORN's *Recommended Practice for Documentation of Perioperative Nursing* (AORN, 2009) suggests that the intraoperative patient care record should include information listed in Box 2-2. Notice that nearly all key components of perioperative clinical documentation relate to actions taken to enhance safety and prevent patient injuries.

Permanent documentation of perioperative patient care in the clinical record also serves risk management functions.

Surgical Safety Checklist

World Health Organization | Patient Safety
A World Alliance for Safer Health Care

Before induction of anaesthesia

(with at least nurse and anaesthetist)

Has the patient confirmed his/her identity, site, procedure, and consent?
- ☐ Yes

Is the site marked?
- ☐ Yes
- ☐ Not applicable

Is the anaesthesia machine and medication check complete?
- ☐ Yes

Is the pulse oximeter on the patient and functioning?
- ☐ Yes

Does the patient have a:

Known allergy?
- ☐ No
- ☐ Yes

Difficult airway or aspiration risk?
- ☐ No
- ☐ Yes, and equipment/assistance available

Risk of >500ml blood loss (7ml/kg in children)?
- ☐ No
- ☐ Yes, and two IVs/central access and fluids planned

Before skin incision

(with nurse, anaesthetist and surgeon)

- ☐ **Confirm all team members have introduced themselves by name and role.**
- ☐ **Confirm the patient's name, procedure, and where the incision will be made.**

Has antibiotic prophylaxis been given within the last 60 minutes?
- ☐ Yes
- ☐ Not applicable

Anticipated Critical Events

To Surgeon:
- ☐ What are the critical or non-routine steps?
- ☐ How long will the case take?
- ☐ What is the anticipated blood loss?

To Anaesthetist:
- ☐ Are there any patient-specific concerns?

To Nursing Team:
- ☐ Has sterility (including indicator results) been confirmed?
- ☐ Are there equipment issues or any concerns?

Is essential imaging displayed?
- ☐ Yes
- ☐ Not applicable

Before patient leaves operating room

(with nurse, anaesthetist and surgeon)

Nurse Verbally Confirms:
- ☐ The name of the procedure
- ☐ Completion of instrument, sponge and needle counts
- ☐ Specimen labeling (read specimen labels aloud, including patient name)
- ☐ Whether there are any equipment problems to be addressed

To Surgeon, Anaesthetist and Nurse:
- ☐ What are the key concerns for recovery and management of this patient?

This checklist is not intended to be comprehensive. Additions and modifications to fit local practice are encouraged.

Revised 1 / 2009

© WHO, 2009

From the World Health Organization: *Surgical safety checklist*, ed 1, available at www.who.int/patientsafety/safesurgery/en/. ©World Health Organization 2008. Accessed September 14, 2009.

BOX 2-1

Perioperative Safety-Related Entities

AHRQ: The federal Agency for Healthcare Research and Quality's mission is to improve the quality, safety, efficiency, and effectiveness of healthcare for all Americans. It has extensive evidence-based resources for nurses and other providers related to patient safety. www.ahrq.gov/.

CSPS: The Council on Surgical and Perioperative Safety is a multidisciplinary coalition of professional organizations whose members are directly involved in immediate perioperative care, including AORN, AST, ACS, ASA, AANA, AASPA, and ASPAN. Its mission is to promote excellence in patient safety in the surgical and perioperative environment. www.cspsteam.org/.

ECRI: ECRI Institute is a nonprofit organization dedicated to using the discipline of applied scientific research to discover which medical procedures, devices, drugs, and processes best improve patient care. www.ecri.org/Pages/default.aspx.

HealthGrades: HealthGrades is a public for-profit healthcare ratings organization. It provides ratings and profiles of hospitals, nursing homes, and physicians to consumers, corporations, health plans, and hospitals. www.healthgrades.com.

HIMSS: The Healthcare Information and Management Systems Society is the healthcare industry's member organization exclusively focused on providing leadership for optimal use of healthcare information technology (IT) and management systems to better healthcare. www.himss.org/.

IOM: The Institute of Medicine was chartered in 1970 as a component of the National Academy of Sciences. The Institute works outside the framework of government to ensure scientifically informed analysis and independent guidance. The IOM's mission is to serve as adviser to the nation to improve health, providing unbiased, evidence-based, and authoritative information and advice on health and science policy. www.iom.edu.

ISMP: The Institute for Safe Medication Practices is the nation's only nonprofit organization devoted entirely to medication error prevention and safe medication use. ISMP focuses on helping healthcare practitioners keep patients safe and leading efforts to improve the medication use process. www.ismp.org.

NHQA (National Hospital Quality Alliance): In 2002 the American Hospital Association (AHA), Federation of American Hospitals (FAH), and Association of American Medical Colleges (AAMC) launched the Hospital Quality Alliance (HQA), a national public-private collaboration to encourage hospitals to voluntarily collect and report hospital quality performance information. This effort is intended to make important information about hospital performance accessible to the public and to inform and invigorate efforts to improve quality. CMS and TJC participate in the HQA, along with the AHA, FAH, AAMC, AHRQ, American Medical Association (AMA), American Nurses Association (ANA), National Association of Children's Hospitals and Related Organizations, American Association of Retired People (AARP), American Federation of Labor and Council of Industrial Organizations, Consumer-Purchaser Disclosure Project, National Quality Forum (NQF), Blue Cross and Blue Shield Association, National Business Coalition on Health, General Electric, and U.S. Chamber of Commerce. www.qualidigm.org/Professionals/Setting/Hospital/NQAProject.aspx.

NQF: The National Quality Forum is a public-private partnership created to develop and implement a national strategy for healthcare quality measurement and reporting. www.qualityforum.org.

NSQIP: National Surgical Quality Improvement Program originated in the Veteran's Administration in 1991 and is now affiliated with the American College of Surgeons and available to the private sector. It prompts the surgical community to place patient safety in surgery within a large conceptual framework and provides a quantitative metric for the assessment of patient safety initiatives. www.acsnsqip.org/.

SCIP: The Surgical Care Improvement Project is a national quality partnership interested in improving surgical care by significantly reducing surgical complications. It is a part of the Medicare Quality Improvement Community (MedQIC) that was established by CMS to provide healthcare quality improvement news, resources, and data reporting tools and applications. SCIP created an original goal of reducing by 25% the national incidence of three types of surgical complications by 2010 (surgical site infections, perioperative MI, and DVT/PE). New SCIP measures have been added and are among measures that acute care hospitals must disclose to receive full annual payment updates from Medicare (Patterson, 2009). www.qualitynet.org/dcs/ContentServer?pagename=Medqic/MQPage/Homepage.

The Leapfrog Group: The Leapfrog Group is a voluntary program aimed at mobilizing employer purchasing power to alert America's health industry that "big leaps" in healthcare safety, quality, and customer value will be recognized and rewarded. It reports comparison data on providers. www.leapfroggroup.org/.

In addition, many states have state-based coalitions that encourage cost-effective, safe, quality healthcare.

Documentation requirements serve as reminders of actions needed to provide safe care, thus prompting risk reduction strategies and preventing injury. Information in the clinical record enhances continuity of care. If a patient injury occurs, documentation that preventive measures or other actions to mitigate risks were taken lessen the likelihood of a successful lawsuit.

Perioperative nursing documentation needs to describe the assessment, planning, and implementation of perioperative patient care that reflects individualization of care and evaluation of patient outcomes. Any unusual or significant incidents/events/occurrences pertinent to patient outcomes should be documented as well as their remediation as related to this patient's care.

Thought should be given to the design of perioperative nursing documentation tools that include identified elements in a format that minimizes time needed for the documentation process (e.g., checklists). Ideally, collaboration with preoperative, PACU, and postoperative nursing units will produce one documentation tool used across all areas, avoiding duplication of patient data by different nursing staff. Increasingly, settings where operative and other invasive procedures are performed use electronic records to enter and track patient care information. Such point-of-care technology can help to streamline workflow and reduce documentation errors.

Hand-offs/Handovers

As noted previously, written documentation alone, however crucial, is insufficient to assure patient safety as care responsibility passes from one team or individual caregiver to another. As they reviewed the evidence related to hand-offs, Friesen

and colleagues (2008) defined the transfer of information and responsibility for care of the patient from one provider to another as a "hand-off" or (internationally) "handover." The IOM, in its 2001 publication *Crossing the Quality Chasm*, identified patient hand-off as an opportunity for error. In 2006 TJC required healthcare organizations to implement a standardized approach to hand-off communication to reduce the risk for error.

TJC, AORN, and WHO all recommend that both "time-outs" (non-handoff/handover communication) and pre- and postoperative hand-off/handover be formalized. In healthcare settings, processes for transfer of care such as hand-offs include nursing shift changes, temporary relief or coverage, nursing and physician hand-offs from one department to another, various other transfers of information in inpatient settings, and interhospital transfers. The purpose of hand-off communication and reports is to provide essential, up-to-date, and specific information about the patient. Standardized hand-off communication must include an opportunity to ask and respond to questions. Strategies to assist in effective and efficient hand-off communication and reports are listed in the Patient Safety box.

RESEARCH HIGHLIGHT

The Importance of OR Briefings

In this study, researchers used real-time observations during cardiovascular surgery to measure the effect of preoperative briefings on specific disruptions, classified as patient-related issues, equipment or resource issues, procedural knowledge issues, and miscommunication events (Henrickson et al, 2009). The format for the briefings was developed following analysis of questionnaires and focus group results. Briefings, which lasted from 1 to 8 minutes, were conducted in the OR immediately before the patient's arrival. Each team member discussed his or her role in the procedure and any concerns specific to the patient. The briefings were then evaluated by monitoring surgical flow disruptions, circulating nurse trips to the sterile core for additional supplies, time spent in the sterile core, and cost-waste reports before and after implementation of the briefings.

Implementation of the briefings led to reductions in surgical flow disruptions, procedural knowledge disruptions, and miscommunication events. There was no significant reduction in disruptions caused by equipment preparation or patient-related issues. The researchers concluded that surgical teams that use specialty-specific preoperative briefings can decrease surgical flow disruptions and improve patient safety. Although they did not correlate circulating nurse trips to the sterile core for additional supplies with issues such as door openings and disruptions in environmental controls, another study (Lynch et al, 2009) found that the circulating nurse and core staff generated 37% to 51% of door openings, compromising the sterile environment of the OR. Future research might focus on the relationship of preoperative briefings to infection control measures.

Finally, the implications of improved communication from preoperative briefings have significant potential for decreasing adverse events such as wrong person, wrong procedure, or wrong site surgery. In a review conducted by the Patient Safety Committee of the American Academy of Orthopaedic Surgeons, the second most frequent source of errors was related to communication problems (24.7%) (Wong et al, 2009). Medication errors (9.7%) and wrong site surgery (5.6%) had the most serious potential for harm. Wrong site surgery involved the wrong side in 59%, another wrong site in 23%, wrong procedure in 14%, and the wrong patient in 5%. Clearly, the benefits of a preoperative briefing that focuses on team communication can significantly impact patient safety.

Modified from Henrickson SE et al: Development and pilot evaluation of a preoperative briefing protocol for cardiovascular surgery, *J Am Coll Surg* 208:1115-1123, 2009; Lynch RJ et al: Measurement of foot traffic in the operating room: implications for infection control, *Am J Med Qual* 24:45-45, Jan/Feb 2009; Wong DA et al: Medical errors in orthopaedics: results of an AAOS member survey, *J Bone Joint Surg Am* 91:547-557, 2009.

PATIENT SAFETY

Strategies to Assist in Effective Hand-Off Communication

1. *Use clear language.* Avoid unclear or potentially confusing terms. When appropriate, define the terms you are using. Use only approved abbreviations and avoid jargon that could be misinterpreted.
2. *Incorporate effective communication techniques* such as the SBAR technique (situation, background, assessment, and recommendations), MAPS (medications, allergies, procedure/pertinent information, special needs), or other mnemonic or acronym to facilitate sequence and type of information. Limit interruptions and distractions, focus on information being exchanged, and allocate sufficient time to this important task. Keep the report patient-centered, and avoid irrelevant details. Use read-back, report-back, or check-back techniques to ensure there is a common understanding about information exchanged. There must be an opportunity for each caregiver to ask and respond to questions.
3. *Standardize shift-to-shift and caregiver-to-caregiver (relief) reporting.* A consistent format increases the information staff members accurately record and improves their ability to plan patient care. Keep reports concise and accurate.
4. *Standardize perioperative nursing reports to the PACU or postoperative ambulatory surgery units.* Consider essential information such as reporting the procedure done, duration (and whether longer or shorter than expected), complexity of the procedure (greater than, less than, or as expected), whether there were events or deviations from the expected course, implants, medications administered, current status of vital signs (including temperature and warming methods used), pulses, incision/dressings/drains, blood/fluids administered, and urinary output.
5. *Use technology.* Communication systems that transmit information across settings and providers improve consistency and coordination. Automated electronic perioperative records can facilitate transitions by providing consistent, accessible information about surgical patients and their care in the OR. Staff members should be able to access readily essential components of care, such as whether a newly ordered medication was administered, whether laboratory studies were done, or if a do-not-resuscitate (DNR) order is in place.

Modified from Beyea SC: Distractions, interruptions and patient safety, *AORN J* 86(1):109-112, 2007; Committee on the Quality of Health Care in America, Institute of Medicine: *Crossing the quality chasm.* Washington, DC, 2001, National Academy Press; DeJohn P: ASCs take steps to improve handoffs, *OR Manager* 25(1):26-27, 29, 2009; Greenberg CC et al: Patterns of communication breakdown resulting in injury to surgical patients, *J Am Coll Surg* 204(4):533-540, 2007; JCAHO comments on hand-off requirement, *OR Manager* 21(8):8, 2005; Moore DT: Clinical issues—national patient safety goals, *AORN J* 82(2):275-277, 2005.

Instruction:
To be completed by RN.

Page 1 of 3

CASE PARTICIPANTS					
Attending surgeon:			Resident:		
Attending surgeon:			Resident:		
Attending surgeon:			Resident:		
Assistant:			Assistant:		
Anesthesiologist:			Anesthetist:		
Perfusionist:			Autotransfusionist:		
X-Ray tech:			Laser operator:		
Circulating nurse:			Scrub person:		
Circ relief:	Time in:	Out:	Scrub relief:	Time in:	Out:
Circ relief:	Time in:	Out:	Scrub relief:	Time in:	Out:
Circ relief:	Time in:	Out:	Scrub relief:	Time in:	Out:
Other/observer:			Other/observer:		

CASE TIMES

Patient in O.R.: _____ Anesthesia induction: _____ Incision/start: _____ Closure/end: _____ Patient out: _____

Recovery in O.R. Start: _____ Recovery in O.R. Stop: _____

ARRIVAL TO O.R.

Via: ☐ Ambulatory ☐ Stretcher ☐ Patient bed ☐ Other: _____ ☐ Personal items to O.R.: _____

Pre-op skin condition: ☐ Dry and intact ☐ Other: _____

Safety strap applied ☐ Abdomen ☐ Thighs ☐ Other: _____

PLAN OF CARE

☐ Allergies verified ☐ Perioperative history and assessment reviewed ☐ Standard plan of care implemented

Plan of care exceptions: ☐ Latex precautions ☐ Contact precautions ☐ Airborne precautions ☐ Droplet precautions

☐ Other: _____

PATIENT POSITIONING

Body position: ☐ Supine ☐ Prone ☐ Lithotomy ☐ Sitting ☐ Lateral right side up ☐ Lateral left side up

☐ Other: _____

LEFT arm: ☐ Board ☐ Side ☐ Chest ☐ Arm holder RIGHT arm: ☐ Board ☐ Side ☐ Chest ☐ Arm holder

Traction weight _____ lbs. ☐ Positioned by self ☐ Positioned by (initial): _____

Positioning device/site:

☐ Andrews bed ☐ Axillary roll ☐ Donut ☐ Fracture table ☐ Gel pads ☐ Hall Relton frame ☐ Jackson table

☐ Mayfield headrest ☐ McGuire positioner ☐ LamiRolls ☐ Stirrups ☐ Stryker frame ☐ VacPac

☐ Other/Comments: _____

INTERMITTANT COMPRESSION DEVICES ☐ N/A

Serial #: _____ Setting: _____ mmHg ☐ To O.R. with compression device on

Device type: ☐ Calf ☐ Thigh ☐ Bilateral ☐ Left ☐ Right Applied by (initial): _____

SKIN PREP ☐ N/A

Hair removal method: ☐ None ☐ Dry clip ☐ Dry shave ☐ Wet clip ☐ Wet shave Hair removed by (initial): _____

In O.R. Pre-op scrub: ☐ Betadine scrub ☐ Chlorhexidine ☐ Other: _____

Prep agent: ☐ Betadine ☐ Chloraprep ☐ Other: _____

22280 S(15730)(0808)C

FIGURE 2-1 Sample intraoperative report. *Continued*

CATHETERS, DRAINS, TUBES ☐ N/A

Catheter/drain description: _____ ☐ Straight catheter

Location: _____ Collection device: _____

Balloon fill amount: _____ Inserted by (initial): _____ Date: _____ Time: _____

Drainage description: _____

☐ Present on arrival ☐ Removed at end of case

ESU/OTHER EQUIPMENT ☐ N/A

Type: ☐ Monopolar ☐ Other: _____ Serial #: _____ Settings: _____ Cut _____ Coag

Grounding pad site: _____ Applied by (initial): _____

☐ Bipolar ☐ Tripolar Serial #: _____ Setting: _____ Coag

☐ Argon beam coagulator Serial #: _____ Beam Setting: _____

TOURNIQUET #1 ☐ N/A

Tourniquet side: ☐ Left ☐ Right Site: ☐ Thigh ☐ Calf ☐ Upper arm ☐ Forearm ☐ Ankle

Pressure _____mmHg Time inflated: _____ Deflated: _____ Time inflated: _____ Deflated: _____

Pressure _____mmHg Time inflated: _____ Deflated: _____ Time inflated: _____ Deflated: _____

Applied by (initial): _____ Serial #: _____ ☐ Tourniquet applied but not inflated

TOURNIQUET #2 ☐ N/A

Tourniquet side: ☐ Left ☐ Right Site: ☐ Thigh ☐ Calf ☐ Upper arm ☐ Forearm ☐ Ankle

Pressure _____mmHg Time inflated: _____ Deflated: _____ Time inflated: _____ Deflated: _____

Pressure _____mmHg Time inflated: _____ Deflated: _____ Time inflated: _____ Deflated: _____

Applied by (initial): _____ Serial #: _____ ☐ Tourniquet applied but not inflated

EXPLANTS ☐ N/A

Explant description: _____

LASER DATA ☐ N/A

Laser type/model/serial #: _____ Laser time: _____ ☐ Standby

X-RAYS and IMAGES ☐ N/A

Type: ☐ Angiography ☐ Flat plate ☐ Fluoroscan/self image ☐ Fluoroscopy

CELLSAVER ☐ N/A

☐ Used

GENERAL CASE DATA

O.R.: _____ ☐ ASA class: _____ ☐ Return to O.R. ☐ See implant record

Pre-op diagnosis: _____

Post-op diagnosis: _____ ☐ Same as Pre-op

SURGICAL PROCEDURE

Procedure performed: _____

_____

_____

_____

Anesthesia type: ☐ General ☐ M.A.C. ☐ Spinal ☐ Block (type) _____ ☐ Epidural ☐ Local

Wound class: ☐ 1 ☐ 2 ☐ 3 ☐ 4

FIGURE 2-1 cont'd Sample intraoperative report.

Page 3 of 3

MEDICATIONS ☐ N/A

Medication	Dose	Route	Given by (Initial)	Date	Time

Hemostatic agents: _____

IRRIGATION ☐ N/A

Irrigation	Additives	Estimated In	Estimated Out

FAMILY COMMUNICATION ☐ N/A

☐ By Phone ☐ In person Communicated to: _____

Communicated by (initial): _____ Date: _____ Time: _____

SPECIMENS/CULTURES

Number of specimen: Tissue:_____ Frozen section:_____ Culture:_____ Fluid:_____ Foreign body:_____ ☐ None

Examined and disposed per Dr. (Print Name):_____

Skin/bone freezer: Description:_____

PACKING ☐ N/A

Packing type: _____ Packing site: _____

DEPARTURE FROM O.R.

Post-op skin condition excluding operative site: ☐ Dry and intact ☐ Unchanged ☐ Other, description:_____

Via: ☐ Ambulatory ☐ Bed ☐ Crib ☐ ICU bed ☐ Post-op chair ☐ Stretcher ☐ Surgilifter ☐ Other:_____

Destination: ☐ PACU ☐ PACU Phase I ☐ PACU Phase II ☐ Home ☐ Other:_____

Dressings:_____

COMMENTS

Abbreviations:
ASA–American Society of Anesthesiology
Circ–Circulator
Coag–Coagulation
ESU–Electrosurgical Unit
M.A.C–Monitored Anesthesia Care
Op–Operative
O.R.–Operating Room
PACU–Post Anesthesia Care Unit

Initial	Signature/Title	Print Name	Initial	Signature/Title	Print Name

FIGURE 2-1 cont'd Sample intraoperative report.

BOX 2-2

Key Components in Perioperative Patient Care Documentation*

1. Evidence of patient assessment on arrival in the OR, which includes assessment of the patient's skin condition immediately before and after the procedure.
2. Confirmation that members of the surgical team took a "time-out" before starting surgery, verifying and agreeing on the correct patient, surgical site/side, and procedure; that equipment and special needs such as implants or imaging studies were available; and that the patient was in the proper surgical position. The surgical site mark must be clearly visible.
3. Evidence of a plan of care, individualized for the patient and that considers the patient's base-line psychosocial, physical, emotional, and religious or cultural status/preferences. The plan of care, with identified outcomes, might include data elements and nursing interventions based on AORN's Perioperative Nursing Data Set (PNDS) (see Chapter 1).
4. Any sensory aids or prosthetic devices worn by the patient on admission to the OR and their subsequent disposition.
5. Patient position, including supports or restraints/immobilizing/safety devices used.
6. Location of electrosurgical unit (ESU) dispersive electrode/pad placement, identification of ESU and settings used.
7. Use of temperature-regulating device, its placement, identification of unit used, and recording of time and temperature, on admission and discharge from the OR.
8. Type and placement of monitoring electrodes (noninvasive and invasive).
9. Medications administered or dispensed by the perioperative nurse, complying with the institution's "Do No Use" list for abbreviations (Table 2-1).
10. Presence of catheters, drains, packing, tubes, other devices, and dressings.
11. Type of tourniquet, location of cuff placement, identification of unit, pressure setting, and inflation and deflation times.
12. Blood products administered and fluid output, including estimated blood loss (EBL), as appropriate. Unused blood returned to the blood bank or taken with the patient to the postanesthesia care unit (PACU) should be noted.
13. Implant type, size, expiration date (if applicable); name of manufacturer or distributor; and identification information used by manufacturer (e.g., lot, batch, model, serial number). A separate implant logbook entry also should be completed with FDA-required information, noting name and address of facility where surgery took place; identification information used by the manufacturer; patient's name, address, and social security number (unless the patient refuses permission to use this information); and name, address, and telephone number of implanting surgeon.
14. Skin preparation solutions used, areas prepared, precautions taken (such as to prevent chemical injury or fire), and any reactions to prep solution.
15. Known patient allergies to medications, prep solutions, tape, latex, dyes, and other substances.
16. Sponge, sharp, and instrument counts taken and results obtained.
17. Wound classification (see Chapter 8) and anesthesia physical status classification (see Chapter 4).
18. Time of discharge and disposition of patient from OR, including mode of transfer and patient status.

*This SBAR hand-off communication outline is also applicable for phase I PACU to phase II recovery hand-off communications.
Adapted from AORN Recommended practice for documentation of perioperative nursing care. In *Perioperative standards and recommended practices*, Nursing, Denver, 2009, The Association.

TABLE 2-1

Do Not Use Abbreviations

Use	Do Not Use	Reason
units	U or u	Mistaken as "0", "4," or "cc"
0.1 mg	.1 mg	No leading zero results in easily missed decimal point (i.e., 10 times the dose)
0.1 mg or 1 mg	.10 mg or 1.0 mg	Trailing zero results in easily missed decimal point (i.e., 10-100 times the intended dose)
mcg or micrograms	μg	Mistaken for mg
morphine sulfate	MS	Mistaken for MSO_4 and $MgSO_4$
morphine sulfate	MSO_4	Mistaken for MS and $MgSO_4$
magnesium sulfate	$MgSO_4$	Mistaken for MS and MSO_4
International unit	IU	Mistaken for IV and 10
daily	Q.D.	Mistaken for Q.O.D.; the period after the Q can be mistaken for an "I"
every other day	Q.O.D.	Mistaken for Q.D.; the period after the Q can be mistaken for an "I" and the "O" can be mistaken for "I"
left ear	as	confused with left eye (os)
right ear	ad	confused with right eye (od)

Amato-Vealey and colleagues (2008) identified and further developed elements of effective hand-off communication for use at each perioperative hand-off stage using the SBAR mnemonic. Identifying critical elements for hand-offs from preoperative to intraoperative (Box 2-3), from intraoperative to PACU or other postanesthesia recovery area (Box 2-4), and from PACU or other postanesthesia recovery area to inpatient unit (Box 2-5) can also facilitate development of critical elements for hand-offs from postanesthesia recovery to discharge units in ambulatory surgery.

BOX 2-3

Elements of the Preoperative to Intraoperative Hand-Off Communication

SITUATION
- Name of patient and date of birth
- Name of operative or invasive procedure to be performed, including modifiers and site
- Pertinent documents present and consistent

BACKGROUND
- Elements of patient history pertinent to surgery
- Medical clearance
- Patient allergies and NPO status
- Patient's vital signs and pain level
- Medication profile and medications taken today
- Specific laboratory results
- Code status of patient

ASSESSMENT
- Patient's current level of understanding of the surgery
- Special patient needs or precautions
- Pertinent aspects of the patient's emotional and spiritual status
- Pertinent cultural implications
- Anesthesia requests

RECOMMENDATIONS
- State whether the patient has been seen preoperatively by the surgeon and anesthesia care provider.
- Determine whether the patient is ready for surgery.
- Allow an opportunity for preoperative and intraoperative staff members to ask questions or voice concerns.

From Amato-Vealey EJ et al: Hand-off communication: a requisite for patient safety, *AORN J* 88(5):766, 2008.

BOX 2-4

Elements of the Intraoperative to PACU Hand-Off Communication

SITUATION
- Name of patient and date of birth
- Name of operative or invasive procedure performed, including modifiers and site

BACKGROUND
- Type of anesthesia administered and name of anesthesia care provider
- Intraoperative medications administered, including dose and time
- IV fluids administered
- Estimated blood loss
- Pertinent information related to the surgical site such as dressings, tubes, drains, or packing
- Any significant OR events

ASSESSMENT
- Hemodynamic stability
- Airway and oxygenation status
- Thermal status (e.g., presence of hypothermia or hyperthermia)
- Urine output
- Presence or absence of surgical complications
- Level of pain
- Method of pain management

RECOMMENDATIONS
- Ensure that immediate postoperative orders have been completed.
- Discharge from the PACU when stable.
- Allow opportunity for intraoperative and PACU staff members to ask questions or voice concerns.

From Amato-Vealey EJ et al: Hand-off communication: a requisite for patient safety, *AORN J* 88(5):766, 2008.

Wrong Site, Person, or Procedure Surgery

Surgery that is the wrong procedure or surgery performed on the wrong site or person includes any operative or other invasive procedure performed on the wrong patient, wrong body part, wrong side of the body, or at the wrong level of the otherwise correctly identified anatomic structure, such as in spinal surgery. Evidence shows that wrong site surgery not only can devastate the patient and family but also can impact the perioperative team adversely (Mulloy and Hughes, 2008). All institutions accredited by TJC must follow the Universal Protocol for Preventing Wrong Site, Wrong Procedure, Wrong Person Surgery. Selected components of the Universal Protocol relating to correct site verification include:

- *Preoperative verification process* to ensure that all relevant documents (e.g., the history and physical examination, surgical consent, required laboratory studies) and imaging studies (properly labeled and displayed) are available before the start of the procedure. The surgical team must agree that this is the correct patient and the planned procedure on the specified side and site.
- *Marking the surgical site* must be done so that the intended site of incision or insertion is clear and unambiguous. Procedures that involve left/right distinction, multiple structures, or multiple levels must be marked. The mark also must be unambiguous; initials, a "yes," or a line at or near the incision site may be used. The person performing the procedure who is accountable for it and who will be present when the procedure is performed must do the site marking; in addition, the patient should be involved in the marking. The method of marking should be consistent throughout the institution. The mark must be visible after the patient has been prepped and draped. Institutions should have procedures in place for patients who refuse site marking.
- *Taking the time-out*. The time-out must take place before starting the procedure or making the surgical incision. The surgeon or other physician who is conducting the procedure must be present for the time-out. If there is more than one procedure being performed by separate teams, there needs to be a time-out before each procedure. This does not apply to patients where the same surgical team is performing multiple aspects of a procedure. Specific situations where two time-outs are required are those when hospital policy or law/regulation requires two separate consents (e.g., for a cesarean section followed by a tubal ligation). During the time-out, active involvement and communication among all surgical team members is expected as they confirm and agree that they have the correct patient, correct side and site, and the correct procedure to be performed. It is helpful to also verify that the patient is in the correct position and that any needed equipment, supplies, or implants are available. In some facilities, the presence and review of relevant imaging studies are also confirmed as is the agreement that all prep solutions have dried to minimize surgical fire risks. The Patient Safety box presents an example of a universal protocol and fire risk assessment.

PATIENT SAFETY

Universal Protocol and Fire Risk Assessment

Planned Procedure: _____

_____

_____

_____ Date of procedure

COMPONENT #1 VERIFICATION PROCESS

Mark all that apply ***indicates required field*	Sending Unit	Prep & Holding	Unit Doing Procedure
Name and date of birth confirmed**			
Patient/decision maker verbalizes planned procedure			
Schedule confirms planned procedure			
Consent confirms planned procedure**			
History and physical confirms planned procedure			
Diagnostic study confirms planned procedure			
Progress record/consult confirms planned procedure			
Site marking required (*go to component 2*)			
Site marking not required			
Date/time:			
Initial:			

COMPONENT #3 TIME OUT

The entire procedure team has performed a Time Out and all members have verbally agreed.

Time out included the verification of:	**1st**	**2nd**	**3rd**
Correct patient identity			
Agreement on procedure to be done			
Correct site and side			
Diagnostic study confirmation of site and side			
Availability of implants			
Availability of special equipment			

1st Time out: Time: _____ Initial: _____

2nd Time out: Time: _____ Initial: _____

3rd Time out: Time: _____ Initial: _____

COMPONENT #2 SITE MARKING (if required)

After verification has been completed, the patient if able, will write "**Yes**" with a permanent marker on or as near the site as possible:

☐ Right _____ ☐ Left _____

Side marked by:

☐ Patient ☐ Family member (Relationship): _____ ☐ Healthcare provider

Initial: _____ Time: _____

FIRE RISK ASSESSMENT

Procedure site or incision above the xiphoid	1 (Yes)	0 (No)
Open oxygen source (face mask/nasal cannula)	1 (Yes)	0 (No)
Ignition source (cautery, laser, fiberoptic light source)	1 (Yes)	0 (No)

Score 1 or 2: ☐ Initiate routine protocol

Score 3: ☐ Initiate high risk fire protocol (see side 2 for specifics)

Initial: _____

Total score: _____

Initials	Signature/Title	Print Name

Initials	Signature/Title	Print Name

21020 S(36590)(0307)C

UNIVERSAL PROTOCOL AND FIRE RISK ASSESSMENT
(For Operating Room and Non-Operating Room Settings)

COMPONENT #1 VERIFICATION PROCESS

Purpose: To outline the process for identifying the correct person, correct procedure, and correct site for surgical and invasive procedures with involvement of the patient or decision maker when possible.

A. The caregiver (RN/LPN, anesthesia provider, surgeon, resident, PA) beginning the verification process will initiate the form.
B. When care of the patient is transferred to a new care area, the new caregiver will complete the appropriate columns and initial.
C. Mark (√) only the boxes that indicate the method reviewed to confirm the planned procedure.
D. Resolve discrepancies identified through the verification process prior to moving the patient to the procedure area or prior to the initiation of the bedside procedure/anesthesia regional block.

COMPONENT #2 SITE MARKING

Purpose: To clearly identify the intended site of incision or insertion.

A. Document site marking for patients having surgical/invasive procedures involving laterality or digits. (Patients having surgical/invasive procedures involving level(s) (i.e., spine or ribs) will have level(s) marked by the Licensed Independent Practitioner (LIP) performing the procedure or identified by the LIP using radiographic techniques during the procedure.)

COMPONENT #3 TIME OUT

Purpose: To conduct a final verification of the correct patient, procedure, site and implants, if applicable.

A. Time out is completed prior to the start of the procedure and a designated person (circulating RN, assisting RN or tech) will complete the section and initial.
B. Mark (√) only the boxes that indicate the components confirmed.
C. An additional Time Out is documented for a second procedure.
D. In the event that the physician performing the procedure leaves the patient or repositions the patient after the Time Out process has occurred, the Time Out process is repeated and documented.

FIRE RISK ASSESSMENT

- Routine Protocol
  1. FUEL:
     A. When an alcohol based solution is used, use minimal amount of solution and allow sufficient time for fumes to dissipate before draping. Observe drying time (minimum 3 minutes). Do not drape patient until flammable prep is fully dry.
     B. Do not allow pooling of any prep solution (including under the patient).
     C. Remove bowls of volatile solution from sterile field as soon as possible after use.
     D. Utilize standard draping procedure.
  2. IGNITION SOURCE:
     A. Protect all heat sources when not in use. (Cautery pencil holster, laser in stand by mode etc.)
     B. Activate heat source only when active tip is in line of sight.
     C. De-activate heat sources before tip leaves surgical site.
     D. Check all electrical equipment before use.
- High Risk Protocol (includes all of routine protocol)
  A. Use appropriate draping techniques to minimize O_2 concentration (i.e., tenting, incise drape).
  B. Electrical Surgical Unit (ESU) setting should be minimized.
  C. Encourage use of wet sponges.
  D. Basin of sterile saline and bulb syringe available for suppression purposes only.
  E. Anesthesia Care Provider considerations:
     - A syringe full of saline will be available, in reach of the anesthesia care provider, for procedures within the oral cavity.
     - Documentation of oxygen concentration/flows. Use of “MAC Circuit” for oxygen administration.

BOX 2-5

Elements of the PACU to Inpatient Unit Hand-Off Communication*

SITUATION
- Name of patient and date of birth
- Name of operative or invasive procedure performed, including modifiers and site

BACKGROUND
- Type of anesthesia administered and name of anesthesia care provider
- Medications administered in the OR and PACU, including dose and time
- IV fluids administered in the OR and PACU
- Estimated blood loss
- Pertinent information related to the surgical site such as dressings, tubes, drains, or packing
- Any significant OR events
- Any significant PACU events

ASSESSMENT
- Hemodynamic stability
- Airway and oxygenation status
- Thermal status (e.g., presence of hypothermia or hyperthermia)
- Urine output
- Presence or absence of surgical complications
- Level of pain
- Method of pain management

RECOMMENDATIONS
- Ensure that PACU physician orders have been completed.
- Ensure that the surgeon's plan of care has been implemented.
- Identify patient's and family members' educational needs.
- Provide discharge instructions.
- Discharge after 2 hours or when stable.
- Allow an opportunity for PACU and inpatient unit staff members to ask questions or voice concerns.

*This SBAR hand-off communication outline also is applicable for phase I PACU to phase II recovery hand-off communications.
From Amato-Vealey EJ et al: Hand-off communication: a requisite for patient safety, *AORN J* 88(5):767, 2008.

RESEARCH HIGHLIGHT

Significance of Retained Foreign Objects (RFOs)

Retained foreign objects (RFOs) after surgical procedures can be associated with significant patient morbidity or mortality. They also can have a significant negative impact on the institution's reputation and can result in litigation.

In one quality improvement project (Cima et al, 2009) the OR was averaging a retained foreign object event every 16 days. The project team undertook a defect analysis to identify patterns of failures unique to the OR culture followed by policy review, focusing on increased clarity and consistency in count policies. This was followed by intense staff education. After the intervention, the average interval between RFO events increased to 69 days. This improvement has been sustained for more than 2 years.

There are also new technologies available to reduce or prevent retained surgical sponges. To understand their cost-effectiveness, researchers in another study (Regenbogen et al, 2009) compared standard sponge counting (incidence of retained sponges is approximately 67 per 100,000 procedures) with universal or selective x-ray, bar-coded sponges, and radiofrequency (RFID)-tagged sponges. While standard counting prevented 82% of retained sponges, bar-coded and RFID-tagged sponges prevented about 97.5% of retained sponges. The bar-coded sponges were the most cost-effective. These researchers suggest that, given medical and liability costs of more than $200,000 per incident, sponge-tracking technologies can substantially reduce the incidence of retained surgical sponges at an acceptable cost.

Adapted from Cima RR et al: A multidisciplinary team approach to retained foreign objects, *Jt Comm J Qual Patient Saf* 35:123-132, 2009; Regenbogen SE et al: Prevention of retained surgical sponges: a decision-analytic model predicting relative cost-effectiveness, *Surgery* 145:527-535, 2009.

In addition to designating a universal protocol to prevent wrong site errors, TJC in 2005 identified numerous risk factors that contribute to an increased risk of wrong site surgery, including the following:
- More than one surgeon involved in the procedure (multiple procedures or care of patient transferred to another surgeon)
- Multiple procedures conducted on the same patient
- Unusual time pressures
- Unusual patient characteristics, such as physical deformity or massive obesity

Retained Foreign Objects (RFOs)

Unintentional retained foreign objects (RFOs) are also a concern of TJC, WHO, and all facilities where surgery is performed. While clinically different, wrong site surgery and RFOs are similar from safety and risk management perspectives. They both also share top positions in TJC's top 10 annual sentinel events. The physiologic, financial, and public relations sequelae from both wrong site surgery and RFOs are very serious (Research Highlight). In some ORs, following the Universal Protocol and conducting correct count processes (audible, visual, and concurrent) are considered inviolable rules (Cima et al, 2009). Applying Judge Learned Hand's legal calculation that the burden of precaution (BP) is directly proportionate to the gravity or severity of the injury (S) times the probability (P) of its occurrence (BP = S × P), the consequent severity of an RFO requires intense attention to prevention despite its relative rarity (*U.S. vs. Carroll Towing, 159 F.2d 169 [2d Cir. 1947]*).

Gawande and others (2003) projected the rate of RFOs as 1500 out of 28 million patients, with sponges being the item most frequently retained inadvertently. The actual rate is likely higher because previously facilities were not required to report RFOs. Physiologic consequences of a RFO include possible infection, obstruction, fistula formation, perforation or consequent pain, suffering (and possible death), and the likely need for reoperation. As noted earlier, CMS and many private insurers now refuse payment for remedial treatment such as reoperation to remove a sponge or treat the physiologic consequences of its inadvertent retention. The healthcare facility must absorb the costs of extended hospitalization and corrective treatment required. Additional financial loss can be incurred from malpractice litigation (Legal issues pertaining to retained sponges and towels, presented at AORN, March, 2009), impaired public reputation, and the need to respond to licensing and regulatory body inquiries.

Prevention of RFOs. At a minimum, all facilities should have a "count" policy that reflects AORN's *Recommended Practices for Sponge, Sharp, and Instrument Counts* (AORN, 2009). Key components of that RP are highlighted in the Patient Safety box and a sample count record is presented in Figure 2-2. The

Purpose: To document sponge, sharp and instrument counts for invasive procedures.

Date: _____

COUNTS	BASELINE	CAVITY IN CAVITY	BEFORE WOUND CLOSURE	FINAL - SKIN CLOSURE	PERMANENT RELIEF	TEMPORARY RELIEF
Time:						
Sponges						
Sharps						
Miscellaneous items						
Instruments						
Circulator initials:						
Scrub initials:						

FINAL COUNT			
Sponges	☐ Correct	☐ Correct with packed sponges	☐ Unresolved
Sharps	☐ Correct	☐ N/A	☐ Unresolved
Miscellaneous items	☐ Correct		☐ Unresolved
Instruments	☐ Correct	☐ Correct with packed instruments	☐ Unresolved

CORRECT WITH INTENTIONALLY PACKED SPONGES/INSTRUMENTS

Wound was packet with: _____ (number) _____ (name of item)

Packing communication log initiated: ☐ Yes **Purple arm band applied:** ☐ Yes _____(RN initials)

UNRESOLVED COUNT

Name of unresolved item: _____

☐ Physician notified: _____ (name of physician)

X-ray taken: ☐ Yes ☐ No, reason: _____ _____(RN initials)

Initial	Signature/Title	Print Name	Initial	Signature/Title	Print Name

Instructions:

1. To be completed by RN assigned to the procedure.
2. Record sponge, sharps, and miscellaneous items on dry erase board per policy.
3. Instruments are counted and recorded on the inventory list. If baseline instrument count is not indicated per the policy, document N/A (not applicable).
4. Record the time each count is performed in the appropriate column.
5. Initials and signatures are required for the RN and scrub person that performed each count.
6. Permanent relief is an RN and/or scrub person that provides relief for the circulating RN or scrub person for the remainder of the procedure or until the next shift. A complete sponge, sharps, miscellaneous item, and instrument count is required for permanent relief.
7. Temporary relief is an RN and/or scrub person that provides relief for the circulating RN or scrub person for lunch relief/break. A sponge, sharps, and miscellaneous item count is required.
8. RN performing final count will check appropriate boxes:
   - Correct
   - Unresolved
   - N/A when applicable

FIGURE 2-2 Count record.

policy should also incorporate human factors and keep interruptions, distractions, and repetition-induced attention deficits to their minimum. Counting aloud by two persons combined with the surgeon's manual exploration and the scrub person keeping mental track of sponges and other counted objects in the wound (situational awareness) have long been mainstay approaches to preventing RFOs. New sponge-tracking technologies have emerged in the last decade to enhance risk reduction strategies for preventing inadvertent retention of RFOs (Regenbogen et al, 2009). These include sequentially numbered sponges, bar coding, and radiofrequency identification (RFID) products. Typically, sequentially numbered sponge products are prepackaged, presterilized sponges in groups of 5 or 10 in sequentially numbered packages (e.g., 4 × 8's of 1-10, 11-20, 21-30; or laparotomy sponge packs of 1-5, 6-10 (Pelter et al, 2007). With such systems, surgical teams are more likely to detect a missing/retained sponge because they must account for each individual sponge rather than account for their aggregate number. The usual tenets of counting are still used. Counts are performed audibly, concurrently, and visibly. Distractions are minimized; in some institutions, a "pause for the cause" is taken while counts are conducted.

RFID and bar-code technologies are also incorporated into equipment to prevent retained foreign bodies. Bar-code scanning systems require scanning items as the procedure begins and/or as they are put into the body and again as they are removed from the body and/or as the procedure ends. RFID systems tag instruments, sponges, and other items likely to enter the body during a procedure and use a scanning wand through tissue to ascertain the location of these items before the procedure ends.

Other technological approaches will emerge. No matter which "counting" modality a facility adopts, none is a panacea for the risk of foreign object retention. All technologies need to be used precisely, as designed and in accordance with the manufacturer's instructions. As with any new technology or approach, all team members must be alert to possible unintended consequences of its use (e.g., electrical interference with other equipment or overreliance on the additional margin of safety provided by an approach, which may lead to less vigilance).

INCORRECT COUNTS. An "incorrect" or unreconciled count occurs when the number of items on the count record or worksheet fails to match the number of items recovered during a closing count. All incorrect closure counts should be reported immediately, and attempts made to resolve every discrepancy. If the count remains unresolved, the circulating nurse again notifies the surgeon of the unresolved count, and a search is made for the missing item, including the surgical wound, field, floor, linen, and trash (thus, the rationale that linen and trash not leave the OR until the end of the procedure). All personnel direct their immediate attention to locating the missing item. If it is not found, an x-ray film may be taken and read by the radiologist or surgeon as specified in institutional policy. If the x-ray is negative, the count is recorded as incorrect or unreconciled and the x-ray results noted on the patient's intraoperative record. An incident/occurrence/event report should be initiated according to institution policy. Accurate counting and recording of sponges, sharps, and instruments are essential for the protection of the patient, personnel, and the institution, and are integral to effective risk management.

PATIENT SAFETY

Key Components of Sponge, Sharp, and Instrument Counts

Risk reduction strategies include good communication among the surgical team, application of standardized process, counting that includes wound exploration before the closure of the operative site, and use of technology as applicable in the facility. Prevention of retained foreign objects is a crucial part of patient safety, advocacy, and teamwork in perioperative settings.

1. The scrub person and the circulating nurse count all items in unison (concurrently), aloud (audibly), and quietly, as the scrub person touches each item (visibly). This is referred to as the "first" count.
2. Counting should not be interrupted nor should the persons who are counting be distracted.
3. If any uncertainty exists about a count, it should be repeated.
4. The circulating nurse should record the count for each type of item immediately on the count record or worksheet (see Figure 2-2).
5. If additional sponges, instruments, sharps, or other items are dispensed during the procedure, they are similarly counted, and the circulating nurse records the number added.
6. The names of the circulating nurse and the scrub person are recorded as soon as each count is completed.
7. Additional counts should be performed whenever there is a change in personnel or when a cavity is closed within a cavity, such as the uterus or heart being closed. This is sometimes referred to as a "cavity" count.
8. As the first layer of closure begins, the scrub person and circulating nurse count all items consecutively in a standardized routine (e.g., proceeding from the sterile field to the Mayo stand to the back table and then off the field, or vice versa). The count is done audibly, visibly, and concurrently. This is referred to as the "second" count.
9. The circulating nurse informs the surgeon of the results of the count.
10. The count procedure (final count) is repeated as skin closure begins.

Adapted from AORN Recommended practice on sponge, sharp and instruments counts. In *Perioperative standards and recommended practices*, 2009, Denver, The Association.

Care and Handling of Specimens

During the many years perioperative patient care has included safe handling of surgical specimens, laboratory medicine's safety practices focused on the analysis of the surgical specimen. The WHO World Alliance for Patient Safety now recognizes that to further improve patient safety in laboratory medicine, the pre- and postanalytical stages are equally important. They urge requirements for multidisciplinary, multistage, and multisystem approaches (McCoy et al, 2009). Like other areas of patient safety, laboratory labeling errors occur more frequently than commonly believed (Carraro and Plebani, 2007). Makary and colleagues (2007) found specimen labeling errors occur in 4.3 of every 1000 surgical specimens. Errors were slightly more common in outpatient (0.512%) than inpatient ORs (0.346%) and included unlabeled specimens, empty containers, incorrect laterality, incorrect or no identified tissue site, or incorrect or no patient names (Research Highlight).

RESEARCH HIGHLIGHT

Surgical Specimen Errors

It is well-established that communication errors are a major factor in sentinel events in surgical patient care. One type of communication error that poses significant risks to patients is the misidentification of a surgical specimen before its arrival in the pathology lab. This study was designed to quantify the extent to which specimen errors occur. Of 21,351 surgical specimens involved in the research analysis, there were 91 errors—for an annualized rate of 182 specimen errors a year. These errors included:

- 18—specimen not labeled
- 16—empty specimen container
- 16—incorrect laterality
- 14—incorrect tissue site
- 11—incorrect patient
- 9—no patient name
- 7—no tissue site

Procedures involving the breast had the most common specimen errors; nearly 60% of errors were associated with a biopsy procedure. The researchers aptly concluded that specimen errors are common and pose important risks to patients. Quantifying specimen error rates may be an important measure of patient safety and quality in surgical care.

Modified from Makary MA et al: Surgical specimen identification errors: a new measure of quality in surgical care, *Surgery* 141:450-455, 2007.

TJC does not specifically address specimen handling in the *2009 National Patient Safety Goals*. However, under its communication goal it requires action to improve timeliness of reporting critical laboratory results. Accurate and timely communication and delivery of specimens are necessarily implicit in timely reporting of results. The care and handling of specimens raise considerations unique to perioperative settings, and again AORN's *Recommended Practices for Care and Handling of Specimens in the Perioperative Environment* provides the best guidance. The Patient Safety box summarizes key points in safe specimen care and handling.

PATIENT SAFETY

Key Points in Handling Specimens in the Perioperative Environment

1. Assessment of specimen collecting and handling needs begins when the procedure is scheduled.
2. Procedures for correct patient and specimen identification should include consistent and accurate information on labels and forms.
3. Institute methods to prevent contamination of personnel and specimens including the proper use of preservatives.
4. Forensic specimens may require unique handling to preserve the chain of evidence.

Proper care and handling of specimens are critical to the outcome of a patient's surgery. It is the responsibility of the circulating nurse to identify, document, and care properly for specimens collected in the OR. Common specimens include blood, soft tissue, bone, body fluids, and foreign bodies. Complete and accurate identification and labeling of specimens and timely delivery to the proper laboratory for analysis are imperative. A mislabeled specimen may result in misdiagnosis and subsequent inappropriate treatment of the patient. At a minimum, each specimen is labeled with the correct patient name and identification number, specific origin of the specimen, and laterality (e.g., Jane Doe, 100001, right breast biopsy). The surgeon should provide descriptive information about the specimen (e.g., suture tag at 6 o'clock). The nurse should "repeat-back" to the surgeon information being sent to the laboratory (e.g., patient name, type of specimen, source/location, required tests, special handling needs). All specimens and their disposition are documented on the patient's intraoperative record.

Each specimen is handled according to the specific protocol established by the receiving laboratory. Generally, all tissue should be handled to preserve its integrity, kept moist, and transported to the laboratory as soon as possible. Standard transmission-based precautions should be used to protect individuals handling the specimen (see Chapter 3). Labels should identify the need for precautions and the presence of biohazardous material. Formalin, a combination of methanol, water, and formaldehyde, is frequently used to preserve specimens if they are not taken to the laboratory immediately. Formaldehyde is considered a hazardous substance. Formaldehyde fumes can cause watery eyes and respiratory irritation. Direct contact will injure human tissue. Gloves must be worn and adequate ventilation provided in areas where formaldehyde is handled. Institutional policy should describe procedures to follow in case of formaldehyde spills.

Specimens for Frozen Section. When immediate tissue identification or identification of malignancy is needed, specimens are quick-frozen, sliced, stained, and examined in the laboratory under a microscope. This method of tissue examination is called *frozen section*. Specimens for frozen section usually are placed on Telfa or into a dry specimen container. They are *never* placed in saline solution or formalin nor are they ever transported on a counted sponge. The results of frozen-section analysis are communicated to the surgeon intraoperatively. If the hospital has no system for direct pathologist-surgeon communication, the perioperative nurse receives the telephone report of a frozen section. Since this is considered a critical test result, the nurse "reads-back" the test result to the pathologist and surgeon and receives a "repeat-back" from the pathologist and surgeon to verify accurate communication of the results.

Risk for Electrical and Thermal Burns

Electrical hazards in the OR include electric shock, fire, explosions, and burns. Electric shock results from current flowing through the body and can occur from touching a damaged plug or an ungrounded piece of metal equipment. Electrosurgery works by sending a specified current from the electrosurgical unit (ESU) through the pencil or other ESU instrument (active electrode) to create sufficient heat to cut or coagulate the vessel touched by the pencil or other instrument. The current then exits the body through a dispersive electrode (sometimes called the "ground pad") and returns to the ESU. Fires and burns can result from improper use of electrical equipment such as lasers (see Chapter 7) and ESUs, particularly in the presence of an oxygen-enriched atmosphere (OEA) or flammable liquids.

Flammable liquids, such as alcohol and acetone, must be properly stored. These liquids, as well as flammable aerosol sprays, should not be used for cleaning and incidental use in hazardous locations. Key components of preventing electrical injury caused by electrical equipment including the ESU are listed in the Patient Safety box. In addition, when using an ESU, the patient must be properly grounded to prevent current from seeking an unintended path of less resistance back to ground. For example, current may pass through a patient's ring touching the stainless-steel OR bed rail and then to ground rather than through the ESU grounding device (dispersive pad) and back to the ESU ground. The greater concentration of current exiting at the smaller ring site will cause a burn that would not occur if the current had exited via the larger area of the ESU dispersive pad.

PATIENT SAFETY

Key Components to Preventing Electrical Equipment Injuries

1. Prohibit the use of any apparatus or device producing an open flame.
2. Evaluate and test all new equipment to ensure optimal safety and performance.
3. Inspect all electrical equipment, regardless of the source, for safety and proper functioning before use, and label with an inspection sticker according to institutional procedure.
4. The biomedical technician or electrical safety officer should determine whether electrical equipment (including ESUs) is safe for use.
5. Establish inventory control, regular inspection, preventive maintenance, and safety approval systems.
6. Instruct personnel in the safe use of all equipment, and require and document a return demonstration of personnel competency.
7. All personnel must be familiar with the procedure for prompt removal from use and expeditious repair of defective equipment.
8. A qualified electrician should inspect electrical outlets and equipment at designated intervals or as requested and should file written reports with the director of surgical services.
9. A standard procedure for care and use of electrical equipment should include the following:
   - The plug, cord, and connections of electrical equipment must be checked before each use for insulation integrity and secure connections.
   - All electrical cords should be of adequate length and flexibility to reach an outlet without stress and without the use of extension cords. Kinks and curls should be removed from electrical cords before plugs are inserted into wall outlets.
   - The plug, not the cord, should be handled when electrical cords are plugged into or removed from an outlet. Pulling on the cord may cause it to break at the point where it is attached to the plug.
   - Cords should not be wrapped tightly around equipment; doing so causes the protective covering to wear and breaks the wires inside the covering over time.
   - Cords always should be removed from traffic pathways before equipment such as a bed or a machine is moved. If the position of electrical equipment necessitates cords lying on the floor where people will be walking during surgery, cords should be taped down to prevent tripping.

Risk for Chemical Burns

Perioperative chemical burns most commonly occur during or after surgical site skin preparation (prepping). Skin preparation solutions should be applied with care to prevent pooling, which can lead to chemical burns. Towels should be tucked under the patient along the area to be prepped to catch any dripping solution and removed as soon as the skin prep is completed (these are sometimes referred to as "drip" towels). In addition to being a chemical irritant, prep solution may be ignited by a spark from an active electrode of the ESU or even from a charge of static electricity. Ignition of vapors can also occur as solution evaporates. Solutions used for skin preparation must be permitted to dry before application of the surgical drapes.

Pressure Injuries

Perioperative pressure injuries include nerve compression (peroneal and ulnar nerves are particularly susceptible); nerve stretching (e.g., brachial plexus extension); and pressure ulcers (especially on the coccyx, heels, or back of head in supine position). Pressure or the lack thereof also may cause vessel stasis and DVT. Each surgical position has its own predictable pressure risks and methods of prevention (see Chapter 5). As a general rule, however, the surgical team should remember that increasing the area of contact or reducing the force pushing on that area will decrease pressure. An easy to remember formula is pressure equals force divided by area ($P = F/A$). This formula explains why both thin and obese patients are at risk for pressure injuries during surgery. Thin patients tend to have a smaller area (e.g., the coccyx) directly in contact with the OR bed or a positioning device. Obese patients, on the other hand, have more force from their increased weight and body mass. Thus both situations can result in increased pressure. Padding typically reduces pressure by increasing the area over which the force is applied. Reminding scrubbed personnel not to lean on the patient reduces force applied to an area, thus also reducing pressure. Both increasing area and decreasing force combine to reduce pressure and the likelihood of pressure injury.

Medication Administration

While Hughes and Blegen (2008) report that current evidence suggests there is an adequate mechanism for medication error reporting, the knowledge base to build safer medication administration interventions in this error-prone process remains weak. Medication administration in the OR/invasive procedure room is further complicated compared to that found in other nursing care areas in that the OR often requires that the circulating nurse and scrub person jointly prepare a medication that is being administered by a third person, usually the surgeon. Vigilance in following established safe medication practices is crucial. Perioperative personnel must pay particular attention to acknowledging medication concentrations, labeling solutions in syringes and containers on and off the sterile field, and performing read backs/repeat backs. Safe medication administration practices in perioperative patient care settings are highlighted in the Risk Reduction Strategies box.

Policies and procedures should be strictly followed to check the medication or solution before it is dispensed to the sterile field. Medications and medication containers (e.g., syringes, cups, basins) both on and off the sterile field must be labeled

RISK REDUCTION STRATEGIES

Medication Safety Practices

- Follow the seven rights (7 R's) of medication delivery: right patient, medication, dose, route, time, technique, documentation.
- Use at least two patient identifiers when administering medications. Identifiers include the patient's name, assigned identification number, or bar coding in a patient ID bracelet that includes two or more specific patient identifiers.
- Identify/verify any patient allergies and sensitivities (e.g., medications, latex, foods, adhesives, chemicals).
- Review patient's medication history (including herbal remedies, over-the-counter [OTC] drugs); identify possible medication interactions or contraindications.
- When receiving a verbal or telephone order for a medication, write the complete order or enter it into the computer; then "read back" the medication order, receiving confirmation from the person who gave the order that it is correct.
- When writing the complete order or entering it into the computer, comply with the institution's "Do not use" list and list of look-alike/sound-alike drugs. Look-alike and sound-alike drugs should be stored separately.
- The circulating nurse and scrub person should audibly review and confirm the medication ordered before transfer to the sterile field. Medication verification should include drug/solution/agent name, strength, dosage, and expiration date. The medication order is sometimes part of a standing protocol on the preference card/pick list.
- Label all medications and containers with solutions (e.g., syringes, medicine cups, basins) on and off the sterile field, even if there is only one medication being used.
- Verify any medication listed on the physician's preference card/pick list with the physician before delivery to the field, labeling, or administration.
- Label any medication or solution when it is transferred from its original package to another container.
- Label each medication or solution one at a time. Verify name and concentration, complete preparation for administration, deliver to the sterile field, and label on the field before another medication/solution is prepared.
- Use medication vial transfer devices to dispense medications onto the sterile field without contaminating the medication during dispensing.
- Keep original packages from medications or solutions available for reference in the OR/procedure room until the surgery/procedure ends.
- Labels should contain the drug name, strength, amount (if not apparent from the container), expiration date when not used within 24 hours, and expiration time when expiration occurs in less than 24 hours.
- Differentiate look-alike and sound-alike products by using "tall man" lettering on products or highlighting/circling the distinguishing information to prevent errors.
- Verify all labels verbally and visually by two qualified individuals.
- Discard any unlabeled medication or solution immediately.
- The scrub person should actively communicate medication/solution name, amount, and dose when transferring it to the surgeon.
- At shift change or when personnel are relieved ("hand-off"), all medications and solutions on and off the sterile field and their labels should be reviewed by entering and exiting staff.
- Document all medications administered on the perioperative nursing record.
- Monitor patients for adverse medication reactions, and document interventions to treat adverse reactions.
- Discard all labeled containers used during the surgical procedure at the procedure's end.
- Follow procedures for reporting and responding to medication errors (adverse drug events [ADEs]), including near-misses.

Modified from AORN Guidance Statement: Safe medication practices in perioperative practice settings, *Perioperative standards and recommended practices,* Denver, 2009, The Association; Beyea SC: *Perioperative nursing data set,* ed 2, Denver, 2007, The Association; Cole LM: Documentation to reduce medication errors, *OR Nurse* 2(7):17-19, 2008; Giarrizzo-Wilson S: Clinical issues—medication practices, *AORN J* 81(6):1326-1329, 2005; Improving the OR's medication safety, *OR Manager* 23(1):17-18, 2007; ISMP Medication Safety Alert: *NurseAdvise-ERR; positive identification—not just for patients, but for drugs and solutions,* 3(8), 2005; JCAHO: *What every health care organization should know about sentinel events,* Chicago, 2005, The Association.

and processes established to verify labels. Scrub persons should identify medications by announcing the name of the medication being passed to the surgeon along with its strength. A repeat-back confirmation from the surgeon ensures that the correct dose of medication or solution is used. The institution's "Do not use" list must be applied to all medication orders and medication-related documentation that are handwritten or on preprinted forms (see Table 2-1).

TJC's list of look-alike/sound-alike drugs, based on findings from the Institute for Safe Medication Practices (ISMP), should be available to all perioperative personnel. The table lists potentially problematic drug names, potential errors and consequences, and specific safety strategies. Drugs listed, particularly relevant to perioperative settings, include ephedrine and epinephrine; hydromorphone and morphine; concentrated morphine and liquid morphine; hydroxyzine and hydralazine; various insulin brand names (e.g., Humulin and Humalog); and oxycodone and OxyContin.

Federal agencies, TJC, and individual institutions increasingly look to bar-code medication administration (BCMA) systems to reduce medication errors. Empirical studies have found a reduction in errors after BCMA implementation. However, precursors to errors, such as workarounds, interruptions, and patient and technology characteristics, continue (Carayon et al, 2007). As is the case for any new approach, the perioperative nurse must nevertheless remain vigilant for possibly unintended consequences.

Risk for Fluid or Electrolyte Imbalance

Blood Loss. Measuring blood loss is a vital procedure in the surgical management of critically ill or elderly patients, patients undergoing complex procedures, trauma and organ transplant patients, patients with abnormal bleeding or clotting time or with extensive renal/liver disease, and infants. Some anesthesia providers prefer to estimate blood loss via visual inspection of drapes, suction canisters, and used sponges. When blood loss estimates must be more accurate, weighing sponges provides a reliable means of judging the amount of blood lost and of gauging the need for transfusion. The weight of dry, unused sponges and the weight of the plastic bag for soiled

sponges must first be determined and then excluded from the weight tally. Grams (g) measured are converted to milliliters (ml) on a 1:1 basis, and blood loss estimates are reported to the anesthesia provider. The setup to weigh sponges requires a gram scale and plastic bags to hold soiled sponges. Box 2-6 details the procedure. The estimated blood loss may be part of the hand-off report in ORs that use a surgical Apgar score (Research Highlight).

BOX 2-6

Procedure to Measure Blood Loss by Weighing Sponges

1. Weigh a dry sponge in a plastic bag, and adjust the scale to register zero.
2. Place used, bagged sponges on the scale.
3. Record the scale reading: 1 g equals 1 ml of blood loss.
4. Note the blood loss on the record.
5. Add subsequent weight to the preceding weight each time sponges are weighed so that a running total blood loss, calculated from sponges, is available.
6. Measure blood in the suction canister(s) at regular intervals, subtracting the amount of any irrigating solution used.
7. Add the amount of blood loss calculated from suction canisters to the total recorded from sponges to obtain accurate blood loss estimates.

RESEARCH HIGHLIGHT

The Surgical Apgar Score

In 1953, Virginia Apgar introduced a 10-point scoring system to evaluate the condition of a newborn. The Apgar score revolutionized obstetric care. About 20 years later, interest in a similar scoring system has led to the development and testing of a surgical Apgar score to provide a routine, reliable scoring method to measure a patient's condition and the chances of major complications or death at the end of surgery. Researchers from Harvard and Brigham and Women's Hospital, Boston, developed a 10-point score, similar to an Apgar score, based on a patient's estimated amount of blood loss (EBL), lowest heart rate, and lowest mean arterial pressure during general or vascular surgery. They validated the surgical Apgar score on 4119 general and vascular surgery patients, finding a consistent trend toward worse outcomes with lower scores. Patients with scores of 9 or 10 had only a 5.0% incidence of major complications and a 0.1% incidence of death. On the other hand, patients with scores of 4 or less had a 56.3% incidence of major complications and a 19.5% incidence of death. The researchers concluded that the simple 10-point surgical Apgar score can successfully identify patients at higher and lower than average risk of major complications and death after surgery.

Perioperative nurses frequently accompany surgical patients to PACU and participate in the hand-off report. One of the intraoperative measures they often track and report or record is EBL. This measure may become a routine category in hand-off reports as the anesthesia provider and perioperative nurse collaborate to report measures used in assigning surgical Apgar scores.

Adapted from Gawande AA et al: An Apgar score for surgery, *J Am Coll Surg* 204:201-208, 2007; Regenbogen SE et al: Utility of the surgical Apgar score: validation in 4,119 patients, *Arch Surg* 144:30-36, 2009.

Blood and Blood Products. Maintenance of circulating blood volume is crucial during surgical procedures; this is accomplished with administration of whole blood or blood components (History box). Whole blood is rarely administered unless the patient has an acute, massive loss (often empirically determined as a loss that exceeds one third of the circulating volume, or approximately 1500 ml for an adult). Instead, packed red blood cells (PRBCs) that improve oxygen-carrying capacity and oxygen transport to tissues, with or without crystalloid or colloid solutions, are administered to maintain intravascular blood volume. Crystalloid solutions include normal saline and lactated Ringer's solution; colloid solutions include albumin, purified protein factors, dextran, and hydroxyethyl starch (hetastarch). If coagulopathy is an issue, fresh frozen plasma (FFP) platelets and cryoprecipitate sould be considered. When blood or any blood products must be given, appropriate precautions are necessary to reduce the hazards of its administration.

Elective surgery patients who may need blood products during surgery have a pretransfusion sample taken 1 to 7 days (facility policy and patient history dependent) before surgery to ensure compatibility and to avoid antibodies that may emerge in response to exposure through blood transfusions, pregnancy, or environmental factors or as a consequence of the

HISTORY

Blood Transfusion

The safe transfusion of blood and blood products is commonplace in surgery. It is a relatively recent advance, however, compared with other surgical milestones. Bloodletting and phlebotomy, described in many historical references, were recommended for many ailments, including insanity. Transfusions were attempted several hundred years ago to change the nature of an individual; for example, they were used for individuals accused of being witches, to infuse them with the proper sprits. In 1825 Dr. Philip Syng Physick of Philadelphia administered what might have been the first successful transfusion of human blood. In the 1900s the A, B, AB, and O blood types were discovered, and by the 1940s techniques for cross-matching, anticoagulation, storage of blood, and blood banks made routine blood transfusion possible. A 1942 nursing textbook noted, "blood transfusion is a procedure employed in the treatment of severe shock, especially when accompanied by hemorrhage, whether due to injury or some such emergency…." The textbook showed a procedure for "taking blood," wherein a cuff was applied to the arm to distend the veins, a venesection needle with rubber tubing attached was inserted, and the blood was drained by gravity into a glass bottle that was rotated by an assistant to ensure that it mixed properly with the citrate solution already in it. A second assistant was shown who "may suck the air out of the bottle and so hasten the flow of blood" during the "taking blood" procedure. After the blood was taken, the glass bottle had beads added to it to prevent clots from passing out, glass tubing was placed in the rubber tubing so that the flow of blood could be observed, and a flattened end was placed at the administration part of the tubing so that blood (but not the beads) could pass into the patient. It was noted that a syringe could be used to blow air into the bottle if blood was running too slowly.

Modified from Fakhry SM et al: Hematologic principles in surgery. In Townsend CM, editor: *Sabiston textbook of surgery,* ed 16, Philadelphia, 2001, Saunders; Houghton M: *Aids to tray and trolley setting,* ed 2, London, 1942, Bailliere, Tindall & Cox.

patient's disease process. *Type* refers to the test to determine the ABO and Rh blood type. Screen refers to the test for unexpected antibodies. *Crossmatching* refers to the test for the compatibility of the recipient's serum and the donor's red blood cells. It is crucial to identify the patient correctly before the pretransfusion blood sample is drawn and then to ensure that the sample is properly labeled (Hendler, 2008). Improperly identified pretransfusion blood samples can result in acute hemolytic transfusion reactions at the time of transfusion.

A patient having an elective surgical procedure for which blood has been requested should not be anesthetized without verification that the requested blood products are typed, crossmatched, and available and that informed consent to receive blood products has been documented. This should be part of the preoperative verification process and then reverified during the time-out. An institutional blood requisition form, with complete and accurate patient identification information, should be sent to the blood bank when blood or blood products are being requested. Included on or with this requisition should be the number of units desired. Many institutions have computerized ordering and the same information is required.

If the patient is sent to the OR directly from the emergency department or trauma admitting area without a chart, all patient identification information must be printed plainly on a piece of paper. The perioperative nurse should contact the blood bank to explain the emergency situation and facilitate release of the needed blood products.

Storage of blood products is important to ensure patient safety and to avoid wasting improperly stored products. Whole blood and blood products must be stored under continuously monitored conditions, in accordance with the American Association of Blood Banks (AABB) rules and FDA regulations. Temperatures must be documented and all storage equipment for blood products must be properly maintained and tested, including function checks on alarms. When blood components have been out of monitored refrigeration for more than 30 minutes, they cannot be returned to the blood bank for reissue. Always follow facility policy for return of unused blood products and be aware each component has specific requirements.

Before administration of any blood product, the circulating nurse and anesthesia provider (or a second licensed individual) must confirm the following:

- The unit number on the blood product corresponds with the unit number on the blood requisition. Facilities using electronic records will return a "transfusion card" or "crossmatch card" as verification that this unit can be given to this patient in lieu of the requisition.
- The name, birth date, and number on the patient's identification band agree with the name, birth date, and number on the blood product.
- The patient's name on the blood product corresponds with the name on the requisition.
- The blood group indicated on the blood product corresponds with that of the patient.
- The date and time of expiration has not been reached.
- The blood product bag is free of leaks, damage, or signs of possible bacterial contamination (e.g., presence of fine gas bubbles, discoloration, clots or excessive air in the bag).

Both individuals who verify this information must sign the slip that comes with the blood product. If a discrepancy arises with any of these checks, the blood product must not be infused until and unless the discrepancy is resolved.

When it becomes apparent that additional blood products will be needed than originally anticipated, the perioperative nurse should request the blood bank prepare a specified number of units in advance of the actual need to transfuse. This procedure allows the blood bank time to crossmatch the units carefully, without rushing and jeopardizing patient safety. Crossmatch requisitions should be sent for any additional units requested. If a significant amount of blood product has been required, a new, properly labeled sample with a blood grouping requisition may be needed to have adequate serum for crossmatching or to ensure antibody compatibility although blood banks prefer using the original undiluted sample when possible.

Rapid blood transfusion requires warming of blood product to prevent hypothermia, which may induce cardiac arrest. Blood product should be warmed during its passage through the transfusion set. The warming device must incorporate a temperature monitor and, ideally, an audible warning system. The probability of a transfusion reaction increases in direct proportion to the number of units transfused. The circulating nurse should be alert to any signs of reaction, including the following:

- Hyperthermia
- Increased intraoperative bleeding
- Weak pulse
- Hypotension
- Visible hemoglobinuria
- Vasomotor instability
- Greatly decreased or no urinary output

If any such suspicious signs of reaction occur, the circulating nurse should assist the anesthesia provider to do the following:

1. Stop the transfusion. The tubing is disconnected and a new infusion of fluid such as 0.9% sodium chloride is begun to maintain venous access.
2. Report the reaction to the surgeon and blood bank immediately.
3. Anticipate possible order for stat antihistamines.
4. Return the unused portion of the blood product, the IV tubing used during the transfusion, and a sample of the patient's blood to the blood bank.
5. Send a urine sample to the laboratory if requested.
6. Monitor the patient's reaction carefully.
7. Complete an incident/occurrence/event report covering the details of the suspected reaction. These might include time and date of reaction, type and amount of blood/blood product infused, and times transfusion started and stopped. Signs and symptoms, in the order of occurrence, along with the patient's vital signs, any urine or blood samples sent to the laboratory for analysis, any treatment given, and the patient's response should all be noted. A suspected transfusion reaction report must be sent to the blood bank.

Any unused blood product should be returned to the blood bank as soon as the patient leaves the OR. Returned blood can be reissued if it has not been allowed to warm to a temperature greater than 10° C or been out of monitored refrigeration for more than 30 minutes. New external blood bag thermometers (e.g., HemoTemp II), similar to a skin contact tape thermometer, are being used on blood product bags by many blood banks to quickly identify blood that has exceeded safe storage temperatures.

Autotransfusion—the reinfusion of a patient's own blood—is being used with increasing frequency. In autologous blood donations, the blood is predonated typically 3 to 5 weeks before surgery for use in the patient's own planned surgery. During intraoperative autotransfusion (cell salvage), blood is collected as it is lost during the surgical procedure and reinfused to the patient after it is filtered or washed. This technique can be lifesaving in emergency situations, as with major trauma, or in procedures with major blood loss, as in liver transplantation. It is also used for patients who refuse blood based on religious beliefs.

Maintaining Fluid and Electrolyte Balance

Fluid and electrolyte balances are important to the health and safety of the patient in surgery. The body's fluids and electrolytes play a key role in maintaining homeostasis, transporting necessary oxygen and nourishment to the cells, removing waste products of cellular metabolism, and helping to maintain body temperature. Electrolytes are also essential to transmission of nerve impulses, regulation of water distribution, contraction of muscles, generation of adenosine triphosphate (ATP, needed for cellular energy), regulation of acid-base balance, and hemostasis (clotting blood). The intake, distribution, and output of water and electrolytes, regulated by the renal and pulmonary systems, normally maintain fluid and electrolyte balance.

Fluid and electrolyte imbalances may occur rapidly in the surgical patient, and can be caused by numerous factors, including preoperative fluid and food restrictions, intraoperative fluid loss, or the stress of surgery. The surgical patient is unable to regulate body fluid and electrolyte requirements by normal activities of drinking, eating, excreting, and breathing unaided. It is therefore imperative that the perioperative nurse monitor and collaborate in controlling the fluid and electrolyte status of the patient intraoperatively.

Body Fluids. The adult human body is approximately 60% water, although water content varies by age, gender, and body mass. In the elderly, body water content averages 45% to 55% of body weight, whereas it ranges from 70% to 80% in infants. Older adults are at higher risk for fluid balance problems because they have less fluid reserve, while the very young are at risk for fluid problems because a greater percentage of their body weight is water. Both age groups have a decreased ability to compensate for fluid loss. Muscular tissue contains more water than the same amount of adipose tissue; men generally have higher water content because they usually have more lean muscle mass than women.

Body fluids are distributed in two main functional compartments—intracellular and extracellular. *Intracellular fluids (ICFs)* are liquids within cell membranes that contain dissolved substances essential to fluid and electrolyte balance and metabolism. Intracellular fluids constitute approximately 70% of the body's fluid. Consequently, anything that affects water loss at the intracellular level has significant implications for the entire body. *Extracellular fluids (ECFs)* (30% of the body's fluid) are fluids in compartments outside the cells of the body, including plasma, intravascular fluids, fluids in the gastrointestinal (GI) tract, and cerebrospinal fluid (CSF).

Fluid spacing is a term used to classify distribution of body water. *First spacing* is the normal distribution of fluid in extracellular and intracellular compartments. *Second spacing* refers to excess accumulation of interstitial fluid (edema), while *third spacing* occurs when fluid accumulates in areas that normally have no fluid or only a minimal amount of fluid. This fluid accumulation occurs with burns, ascites, peritonitis, or small-bowel obstruction. Third spacing traps fluid away from normal fluid compartments and results in a deficit in extracellular fluid volume.

Electrolytes. Electrolytes (Table 2-2) are found in both intracellular fluids (ICFs) and extracellular fluids (ECFs). When dissolved in water, electrolytes dissociate into ions and are able to carry an electric current. Positively charged ions are cations, and negatively charged ions are anions. The electrolytes found in the ICF and ECF are essentially the same, but their concentrations in each compartment differ. The primary intracellular cation is potassium, and the primary extracellular cation is sodium. The primary intracellular anion is phosphate, and the primary extracellular anion is chloride. Fluids and electrolytes move between the intracellular and extracellular spaces to facilitate body processes, such as acid-base balance, tissue oxygenation, response to drug therapies, and response to illness. Diffusion, active transport, and osmosis control this movement.

Diffusion, Active Transport, and Osmosis. *Diffusion* is the movement of molecules from an area of high concentration to one of low concentration. When diffusion occurs across a membrane, movement continues until there is an equal concentration of molecules on both sides of the membrane.

Active transport is a process by which molecules are moved across a cell membrane against a concentration gradient (i.e., from an area of low concentration to an area of high concentration) with the use of external energy. The sodium-potassium pump moves sodium out of the cell and potassium into the cell to maintain the intracellular and extracellular concentration differences of sodium and potassium. ATP is the energy source for the sodium-potassium pump.

Osmosis is the movement of a fluid through a semipermeable membrane from a solution that has a lower solute concentration to one that has a higher solute concentration (Figure 2-3). The semipermeable membrane prevents movement of solute particles. The number of particles is measured in a unit called the osmole *(osm)*. *Osmolality* is the term used to express the concentration of a solution in milliosmoles per kilogram (mOsm/kg) of water. A solution with the same osmolality as blood plasma is called *isotonic*. Isotonic solutions, such as 0.9% normal saline or lactated Ringer's solution administered intravenously (IV), prevent the shift of fluid and electrolytes from intracellular compartments. A hypotonic IV solution (0.45% saline or 2.5% dextrose) has a lower concentration of solutes than that found in plasma and moves water into the cells. Administration of a hypertonic IV solution (5% dextrose in normal saline or 5% dextrose in lactated Ringer's solution) with a greater concentration of solutes than that of plasma moves water out of the cells.

Preoperative Considerations. A crucial part of assisting the surgical patient to maintain fluid and electrolyte balances is preoperative assessment and identification of risk factors for fluid and electrolyte imbalances. Preoperative laboratory analysis of electrolyte levels should be checked and abnormalities

TABLE 2-2

Electrolyte Functions and Regulators

Electrolyte	Reference Range	Functions	Regulation
Sodium (Na^+)	135–145 mEq/L	Maintains blood volume Controls water shifting between compartments Major cation involved in sodium-potassium pump necessary for nerve impulse conduction Interacts with calcium to maintain muscle contraction Major cation in bicarbonate and phosphate acid-base buffer system	Renin-angiotensin-aldosterone system ◆ Retains sodium and water is passively absorbed
Potassium (K^+)	3.5–5 mEq/L	Affects osmolality Major cation involved in sodium-potassium pump necessary for nerve impulse conduction Promotes nerve impulse conduction, especially in heart and skeletal muscles Assists in conversion of carbohydrates to energy and of amino acids to protein Promotes glycogen storage in liver Assists maintenance of acid-base balance through cellular exchange with hydrogen	Renin-angiotensin-aldosterone system ◆ Kidneys excrete potassium in exchange for sodium
Calcium (Ca^{2+})	4.5–5.5 mEq/L (or 9-11 mg/ml)	Nonionized form promotes strong teeth and bones Promotes blood coagulation Promotes nerve impulse conduction; decreases neuromuscular irritability Strengthens and thickens cell membrane Assists in absorption and utilization of vitamin B_{12} Activates enzymes for many chemical reactions Inhibits cell membrane permeability to sodium Activates actin-myosin muscle contraction	Parathyroid hormone, calcitonin, and vitamin D ◆ Increases calcium reabsorption from bone ◆ Increases calcium reabsorption by inhibiting phosphate reabsorption from kidney tubules ◆ Increases calcium absorption from gastrointestinal tract
Chloride (Cl^-)	98–106 mEq/L	Inhibits smooth muscle contraction Regulates extracellular fluid volume Promotes acid-base balance through exchange with bicarbonate in red blood cells (chloride shift) Promotes protein digestion through hydrochloric acid; acid pH required for activation of protease	Renin-angiotensin-aldosterone system ◆ Kidneys excrete chloride if body fluids are acidic and reabsorb it if body fluids are alkalotic
Magnesium (Mg^{2+})	1.5–2.5 mEq/L	Promotes metabolism of carbohydrates, fats, and proteins Activates many enzymes (B_{12} metabolism) Promotes regulation of Ca^{2+}, PO_4^{2-}, K^+ Promotes nerve impulse conduction, muscle contraction, and heart function Powers sodium-potassium pump Promotes conversion of adenosine triphosphate to adenosine diphosphate for energy release	Kidneys ◆ Increases or decreases magnesium reabsorption in kidney tubules according to need
Phosphate (HPO_4^-)	1.2–3 mEq/L (or 2.5–4.5 mg/ml)	Nonionized form promotes bone and teeth rigidity Promotes acid-base balance through phosphate buffer system Necessary for adenosine triphosphate production	Parathyroid hormone, calcitonin, and vitamin D ◆ Increases phosphate resorption from bone ◆ Inhibits phosphate reabsorption in kidney tubules ◆ Increases phosphate absorption in gastrointestinal tract as needed

From Harkreader H et al: *Fundamentals of nursing: caring and clinical judgment,* ed 3, St Louis, 2007, Saunders.

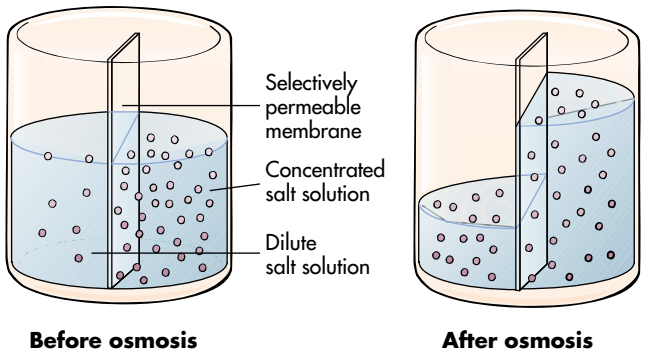


FIGURE 2-3 Osmosis is the movement of solvent molecules across a membrane to an area of higher solute concentration. The solvent moves because the solute cannot pass through the membrane. The result of osmosis is two solutions, separated by a selectively permeable membrane, that are equal in concentration.

corrected to within normal limits before any surgical procedure, unless the surgery is needed to correct a life-threatening problem. Preexisting conditions, such as diabetes mellitus, liver disease, or renal insufficiency, may be aggravated by surgical stress, increasing a patient's risk of fluid and electrolyte imbalances. Diagnostic procedures that require the administration of IV dyes may produce osmotic diuresis, with resulting urinary excretion of water and electrolytes. Preoperative steroids or diuretics affect the excretion of water and electrolytes; diuretics, used in the management of hypertension, cause the loss of potassium. Preoperative surgical regimens, such as bowel cleansing routines, may act to increase fluid loss from the GI tract. Medical management of preexisting conditions, such as gastric suction, can also affect fluid and electrolyte balance in the surgical patient, as can preoperative fluid restriction.

Preoperative fluid restrictions are used to reduce nausea, vomiting, and aspiration risk in the surgical patient. This practice is being modified in many healthcare settings because newer anesthetic agents cause less nausea and vomiting than in the past. Prolonged fluid restrictions may not be necessary in healthy patients before surgery (Anderson and Comrie, 2009); black coffee or pulp-free juice may be ingested 2 to 3 hours before surgery safely, without an increase in gastric volume (see Chapter 4).

Deficient Fluid Volume. The most common patient problems associated with fluid and electrolyte balance during surgery include deficient fluid volume (DFV), water imbalances, and potassium imbalances. DFV is an imbalance in isotonic body fluids related to decreased intravascular, interstitial, or intracellular fluid. Very young and very old surgical patients are affected most rapidly by fluid losses from bleeding; inadequate intake because of previous nothing-per-mouth (NPO) status; inadequate IV fluid replacement; excessive cutaneous losses from fever and sweating; third-space fluid losses attributable to bowel obstructions, ascites, or peritonitis; excessive GI losses resulting from diarrhea, vomiting, GI suctioning, or fistulas; evaporation of fluid from the exposed peritoneum during abdominal surgery; shifting of intravascular fluid into the surgical site (third-space edema); and inhalation of dry gases. Third-space fluid losses cannot be measured directly, but can be considerable after extensive dissection of tissue. Intraoperative use of an electrolyte solution, such as lactated Ringer's solution, for fluid replacement can help correct intraoperative third-space fluid losses.

The effect of fluid loss on the surgical patient depends on the amount of fluid lost and the speed at which the fluid is lost. A patient who loses a large amount of fluid (>500 ml) or loses fluid rapidly exhibits symptoms of shock; immediate fluid replacement therapy is required. A slow loss of fluid may be compensated through albumin synthesis and erythropoiesis.

Sodium and Water Imbalances. Sodium is a cation in ECF; sodium plays a major role in maintaining the osmolality and water balance of the extracellular fluid. Because cell membranes are permeable to water, it also affects ICF volume. Sodium also helps maintain acid-base balance in the body. The sodium-potassium pump plays a vital role in neuromuscular activity.

Hyponatremia (serum sodium level <135 mEq/L) can be caused by increased excretion of sodium with diuretic therapy and the abnormal loss of sodium through nasogastric (NG) suctioning and third spacing. Patients undergoing procedures such as transurethral resection of the prostate (TURP) or uterine endoscopic laser surgery are at risk for dilutional hyponatremia and volume overload, caused by absorption of the irrigation solution used. Because saline is a good conductor of electrical current, fluids that contain no electrolytes, such as glycine, sorbitol, and mannitol, must be used to irrigate in the presence of the electrical current used in tissue dissection during these procedures.

Potassium Imbalances. Potassium is the major intracellular cation and is necessary for contraction of skeletal muscle and smooth muscle. It is necessary for cardiac contractions and for peristaltic movements of the GI tract. It also plays a major role in the transmission of nerve impulses by regulating neuromuscular excitability and in the formation of muscle protein by transporting glucose into the cells with insulin. Potassium also is involved in the maintenance of acid-base balance and intracellular osmotic pressures.

Hypokalemia (serum potassium concentration <3.5 mEq/L) can occur intraoperatively as a result of the suctioning of large amounts of body fluids or using diuretic therapy and other drugs (e.g., mannitol) that increase renal flow. Signs and symptoms of hypokalemia include cardiac effects, such as ectopy, dysrhythmias, conduction abnormalities, and altered sensitivity to digitalis. The neuromuscular effects of hypokalemia include muscle weakness; smooth muscle effects include gastric distention, paralytic ileus, and urinary retention.

Treatment of hypokalemia includes IV replacement when the deficit is severe, as in the development of cardiovascular or other serious symptoms. Potassium irritates veins on infusion; the infusion site should be monitored for redness, heat, swelling, or site pain—all signs of chemical phlebitis. Overcorrection and subsequent hyperkalemia must be avoided by monitoring serum potassium levels at frequent intervals (often every 2 to 4 hours).

Hyperkalemia, a serum potassium level of more than 5 mEq/L, can be caused during surgery by massive transfusions of stored blood; decreased excretion of potassium caused by hypovolemia or renal failure; and shifting of potassium from the cells into the ECF caused by acidosis, tissue breakdown from surgery, crush injuries, or burns. Drugs infused during

surgery can also induce hyperkalemia; such drugs include anti-inflammatory agents, β-adrenergic receptor blockers, digitalis, succinylcholine, heparin, and the penicillins.

Signs and symptoms of hyperkalemia include neuromuscular symptoms, such as weakness and paresthesias in the arms and legs. Smooth muscle symptoms include diarrhea and abdominal distention. Excess potassium can cause serious cardiac symptoms, including ventricular dysrhythmias, heart block, and asystole. Cardiac side effects of hyperkalemia are treated by calcium gluconate. Sodium bicarbonate or insulin-glucose infusions can be given to shift extracellular potassium into the cells, reducing the level of potassium in the plasma.

PATIENT RIGHTS

Protection of a patient's personal, ethical, and legal rights underlies patient safety and risk management. Even if injury occurs, patients who feel they have been treated with respect and dignity are more likely to accept sometimes less than perfect results, are less inclined to litigate, and are more likely to cooperate with postinjury treatment, regardless of fault.

Privacy

In addition to the patchwork of state statutes that protect confidentiality and patient access to their healthcare records and privacy of healthcare data, federal law provides that patients must consent for their health information to be used for treatment, payment, or business purposes. HIPAA limits use or disclosure of protected health information to ensure patient privacy rights with respect to this information, and healthcare facilities must have administrative procedures to protect the privacy and confidentiality of all patient information. Facility policies should include protocols specific to perioperative settings, such as the presence of healthcare industry representatives in the OR.

Perioperative nurses must protect patient privacy even if HIPAA, state law or facility protocol does not specifically address a privacy issue. Care is taken to protect patient's bodies from any more exposure than is required by a procedure. Likewise, comments made in or out of patient care areas about the patient's appearance, lifestyle, or social status, for example, are never appropriate unless required for the safe care of that patient.

Autonomy

Legal cases have long recognized that every adult has the right to determine what happens to his or her body (e.g., *Schloendorff v. Society of New York Hospitals,* 105 N.E.92 [N.Y., 1914]). This legal right is also an ethical right recognized under the ethical principle of respect for persons as autonomous beings (Beauchamp and Childress, 2008). In perioperative practice settings, these rights are protected via informed consent processes for the procedure itself and/or for any research interventions, and via patient wishes expressed in advance directives for healthcare.

Informed Consent

Except in emergencies, surgical procedures should not be performed without documentation of the patient's consent on the chart (Figure 2-4). How this "informed consent" is documented should be described in facility policy, but it is typically accomplished by means of a signed consent form and/or the primary surgeon's entry into the progress notes, which may or may not also be signed by the patient. The surgeon or practitioner performing the procedure is responsible to inform the patient about the proposed operation or other invasive procedure and its inherent risks, benefits, alternatives, and complications before obtaining the patient's oral and written consent. The patient must receive this information in terms that he or she can understand. The patient also must be informed who will perform the procedure and when practitioners other than the primary surgeon will perform important parts of the procedure, even when under the primary surgeon's supervision. Consent documentation must be complete before administration of preoperative medications. On the patient's arrival in the OR, the circulating nurse and anesthesia provider are responsible to verify that documentation of the consent is in the chart and is correct, properly signed, and witnessed before the administration of anesthesia. Typically, the consent process documentation encompasses the following:

- The patient's name (and legal guardian, if applicable)
- Name of facility where the procedure is being performed
- Specific name of the surgical procedure (or when multiple procedures are being done, the names of those procedures) in terms the patient understands
- Site/side of the planned procedure
- Name of the practitioner or practitioners performing the procedure or important aspects of it
- Risks of the procedure
- Alternative procedures, treatments, or therapies
- Signature of the patient (or legal guardian, if applicable)
- Date and time consent is obtained
- Statement that procedure was explained to the patient (or legal guardian or both if applicable)
- Name and signature of person who explained the procedure
- Signature of person witnessing the consent

Nurses who are involved as witnesses to the signing of the consent form attest only to the validity of the patient signature, time, and date. By signing as a witness, they do not assure the adequacy of the patient's understanding, as that assurance remains the duty of the surgeon.

Advance Directives and DNR Orders

Many individual states had statutes to allow patients to make their wishes regarding their future known in a legally recognized fashion if they were unable to do so when a life-threatening situation arose. Then, in the wake of the first U.S. Supreme Court case to deal with the issue, *Cruzan v. Director, Missouri Department of Health,* 497 U.S. 261 (1990), the U.S. Congress in 1991 passed the Patient Self-Determination Act (PSDA) to extend legal protection to all U.S. citizens and residents. Under the Act, patients have the legal right to accept or refuse medical treatment, including resuscitation, even if refusal will likely result in death. The PSDA also provided that all patients admitted to Medicare and Medicaid recipient providers be asked whether they have executed, or wish to be given information about, such an advance healthcare directive, and that information must be included in the patient's medical record. If a patient arrives in a preoperative area with such a directive, the perioperative nurse should immediately clarify with the surgeon and/or anesthesia provider if there has been a presedation discussion with the patient as to the effect the directive should have in the immediate perioperative period.

Date of procedure: _____

Patient name:

Date of birth:

I, _____ (Type or print patient name), request and give consent to _____ (Type or print doctor or practitioner name(s))

to perform the following procedure(s) _____ (Please list site and side if appropriate)

_____

The benefits, risks, complications, and alternatives to the above procedure(s) have been explained to me.

I understand that the procedure(s) will be performed at Christiana Care by and under supervision of my doctor or practitioner. My doctor or practitioner may use the services of other doctors or practitioners, or members of the resident staff as he or she deems necessary or advisable.

I authorize my doctor or practitioner and his or her associates and assistants to perform such additional procedures, which in their judgment are necessary and appropriate to carry out my diagnosis or treatment.

I authorize the hospital to retain, preserve and use for scientific, teaching purposes, or to make other dispositions of, at their convenience, any specimens, tissues, or parts taken from my body during the course of this operation.

I consent to observers in the procedure area in accordance with hospital policy. I consent to a healthcare industry representative being present during the procedure, if necessary, to provide technical assistance or to perform calibration of equipment. I consent to photography or video taping of my surgical procedure for educational purposes, provided my identity remains anonymous and confidential.

I agree to being given blood or blood products as deemed advisable during the course of my procedure. The risks, benefits, and alternatives to receiving blood or blood products have been explained to me.

I consent to the administration of sedation or analgesia during my procedure. The risks, benefits, and alternatives to receiving sedation or analgesia have been explained to me.

If anesthesia is required, I consent to the administration of anesthesia by members of the Department of Anesthesiology. I also consent to the use of non-invasive and invasive monitoring techniques as deemed necessary. I understand that anesthesia involves risks that are in addition to those resulting from the operation itself including, but not limited to, dental injury, hoarseness, vocal cord injury, infection, nerve injury, corneal abrasion, seizures, heart attack, stroke and even death.

If applicable, I consent to the use of fluoroscopy. I understand that prolonged exposure to fluoroscopy may result in skin reactions, such as redness, irritation or a burn.

Please initial one of the following statements (females and those within child bearing years only):

_____To the best of my knowledge I am not pregnant. _____I believe I am not pregnant.

I certify that I have read and understand the above consent statements. In addition, I have been offered the opportunity to ask my doctor or practitioner any questions I have regarding the procedure(s) to be performed and they have been answered to my satisfaction. I acknowledge that I have been given no guarantee or assurance as to the results that may be obtained from the procedure(s).

Signature of patient or decision maker	Date	Time	Doctor or practitioner signature/title	Date	Time
Relationship to patient if decision maker			Doctor ID # or print name		
Witness signature	Date	Time	Practitioner print name		
Witness print name					

Telephone Consent:

Name of person consent obtained from			Relationship to patient if decision maker		
Witness signature	Date	Time	Witness signature	Date	Time
Witness print name			Witness print name		

FIGURE 2-4 Consent for procedure.

The PSDA does not address this issue, but an automatic suspension or continuation of advance directives or DNR orders is not justified under either a legal or an ethical analysis. Again, facility policy should describe a procedure that preserves the patient's right to legal and ethical self-determination.

Veracity and Fidelity

Veracity includes providing accurate information. Fidelity or loyalty carries with it an implicit promise of truth telling. Both principles relate to respect for persons and autonomy—that patients are entitled to the respect of full and accurate information and disclosure. These principles relate most directly to the patient's right to informed consent. Within the patient safety and risk management context, however, veracity and loyalty also demand transparency in disclosure of adverse events to the patient/family. Some states (e.g., Pennsylvania, Florida, and Utah) legally require patient notification when an error occurs (Griffin, 2008, citing Liebman and Hyman, 2004).

Griffin (2008) reviewed data that demonstrated transparency and disclosure after an error has occurred can minimize the consequences of litigation. In fact, articles encouraging full disclosure do so more as a risk management issue than as an issue concerning patient rights (Wojcieszak et al, 2006). In any event, one consequence of the renewed emphasis on patient safety and patient rights has been to merge the heretofore separate systems of perioperative care provision, risk management, and quality improvement (ECRI Institute, 2009) under a patient safety rubric that has enhanced the effectiveness of each.

REFERENCES

Alexander EL: *Operating room technique*, St Louis, 1943, C.V. Mosby.

Amato-Vealey EJ et al: Hand-off communication: a requisite for patient safety, *AORN J* 88(5):763–770, 2008.

Anderson M, Comrie R: Adopting preoperative fasting guidelines, *AORN J* 90(1):73–80, 2009.

Association of periOperative Registered Nurses (AORN): *Perioperative standards and recommended practices*, Denver, 2009, The Association.

Beauchamp T, Childress J: *Principles of biomedical ethics*, ed 6, New York, 2008, University Press.

Brennan T et al: Incidence of adverse events and negligence in hospitalized patients: results of the Harvard Medical Practice Study I, *NEJM* 324(6):370–376, 1991.

Carayon P et al: Evaluation of nurse interaction with bar code medication administration technology in the work environment, *J Patient Saf* 3(1):34–42, 2007.

Carraro P, Plebani M: Errors in a stat laboratory: types and frequencies 10 years later, *Clin Chem* 53(7):1338–1342, 2007.

Cima RR et al: A multidisciplinary team approach to retained foreign objects, *Jt Comm J Qual Patient Saf* 35(30):123–132, 2009.

Cook R, Woods D: Operating at the sharp end: the complexity of human error. In Bogner MS, editor: *Human errors in medicine*, Hinsdale, NJ, 1994, Lawrence Ehrlbaum Associates.

Dillon KA: Time out: an analysis, *AORN J* 88(3):437–438, 440–442, 2008.

ECRI Institute: Risk management, quality improvement and patient safety, *Healthcare Risk Control* (2):1–14, Jul 2009.

Friesen MA et al: Handoffs: implications for nurses. In Hughes RG, editor: *Patient safety and quality: an evidence based handbook for nurses*, 2008, Agency for Healthcare Research and Quality, (2), pp 285–332.

Gawande AA et al: Risk factors for retained instruments and sponges after surgery, *NEJM* 348:229–235, 2003.

Glass LK, Murphy EK: *AORN emergence and growth,* Denver, 2002, The Association of periOperative Registered Nurses, Inc.

Griffin FD: The impact of transparency on patient safety and liability, *Bulletin American Coll Surgery* 3(93):19–23, 2008.

Haynes AB et al: A surgical safety checklist to reduce morbidity and mortality in a global population, *NEJM* 360(5):491–499, 2009.

Hendler CB: A perfect match: preventing blood incompatibility errors, *Nurs Spect* 17(12):24–29, 2008.

Hughes RG, Blegen M: Medication administration safety. In Hughes RG, editor: *Patient safety and quality: an evidence based handbook for nurses*, Rockville MD, 2008, Agency for Healthcare Research and Quality (2), pp 397–458.

Institute of Medicine: *To err is human: building a safer health system*, Washington, DC, 1999, National Academy Press.

Institute of Medicine: *Crossing the quality chasm*. Washington, DC, 2001 National Academy Press.

Leape L: Error in medicine, *JAMA* 272(23):1951–1957, 1994.

Leape L, Berwick DM: Five years after "To err is human": what have we learned? *JAMA* 293(19):2384–2390, 2005.

Leape LL et al: The nature of adverse events in hospitalized patients: results of the Harvard Medical Practice Study II, *NEJM* 324(6):377–384, 1991.

Leonard M et al: The human factor: the critical importance of effective teamwork and communication in providing safe care, *Qual Saf Health Care* 13:85–90. doi:10.1136/qshc.2004.010033, 2004.

Liebman CB, Hyman CS: A mediation skills model to manage disclosure of errors and adverse events to patients, *Health Aff* 23(4):22–32, 2004.

Makary MA et al: Surgical specimen identification errors: a new measure of quality in surgical care, *Surgery* 141(4):450–455, 2007.

McCoy L et al: Laboratory safety and the WHO world alliance for patient safety, *Clin Chem Acta*, 2009.

Mills P, Neily J, Dunn E: Teamwork and communication among surgical teams: implications for patient safety, *J Am Coll Surg* 206(1):107–112, Jan 2008.

Moldenhauer K et al: Clinical triggers: an alternative to a rapid response team, *Jt Comm J Qual Patient Saf* 35(30):164–174, 2009.

Moorman D: Communication, teams and medical mistakes, *Ann Surg* 245(2):173–175, 2007.

Mulloy D, Hughes RG: Wrong site surgery: a preventable medical error. In Hughes RG, editor: *Patient safety and quality: an evidence based handbook for nurses*, Rockville MD, 2008, Agency for Healthcare Research and Quality, (2), pp 381–395.

Patterson P: Surgical care improvement project: four years later, what's the status? *OR Manager* 25(8):1, 7–9, 2009.

Pelter MM et al: An evaluation of a numbered surgical sponge product, *AORN J* 85(5):931–936, 938–940, 2007.

Pronovost PJ, Colantuoni E: Measuring preventable harm—helping science keep pace with policy, *JAMA* 301(12):1273–1275, 2009.

Reason J: *Human error*, Cambridge, 1990, Cambridge Press.

Regenbogen SE et al: Prevention of retained surgical sponges: a decision-analytic model predicting relative cost-effectiveness, *Surgery* 145:527–535, 2009.

Smith AA: *The operating room: a primer for pupil nurses*, ed 2, Philadelphia, 1924, Saunders.

The Joint Commission (TJC): *What every healthcare organization should know about sentinel events*, Chicago, 2005, The Commission.

Wachter RM, Pronovost PJ: The 100,000 lives campaign: a scientific and policy review, *Jt Comm J Qual Patient Saf* 32(11):621–627, 2006.

Wojcieszak D, Banja J, Houk C: The sorry works! Coalition: making the case for full disclosure, *Jt Comm J Qual Patient Saf* 32(6):344–350, 2006.

CHAPTER 3

Infection Prevention and Control in the Perioperative Setting

LILLIAN H. NICOLETTE

Advancements in surgical interventions and the science of infection prevention and control continue to evolve and have become increasingly complex. The complexity is derived from the changes in the healthcare environment, the advancements in minimally invasive and advanced surgical procedures, and the development of new, highly technical instrumentation and equipment. This chapter will provide an overview of the etiology of infection, including emerging drug-resistant bacteria, and will identify various methods to control infection in the perioperative environment. Use of Standard Precautions along with engineering and work-practice controls assists perioperative practitioners in reducing the transmission of pathogenic organisms. Perioperative patient care is based on surgical aseptic principles. Careful adherence to these principles supports infection prevention and control, ultimately improving surgical patient safety and outcomes. Each member of the surgical team must demonstrate the highest integrity in the application of this knowledge. Finally, in today's world, the potential for bioterrorism has forced the United States along with the rest of the world to strengthen security and emergency readiness. If a bioterrorism attack resulted in massive exposure or illness, perioperative personnel could and would be mobilized to serve in a variety of locations, such as in the New York World Trade Center attacks of 2001 and the London tube attacks in July 2005. These attacks redefined the meaning of disaster preparedness for all practitioners. Perioperative personnel need to be familiar with the most likely biologic weapons and the levels of precautions required for patient and personnel safety.

CAUSES OF INFECTION

The human body has three lines of defense to combat infection. The first line of defense consists of *external barriers,* such as the skin and mucous membranes, which are usually impervious to most pathogenic organisms. The second line of defense is the *inflammatory response,* which prevents an invading pathogen from reproducing and possibly involving other tissue. The third line of defense, the *immune response,* is triggered after the inflammatory response. When there is a break in this defense mechanism, the possibility for infection increases (see Box 3-1 for definitions of terms).

Microorganisms that Cause Infection

Microorganisms are living organisms that are too small to be seen with the naked eye. These organisms include bacteria, fungi, protozoa, algae, and viruses. Microorganisms are classified to determine appropriate treatment for an infection. Each organism is assigned two names; the genus is the first name, and the specific epithet (species) is the second. Bacteria are further described by shape, motility, growth in aerobic or anaerobic environments, and reaction to staining processes (Figure 3-1). Scientific names can be assigned to organisms in various ways. *Staphylococcus aureus* is a microorganism commonly found on the skin. *Staphylo* describes the clustered arrangement of the cells; *coccus* (Greek *kokkos,* "berry") indicates that they are shaped like spheres. The species *aureus* is Latin for "golden," the color of the colonies of the bacterium. Bacteria cause most surgical site infections (SSIs). Gram-positive cocci, as a group, are the most common cause of SSIs. The organisms most commonly found in postoperative SSIs include staphylococcal, enterococcal, pseudomonal, and streptococcal species. *S. aureus* is the most frequently identified organism.

Staphylococci. Staphylococci are gram-positive cocci. They are facultative anaerobes but grow best under aerobic conditions. Staphylococci can be found in the indigenous flora of the skin and mucous membranes of the nasopharynx, urethra, and vagina. They are resistant to drying, heat, and high salt concentrations.

The two recognized species of staphylococci are *S. aureus* and *S. epidermidis.* Staphylococci are called *coagulase positive* when they are capable of clotting plasma and *coagulase negative* when the plasma clumps them. Coagulase-positive staphylococci are more virulent or pathogenic than coagulase-negative staphylococci. *S. aureus* is hemolytic, parasitic, pathogenic, and coagulase positive. *S. epidermidis* is parasitic, less pathogenic, and coagulase negative. *S. aureus* is a long-recognized cause of surgical site infections. More recently, *S. epidermidis* has been implicated in infections of prosthetic devices (CDC, 2008a).

The skin surface is the most common site of *S. epidermidis.* Approximately 30% to 70% of individuals carry staphylococci on their skin. This can lead to contamination of clothing and dispersal of the microorganisms. For no known reason, individuals who are skin carriers of staphylococci differ in the rate at which they shed the microorganisms. There is no obvious difference in hygiene and skin condition between light and heavy shedders and no other contributing factor is apparent. Heavy shedders seem to be in normal good health.

S. aureus infections in hospitals can lead to prolonged hospital stays and may result in death. *S. aureus* has been found in the nasal passages of 25% to 35% of the adult population

BOX 3-1

Definition of Terms

Aeration Method by which absorbed ethylene oxide (EO) is removed from EO-sterilized items.

Aerobes Microorganisms unable to live and reproduce without access to free atmospheric oxygen, such as *Mycobacterium tuberculosis*.

Anaerobes Bacteria able to survive only in the absence of molecular oxygen, such as *Clostridium perfringens*.

Bioburden Amount of microbial load and organic debris on an item before sterilization.

Biofilm A thin coating containing biologically active organisms that have the ability to grow in water, solutions, or in vivo and coat the surface of structures or devices. Biofilms may contain viable and nonviable microorganisms that may adhere to a surface and are trapped within organic matter.

Biological indicator A sterilization process–monitoring device commercially prepared with a known population of highly resistant spores to test the effectiveness of the sterilization process being used.

Carrier Person who harbors one or more specific pathogens in the absence of discernible clinical disease.

Cohorting The practice of grouping patients who are colonized or infected with the same pathogen.

Contamination Presence of pathogenic microorganisms on or in animate or inanimate objects. This term generally is used in reference to a specific object, substance, or tissue that contains microorganisms, especially disease-producing microorganisms.

Deep incisional SSI Infection involving deep soft tissue, fascia, and muscle.

Dynamic air removal Mechanically assisted air removal from a sterilizer's chamber. This includes prevacuum and steam flush, pressure pulsed steam sterilizers.

Facultative bacteria Bacteria with enzyme systems that permit them to live and reproduce with or without free oxygen.

Flash sterilization An abbreviated cycle; a sterilization process that is designed for immediate patient use employing the steam sterilization method.

Gram stain A procedure for staining bacteria that is the first step in classifying and differentiating them into two large groups (gram-positive and gram-negative) based on the chemical and physical properties of their cell walls.

Immunity Resistance to infection.

Infection Invasion and multiplication of microorganisms in body tissues, causing cellular injury attributable to competitive metabolism, toxins, intracellular replication, or antigen-antibody response.

Infectious agent Parasite (bacterium, spirochete, fungus, virus, or any other type of organism) that is capable of producing infection.

Healthcare-associated infections (HAIs) Infections acquired by patients during hospitalization, with confirmation of diagnosis by clinical or laboratory evidence. The infective agents may originate from endogenous sources, as from one tissue to another within the patient (self-infection), or from exogenous sources, as acquired from objects or other patients within the hospital (cross-infection). Healthcare-associated infections, which are often referred to as hospital-acquired or nosocomial infections, may not become apparent until after the patient has left the hospital.

Opportunists Microorganisms of low virulence and requiring large numbers to produce infection.

Organ or space SSI Infection involving any part of the anatomy other than the incision.

Parasites Microorganisms that reside on or within the bodies of living organisms called hosts to find the environment and food they require for life and reproduction. Some microorganisms are obligatory parasites, meaning that they depend on their hosts for survival and reproduction. Other microorganisms are facultative parasites, meaning that they normally reside on dead matter, but may receive nourishment from living matter. All disease-producing microorganisms are parasites; however, not all parasites are disease-producing.

Pathogen Any disease-producing agent or microorganism.

Primary pathogens Highly virulent organisms that are capable of producing disease in low numbers.

Resident microorganisms Organisms that habitually live in the epidermis, deep in the crevices and folds of the skin.

Reuse The repeated or multiple uses of any medical device whether marketed as a reusable or single-use device. Repeated/multiple uses may be on the same patient or on a different patient with applicable reprocessing of the device between each use.

Source Object, substance, or individual from which an infectious agent passes to a host. In some cases, transfer is direct from the reservoir, or source, to the host.

Spore Dormant stage of some bacteria that is reversible under favorable conditions. Common spore-forming bacteria include *Clostridium perfringens, Clostridium botulinum, Clostridium tetani,* and *Bacillus anthracis*.

Sterilization process–monitoring device A device used to monitor specific sterilization processes. These devices can be biologic, physical or chemical.

Superficial SSI: Infection involving skin and subcutaneous tissue as opposed to deep tissue.

Surgical site (incisional) infection (SSI) Infection involving body-wall layers that have been incised.

Toxins Protein molecules released by bacteria to affect host cells at a distant site.

Transient microorganisms Organisms with a very short life span, such as the normal flora present on the skin surface of humans. Gram-negative bacteria are transient on the hands of hospital personnel and account for 60% of infections.

Virulence The potency of a pathogen measured in the numbers required to kill the host.

Virus Ultramicroscopic infectious agent that replicates itself only within cells of living hosts.

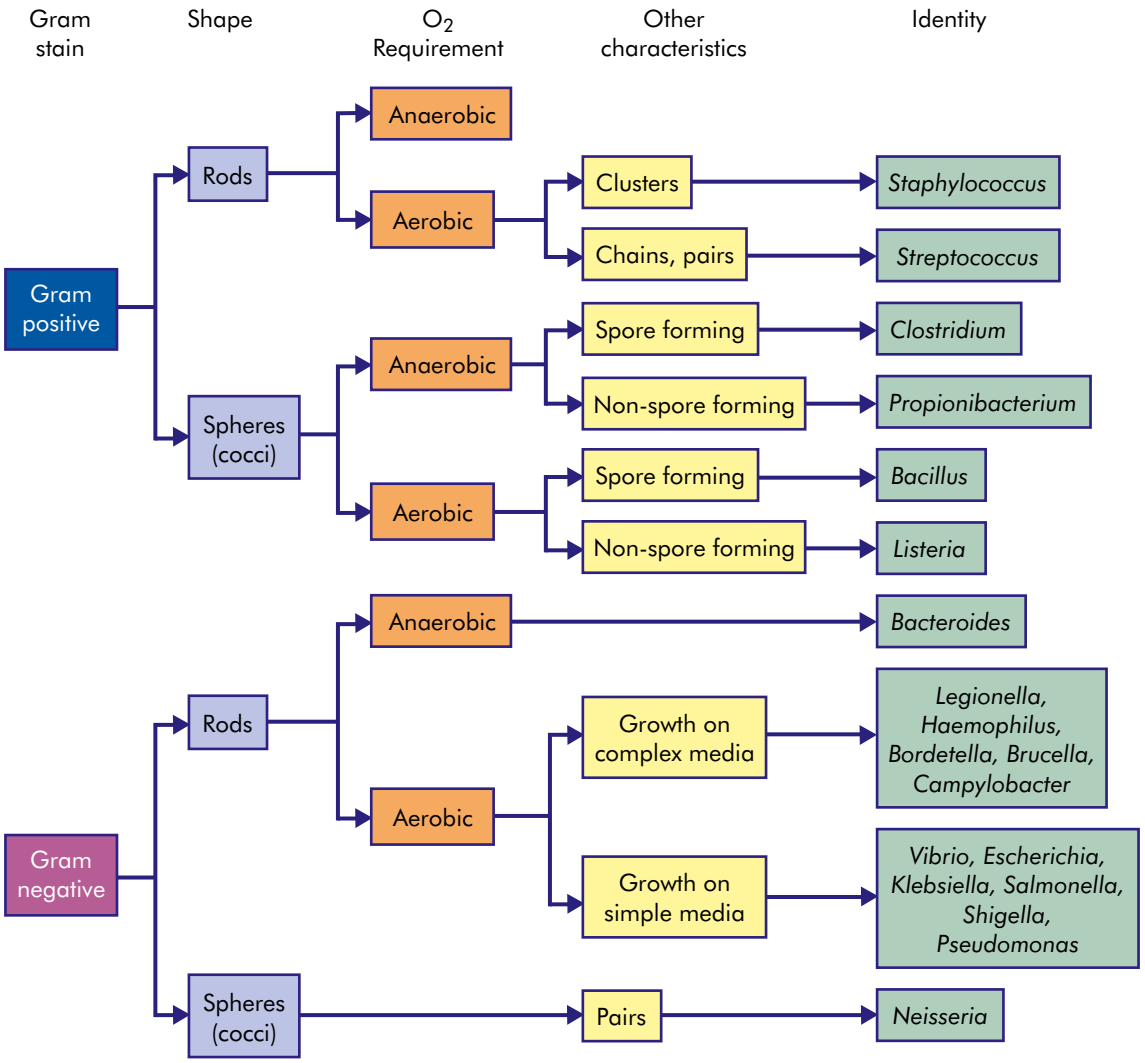


FIGURE 3-1 Types of gram-positive and gram-negative bacteria.

(CDC, 2005a). Human nasal and throat cavities are the most important reservoirs that continually replenish the external environment. Among perioperative personnel, *S. aureus* has been found most commonly in the respiratory passages. The potential for patient infection increases greatly as the personnel carrier rate increases. Nasal carriers also may be skin carriers. Carriers usually harbor either coagulase-positive (pathogenic) or coagulase-negative (nonpathogenic) staphylococci; seldom are there both types and rarely more than one strain is identified. Because an individual may be a carrier of staphylococci one day and a noncarrier the next, frequent swab testing of the nose as an infection control measure is impractical. Staphylococci survive for long periods in the air, dust, debris, bedding, and clothing. Pathogenic staphylococci grow in the sweat, urine, and tissue and on the skin of humans. They are more difficult to destroy than many other non–spore-forming organisms. Cleanliness of the environment; proper handling and, when appropriate, sterilization of linens and equipment; and adherence to adequate hand hygiene practices are important controls to prevent transmission of infection (AORN, 2009a).

Enterococci. Enterococci are gram-positive organisms that are found in the normal flora of the gastrointestinal and female genital tracts. These organisms are responsible for many serious healthcare-associated infections, including surgical site infections, bacterial endocarditis, septicemia, and urinary tract infections (UTIs). This organism also has been implicated in polymicrobial wound infections (CDC, 2007a). Enterococcal infections are most often healthcare-associated and seen in patients with co-morbid conditions.

Pseudomonads. The most common aerobic species of pseudomonads pathogenic to humans is *Pseudomonas aeruginosa.* It thrives in moist environments and is found frequently in soil, water, sewage, debris, and air. It also can be found in the normal flora of the skin and intestines. *P. aeruginosa* was considered a microorganism of slight pathogenic power but is now known to be associated with many infections in humans, including surgical site infections. *P. aeruginosa* seems to be pathogenic only when it is introduced into areas where normal defenses are absent, when it is superimposed on staphylococcal infection, or when it is present in a mixed infection. It may attack

a debilitated patient who has extensive burns or major trauma. The organism is often seen in critical care and burn units. *P. aeruginosa* is resistant to most antimicrobial agents. Other species of pseudomonads have been associated with infections caused by contaminated intravascular cannulae (as from the use of pressure transducers) or by the lumens of equipment (such as endoscopes used in gastrointestinal [GI] studies). An important preventive measure is proper environmental sanitation and strict adherence to aseptic technique.

Streptococci. Most streptococci are gram-positive, non–spore-forming, facultative microorganisms. They are normally found in the indigenous flora of the upper respiratory, genitourinary, and gastrointestinal tracts. Streptococci are classified as alpha, beta, or gamma according to chemical factors, biochemical tests, and their action on red blood cells.

Group A streptococci account for most streptococcal infections in humans. Known as the *flesh-eating bacteria* because of their ability to cause necrotizing fasciitis, group A streptococci are of concern because of the sporadic and deadly outbreaks of community-acquired and healthcare-associated infection (CDC, 2006a). An example is *Streptococcus pyogenes,* which is responsible for most soft tissue infections, otitis media, pharyngitis, impetigo, septicemia, and surgical site infections. Virulent streptococci are more serious invaders than staphylococci. Streptococci tend to involve wide areas of tissue and cause necrosis without localization. Streptococci are usually sensitive to penicillin, whereas staphylococci may not be. Streptococci also occur in mixed infections with other pathogens.

In surgical wounds, streptococci can be introduced into the incision and spread via the lymph vessels and nodes. This distribution can result in inflammation and cellulitis. Streptococcal transmission occurs by droplet transmission and by contamination of the environment. Inhalation of infectious droplets expelled from the nose and mouth of an infected individual is considered direct contact. Indirect contact occurs when infected air and dust from the environment enter a susceptible host. Group A streptococcus can be carried in the nasal passages, anus, or vagina. The upper respiratory tract is not a significant reservoir for microorganisms that cause surgical site infections except in the presence of an acute upper respiratory tract infection. In several randomized, controlled studies, it was found that surgical wound infection rates are unaffected by the use or nonuse of surgical masks by noninfected individuals during the operative procedure. It is not always possible to know who might be infected, and the use of masks during operative procedures continues to be strongly recommended in the prevention of SSIs. Most bacteria in the OR environment are shed from the skin of perioperative personnel (AORN, 2009b).

Clostridia. The clostridia bacteria are spore-forming, anaerobic, gram-positive bacilli that produce virulent toxins. *Clostridium difficile* is a bacterium in the *Clostridium* genus, which also includes *C. perfringens* (gas gangrene), *C. tetani* (tetanus), and *C. botulinum* (botulism). *C. difficile* is an anaerobic, gram-positive, spore-forming bacillus. *C. difficile* is an overgrowth in the colon that can manifest symptoms of diarrhea, colitis, toxic megacolon, dehydration, colonic perforation, and death. The overgrowth of *C. difficile* in the colon usually results from alterations in the normal flora of the colon that are associated with the use of antibiotics (CDC, 2006a). For this organism to cause disease, *C. difficile* must already be in the gastrointestinal system. Subsequently, there must be a change in the normal flora of the colon to allow the organism to grow and produce toxins. The two toxins produced are toxin A, which is an enterotoxin causing excretion of large amounts of fluid from the bowel, and toxin B, which is cytotoxic. Toxin B attacks and disintegrates cells of the intestines. Additionally, *C. difficile* produces tissue-degrading enzymes, which produce an inflammatory response within the colon that can result in a spectrum of disease entities (Matthews, 2008).

In its spore form, *C. difficile* can withstand drying and heat and may be resistant to many disinfectants. The spores can survive up to 5 months in the environment. *C. difficile* can be transmitted between individuals and by touching objects contaminated with the organism. In the healthcare environment, *C. difficile* has been cultured in rooms of infected individuals 40 days after discharge. *C. difficile* also has been cultured from healthcare workers' shoes, fingernails, fingertips, and the underside of rings (Rauscher, 2008; Mitchum, 2009).

Several interventions can assist in the prevention of *C. difficile* transmission in the healthcare environment, including following Contact Precautions, handwashing with antimicrobial soap and water, using personal protective equipment (PPE), cleaning and disinfecting all surfaces and equipment, and cleaning and disinfecting reusable devices in the perioperative suite. The use of disposable equipment only is recommended for infected patients (*Patient Safety Authority* [PSRS], 2005; CDC, 2006a).

Mycobacterium Tuberculosis. *Mycobacterium tuberculosis* is a non–spore-forming, nonmotile, aerobic bacillus. These bacilli can infect almost any tissue—including skin, bones, kidney, lymph nodes, intestinal tract, and fallopian tubes—and cause tuberculosis (TB). Tubercle bacilli spread in the host through the lymphatic channels and bloodstream and by way of the alveoli and gastrointestinal tract. Tuberculosis is responsible for more than 3 million deaths a year and is the most opportunistic infection associated with human immunodeficiency virus (HIV) (Neil, 2008).

Tubercle bacilli are transmitted directly by means of discharge from the respiratory tract (e.g., by inhalation of droplets expelled during coughing or kissing) and, less frequently, through the digestive tract. *M. tuberculosis* is carried via airborne droplet nuclei when infected persons sneeze, cough, or speak. These nuclei particles are less than 5 micrometers in size and contain up to three bacteria, allowing them to be kept airborne for a prolonged period (CDC, 2006a). Infection occurs when individuals inhale these infected droplet nuclei. The droplet nuclei travel through the nasal passages, upper respiratory tract, and bronchi to reach the lung alveoli, where they are engulfed by macrophages and spread throughout the body. Symptoms of TB are dependent on the part of the body infected, but may be vague at the onset and include fever, fatigue, loss of appetite, cough, fever, and night sweats.

Generally 2 to 10 weeks after initial infection, an immune response limits additional multiplication and spread of the bacilli. Some of the bacilli can remain dormant for many years, however, a condition referred to as *latent tuberculosis infection*. Individuals with latent TB usually have positive purified protein derivative (PPD) results, but they exhibit none of the symptoms of active TB and are considered noninfectious. The probability that a person who is exposed to *M. tuberculosis* will

become *infected* depends on the concentration of infectious droplet nuclei and the duration of exposure. When infected, an individual has approximately a 10% risk of developing active TB in his or her lifetime. The risk is greatest during the first 2 years after initial exposure. In individuals with compromised immune systems, there is a higher risk that latent TB will progress into active TB (CDC, 2006a). While the annual rate of TB has declined since the 1980s, the decrease is slowing. Latent TB is treated with isoniazid or rifampin. Active TB is treated with a combination of medications (e.g., isoniazid, rifampin, ethambutol, pyrazinamide) (Neil, 2008).

Viruses. Viruses are classified as small particles, rather than living cells, because viruses have no metabolic activity and must receive all sustenance for survival from a host cell. Viral pathogens are transmitted via the oral and respiratory tracts (e.g., poxvirus, rhinovirus), the intestinal and urinary tracts (e.g., poliovirus, hepatitis A virus [HAV], hepatitis E virus [HEV]), and the genital tract (e.g., herpes simplex 2, human immunodeficiency virus [HIV]) and through blood and some blood products (e.g., HIV, hepatitis B virus [HBV], hepatitis C virus [HCV], hepatitis D virus [HDV], and others). Some viruses have multiple routes of transmission.

When a virus invades a host cell, it combines with the host cell's nucleic acid (deoxyribonucleic acid [DNA] or ribonucleic acid [RNA]) and reprograms the host cell metabolism to accommodate virus replication. Virus replication stimulates the antibody defense in the host. The presence of viruses may be detected by identifying the virus-specific antibodies that are produced by the infected individual's immune system, by detecting the antigens elaborated by the virus and present in the blood, or by growing a culture of the virus itself. Detection of virus-specific antibodies or antigens is termed *seropositivity,* or *seroconversion*. Viruses are susceptible to destruction by high-level disinfection—a process that destroys most disease-producing microorganisms.

HEPATITIS. Hepatitis is defined as a widespread inflammation of the liver, often caused by a virus. It can be acute or chronic. Symptoms include hepatomegaly, right upper quadrant abdominal pain, and jaundice. Hepatitis is a frequently reported viral disease in the United States, with six identified strains (A through E and G).

Hepatitis A virus (HAV) is the causative agent of what is referred to as *infectious hepatitis*. HAV is spread through the fecal-oral route and can be prevented by proper hand hygiene. It is very common in underdeveloped countries with poor sanitation practices. HAV constitutes slightly less than half of all hepatitis cases reported in the United States and usually has an uneventful course and recovery. Immunization against HAV is available and has helped decrease the incidence of this strain of hepatitis.

Hepatitis B virus (HBV) is the causative agent for what is sometimes referred to as *serum hepatitis*. This worldwide virus has reached near-epidemic levels but is preventable via vaccination and the strict use of Universal Precautions. HBV can be transmitted by blood or body fluids, such as serum, saliva, semen, and vaginal fluids. It has an incubation period of 6 weeks to 4 months, depending on the type and amount of exposure. Almost 30% of infected individuals are asymptomatic; individuals with symptoms experience fatigue, abdominal pain, nausea, vomiting, and jaundice. Chronic hepatitis infection leads to progressive liver disease and possible death and is a leading cause of liver transplants. Most adults with HBV recover without incidence and develop immunity, but a small percentage may not develop immunity and will become carriers of the virus. HBV vaccine is recommended, by government regulation, for healthcare workers who may be exposed to blood and body fluids. Postexposure prophylaxis for percutaneous or permucosal exposure to HBV depends on the vaccination status of the healthcare worker. The risk of a susceptible person developing clinical HBV ranges from 1% to 31%, depending on the source person's HBV status (Davenport and Myers, 2009). The Occupational Safety and Health Administration (OSHA) mandates that all healthcare workers report blood and body fluid exposures, and perioperative personnel should follow the institutional protocol for exposure reporting.

Hepatitis C virus (HCV) transmission is most often associated with direct exposure to blood (e.g., via intravenous or subcutaneous routes) or other infectious materials. The average incubation period is 7 weeks. Currently there is no vaccine for the prevention of HCV. Individuals who contract HCV infection are prone to develop chronic infection. A high proportion of this population is asymptomatic and develops chronic liver disease, such as cirrhosis, hepatocellular carcinoma, and portal hypertension. As with HBV, a small proportion of individuals infected with HCV die. Prevention of HCV requires strict use of Universal Precautions, implementation of and adherence to sharps safety programs, compliance with exposure reporting protocols, and completion of a postexposure treatment plan. It is crucial that all perioperative personnel be educated regarding the risk for and prevention of all bloodborne infections, including HCV. These education programs should be conducted routinely and updated for accurate information inclusive of the CDC guidelines. The risk of HCV transmission after percutaneous exposure is about 1.8% (Davenport and Myers, 2009).

Hepatitis D virus (HDV) requires the co-infection of HBV. HDV is transmitted by blood and body fluids. The incubation period is generally 14 to 56 days. Individuals immunized against HBV have protection against contracting HDV. HDV is suspected when individuals present with HBV superinfection. Treatment is supportive for acute infections. With chronic HDV infections, antiviral therapies and liver transplants may be required.

Hepatitis E virus (HEV) is spread by the fecal-oral route. HEV is similar to HAV in the transmission and disease process. Most outbreaks have occurred in developing countries, where fecally contaminated water is found to be the source. The incubation period is 15 to 64 days. No vaccine is available for the prevention of HEV. Prevention is similar to that for HAV, with the use of proper hand hygiene. Treatment for HEV is supportive and the infection generally resolves on its own. The prevalence of HEV in the United States is low.

Hepatitis G virus is a bloodborne pathogen, with a comparable rate of infection as that of HCV in units of banked blood. It is spread in a manner similar to HBV and HCV dissemination, by percutaneous or permucosal exposure. There is no vaccine to prevent hepatitis G virus infection. Similar to HBV and HCV, prudent and consistent use of barrier protection (e.g., Standard Precautions) is recommended. There are no concrete data at present on the chronic nature of this viral disease (CDC, 2006a).

HUMAN IMMUNODEFICIENCY VIRUS. Human immunodeficiency virus (HIV) is a retrovirus (e.g., a virus that carries genetic information in the RNA instead of the DNA) that attacks the immune system by destroying T-helper lymphocytes.

Healthy individuals generally have 800 to 1000 T-helper cells/mm^3 in their blood. Infection with the HIV virus reduces these numbers, and when a person is HIV positive and his or her T-cell count falls below 200 cells/mm^3 (or the person is HIV positive and is diagnosed with an atypical or opportunistic infection and/or cancer) a diagnosis of acquired immunodeficiency syndrome (AIDS) is made (Sampson and Workman, 2010). The period from HIV exposure to actual development of AIDS has been reported to be 12 years or longer. During this time, the individual is a carrier of the virus. HIV has been isolated from all body fluids (e.g., blood, semen, vaginal secretions, saliva, tears, breast milk, cerebrospinal fluid, amniotic fluid, and urine) of infected individuals. Symptoms that result from HIV infection may be attributed to other causes and include fever, night sweats, chills, muscle aches, and headache.

Occupational exposure to HIV can occur by percutaneous injury (e.g., a needle stick or cut with a sharp instrument) or by mucous membrane or nonintact skin (e.g., exposed skin that is abraded) exposure to blood, tissue, or other body fluids that are potentially infectious. The Centers for Disease Control and Prevention (CDC) estimates that there is an average transmission rate of 0.3% per sharps injury (CDC, 2006b). Mucous membrane exposure is associated with a 0.09% transmission risk and exposure through nonintact skin is probably lower (Davenport and Myers, 2009). If an exposure incident occurs, appropriate postexposure management should take place as a part of the workplace safety program. The source patient should be informed of the incident. Serology testing should be done according to institutional policy and governmental requirements. Policies should be established for instances in which source patient consent cannot be obtained. The healthcare worker should be counseled about the risk of infection, and he or she should be evaluated clinically and serologically for evidence of HIV infection as soon as possible after exposure. Postexposure prophylaxis (PEP) regimens (Table 3-1) should be supervised by an expert in the management of exposures; follow-up should be provided for adherence to PEP; and adverse events, including seroconversion, should be monitored. Timely postexposure management and administration is important, and an exposure incident should be treated as an urgent medical condition.

Multidrug-Resistant Organism Infections: Emerging and Resurging Organisms

Historical Perspective. The first antibiotics, sulfonamides, were introduced in 1935 to treat staphylococcal and streptococcal infections. Penicillin was introduced in the 1940s during World War II, followed by the discovery of streptomycin in the mid to late 1940s. While the introduction of these medications was viewed as miraculous and did save many lives, in the mid-1940s strains of previously susceptible microorganisms began showing resistance to some of these medications. During the 1960s, cephalosporin and semisynthetic penicillins were developed, and it was believed that the problem of healthcare-associated infections was solved. Many gram-negative bacteria were found to be susceptible to these new drugs. By the late 1970s, however, strains of *S. aureus* resistant to penicillin, methicillin, cephalosporins, aminoglycosides,

TABLE 3-1

Postexposure Prophylaxis (PEP) for Occupational HIV Exposure*

Basic PEP	Expanded PEP
Basic PEP = two drugs: zidovudine plus lamivudine or emtricitabine; or stavudine plus lamivudine or emtricitabine; or lopinavir/ritonavir	Extended PEP = three or more drugs: zidovudine plus lamivudine or emtricitabine plus lopinavir/ritonavir; or stavudine plus lamivudine or emtricitabine plus lopinavir/ritonavir; or tenofovir plus lamivudine or emtricitabine plus lopinavir/ritonavir
Small-volume (few drops) exposure to mucous membranes or nonintact skin Source patient is HIV positive, asymptomatic with known low viral load Source patient is HIV positive, symptomatic or AIDS with high viral load	Large-volume (major splash) exposure to mucous membranes or nonintact skin Source patient is HIV positive, symptomatic or AIDS with high viral load
Large-volume (major splash) exposure to mucous membranes or nonintact skin Source patient is HIV positive, asymptomatic with known low viral load Optional when source patient is unknown or known with HIV factors	Less severe percutaneous injury (solid needle or superficial injury) Source patient is HIV positive, symptomatic or AIDS with high viral load
Less severe percutaneous injury (solid needle or superficial injury) Source patient is HIV positive, asymptomatic with known low viral load Optional when source patient is unknown or known with HIV factors	More severe percutaneous injury (large-bore hollow needle, deep punctures, visible blood on device, needle was in patient's artery or vein) Source patient is HIV positive, asymptomatic with known low viral load Source patient is HIV positive, symptomatic or AIDS with high viral load

*When PEP therapy is initiated, the recommended course is 28 days.

Modified from Sampson JG, Workman ML: Care of patients with HIV disease and other immune deficiencies. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, St Louis, 2010, Saunders.

clindamycin, erythromycin, and other antibiotics were isolated in hospital outbreaks of infection. This situation led to the development of new antibiotics, including carbapenems, cephamycins, and fluoroquinolones. These broad-spectrum antimicrobials were bactericidal at low concentrations and led to a false sense of euphoria during the 1980s, when it was believed that, at last, resistance to these antimicrobials would be impossible (Sandlin, 2008).

In the 1990s it became evident that the potential for resistance to any and all antimicrobials existed as healthcare-associated outbreaks of multidrug-resistant tuberculosis (MDR-TB) began to occur. Significant outbreaks of methicillin-resistant *S. aureus* (MRSA) (Surgical Pharmacology) and vancomycin-resistant *Enterococcus faecalis* (VRE) also occurred in the 1990s. In some cases, organisms seemed to acquire resistance almost immediately on exposure to the particular antibiotic. As fewer new antimicrobial drugs are being developed by the pharmaceutical industry, many consider the 1990s to be the beginning of the postantibiotic era (Sandlin, 2008).

Mechanisms of Resistance. Similar to their unwilling human hosts, pathogenic bacteria have an instinct to survive. When faced with an antimicrobial attack, they assemble their defensive resources. These microorganisms have the remarkable capability to incapacitate the threatening antibiotic and to mutate and outwit the most lethal clinical weapons. Although carrying only a single chromosome, bacteria by nature have extra minichromosomes called *plasmids*. These plasmids are hearty, and some may survive even the most aggressive antibiotic attack. Surviving plasmids are resistant and reproduce in kind, creating dominant organisms within the host. In addition, incompletely or ineffectively treated infections create the potential for reinfection with resistant organisms (CDC, 2006a).

Microbial resistance can be divided into three categories: (1) presence of a naturally resistant strain of an organism before any drugs are administered, (2) acquisition of a drug-resistant strain from an external source, and (3) drug resistance from treatment-related causes. Occurrence of naturally resistant strains of organisms without any exposure to drugs can occur

SURGICAL PHARMACOLOGY

Treating Methicillin-Resistant *Staphylococcus Aureus* (MRSA)

In the past, vancomycin was the only alternative for treating methicillin-resistant *Staphylococcus aureus* (MRSA). With the increased use of vancomycin, however, strains of *S. aureus* with reduced susceptibility to vancomycin began to appear. Newer antibiotics include daptomycin, linezolid, teicoplanin, and quinupristin-dalfopristin. Of these, linezolid has excellent activity against vancomycin-intermediate and vancomycin-resistant *Staphylococcus* and is approved for skin and soft tissue infection and for pneumonia caused by MRSA.

LINEZOLID (ZYVOX): NURSING CONSIDERATIONS

Assessment

- Assess central nervous system symptoms: headache, dizziness.
- Monitor liver function studies: aspartate aminotransferase (AST), alanine aminotransferase (ALT).
- Monitor allergic reactions: fever, flushing, rash, urticaria, pruritus.
- Assess for pseudomembranous colitis: severe diarrhea, cramping.
- Monitor complete blood count (CBC) weekly, assess for myelosuppression (anemia, leukopenia, pancytopenia, thrombocytopenia).

Nursing Diagnoses

Risk for Infection (uses)
Deficient Knowledge (teaching)
Risk for Impaired Skin Integrity

Implementation

PO route: Store reconstituted oral suspension at room temperature; use within 3 weeks.
IV route: Give over 30 to 120 minutes; do not use intravenous infusion bag in series connections; do not use with additives in solution; do not use with another drug; administer separately.

Patient-Family Education

- Advise patient if dizziness occurs to ambulate and perform activities with assistance.
- Advise patient to complete full course of drug therapy.
- Advise patient to contact prescriber if adverse reaction occurs.
- Advise patient to avoid large amounts of tyramine-containing foods (give list).

SUMMARY

In the early part of 2009 telavancin was approved for specific indications; it is a rapidly bactericidal lipoglycopeptide that operates through mechanisms involving interference with the functions of the cell membrane. This drug has showed promising data in the treatment of methicillin-resistant *S. aureus* (MRSA) and is in the Phase III trial phase. The published Phase 2 randomized trial data have shown that the drug is well tolerated and is at least as effective as vancomycin for complicated skin and skin structure infections. With this and other new promising drugs on the horizon, the perioperative nurse should constantly stay apprised of new and improved therapies for MRSA.

Modified from Skidmore-Roth L: *Mosby's drug guide for nurses with 2010 update,* ed 8, St Louis, 2010, Mosby; Stevens DL: Infections due to gram-positive cocci, *What's New ACP Med* 27(9), Sept 2004, available at www.acpmedicine.com. Accessed July 1, 2009; Centers for Disease Control and Prevention: *Outpatient management of skin and soft tissue infections in the era of community-associated MRSA,* 2007, Atlanta, 2007, available at www.cdc.gov/ncidod/dhqp/pdf/ar/AMA_Flyer_Final.pdf. Accessed July 1, 2009; Gotfried et al: Intrapulmonary distribution of intravenous telavancin in healthy subjects and the effect of pulmonary surfactant on in vitro activities of telavancin and other antibiotics, *Antimicrob Agents Chemother* 52(1):92-97, 2008.

by intrinsic resistance, genetic mutation, or transfer of genetic material. Some microorganisms possess genes that make them resistant to an antibiotic. These genes may always be present in the microorganism but remain in an inactive stage until challenged by an antibiotic. Genetic mutation can occur spontaneously in the course of rapid multiplication of the microbe. These antibiotic-resistant mutants reproduce within the host. New genetic material also can be transferred into bacteria by means of free DNA that contains resistant genes (CDC, 2006a).

Introduction of drug-resistant microorganisms can occur through a person or an inanimate object. Bacteria become mobile and accessible to humans on the hands or clothing of care providers, through instruments and procedures, or through food. Resistant microorganisms may travel from distant parts of the world by means of infected travelers. Surgical instruments that have been ineffectively cleaned and processed can contribute to the spread of resistant organisms. Use of antibiotics in agriculture and in animal feed products also has contributed to the development of resistant organisms. When the food is ingested, resistant genes may be spread to humans (CDC, 2006a).

Drug resistance from treatment-related causes is often the result of misuse (e.g., incorrect use, overuse, or underuse) of antibiotics. It is believed that 50% of all antibiotic use in the United States can be characterized by misuse in one form or another, and efforts to reduce surgical site infections include appropriate prophylactic antibiotic use in surgical patients (Evidence for Practice). It is estimated that half of all antibiotic prescriptions written are not warranted. During antibiotic therapy, the patient may have had a few resistant organisms. By natural selection, as the susceptible organisms are killed, the resistant organisms multiply and become predominant. Inadequate drug therapy may contribute to the phenomenon and may be the fault of the patient, the provider, or both. Failure to perform sensitivity testing along with inappropriate dosing can contribute to resistance. If the patient is noncompliant with the

EVIDENCE FOR PRACTICE

Prevention of Surgical Site Infections: Surgical Care Improvement Project

Surgical site infections (SSIs) occur in 2% to 5% of clean, nonabdominal surgical procedures and in 20% of intraabdominal procedures. Many studies show higher infection rates, suggesting that SSIs account for 14% to 16% of all hospital-acquired infections and are among the most common complications of surgical patient care. SSIs increase morbidity and consume additional resources. Reimbursement for patients without complications exceeded hospital costs, generating a low margin of profitability. Infectious complications result in an increased median hospital stay of 2.8 days and an increased cost to Medicare and private payers. Medicare spent an estimated $326.7 billion on hospital-acquired infections in 2005.

SSIs include superficial incisions, deep incisional, and organ/space infections. These have been defined in the Centers for Disease Control and Prevention (CDC) National Nosocomial Infections Surveillance (NNIS) System and are recognized worldwide. Surgical patients often receive some form of antibiotic prophylaxis. The Surgical Care Improvement Project (SCIP) is a national partnership of organizations committed to improving the safety of surgical care through the reduction of postoperative complications. In 2005 the SCIP launched a multiyear campaign to reduce surgical complications by 25% by 2010. One of the targeted areas is SSIs.

EVIDENCE FOR PRACTICE IDENTIFIED BY SURGICAL CARE IMPROVEMENT PROJECT TO REDUCE SURGICAL SITE INFECTIONS

Although some surgical complications are unavoidable, surgical care can be improved through decisions and subsequent care focusing on evidence-based practice recommendations. Research shows that delivering antibiotics to a patient within 1 hour of beginning surgery can dramatically decrease SSI rates, yet this practice is not followed in all situations.

Numerous more recent, successful projects have shown that institutional implementation of evidence-based practices can have a significant impact on surgical complications.

- Application of the National Surgical Quality Improvement Program (NSQIP) within the Veterans Health Administration resulted in a 27% reduction in mortality related to surgery.
- Hospitals participating in the CDC and NNIS have shown reductions of 44% in device-associated infection rates and SSI rates.
- The national network of Medicare quality improvement organizations (QIOs), working under contract with the Centers for Medicare & Medicaid Services (CMS), conducted a surgical infection prevention collaborative that effectively reduced SSI by 27% at 56 centers across the United States.

Postoperative complications impose a substantial mortality and morbidity ratio on patients. The cost to the healthcare community is overwhelming. One approach to improving outcomes from surgery is to promote adherence to process of care measures such as administering prophylactic antibiotics. The purpose of antibiotic prophylaxis is to reduce intraoperative microbial contamination sufficiently to preclude microbial presence to reduce infection. The antimicrobial used should be safe, inexpensive, and bactericidal against a broad spectrum of the most probable contaminants for the intervention. Key measures identified in the SCIP to reduce surgical site infections and affect outcomes are the following:

- A prophylactic antibiotic should be administered within 1 hour before surgical intervention.
- The appropriate prophylactic antibiotic should be selected for surgical patients.
- Prophylactic antibiotics should be discontinued within 24 hours after surgery.
- Patients undergoing cardiac surgery should have their 6 AM postoperative glucose level controlled.
- Hair of surgical patients should be removed using the appropriate method.
- Patients undergoing colorectal surgery should reach immediate postoperative normothermia.
- Surgery patients should reach immediate postoperative normothermia.

Modified from The Commonwealth Fund: *Case study: The National Surgical Quality Improvement Program,* 2005, Pa, available at www.commonwealthfund.org/Content/Innovations/Case-Studies/2005. Accessed May 1, 2009; Dimick JB et al: National Surgical Quality Improvement Project, *J Am Coll Surg* 199:531-537, 2004; Centers for Disease Control and Prevention: *National Nosocomial Infections Surveillance System,* available at www.cdc.gov/ncidod/hip/SURVEILL. Accessed May 1, 2009; *Surgical Care Improvement Project—A National Quality Partnership,* available at www.medqic.org/scip. Accessed May 1, 2009; American College of Surgeons: *Continuous Quality Improvement, Surgical Care Improvement Project, 2009,* available at www.facs.org/cqui/scip.html. Accessed May 1, 2009.

prescribed regimen or discontinues the drug prematurely, he or she may also be contributing to drug resistance (CDC, 2005a).

Perioperative Considerations

METHICILLIN-RESISTANT *STAPHYLOCOCCUS AUREUS* (MRSA). MRSA infections, which occur in almost 130,000 cases in hospitals each year, lead to 5000 deaths annually (Ignatavicius, 2010). Common sites in which MRSA can be found include wounds (e.g., burns, surgical incisions, abrasions), chest tubes, intravenous catheter tips, intraabdominal abscesses, nasal passages, and the groin. *S. aureus* is one of the most frequently isolated organisms in postoperative surgical site infections. Surgical patients at risk for the development of MRSA infection include high-risk patients with underlying disease, patients who have a prolonged hospitalization, patients who have had previous antimicrobial therapy, patients who receive care in an intensive care unit, and patients who have been in proximity to another patient colonized with MRSA (CDC, 2005a). Patients may present with unrecognized colonization or become infected by caregivers who carry MRSA in their nose or on their skin. The ambient environment is rarely a source of MRSA except for some reported cases in burn units.

The primary mode of transmission for MRSA is most likely direct contact transmission from the hands of healthcare personnel. The organism has been recovered from the hands of personnel after they touched contaminated material and before they washed their hands. It also has been shown that MRSA can be carried in the nares of personnel and transferred to patients by hand contact. The importance of hand hygiene cannot be overemphasized (CDC, 2008a; AORN, 2009a).

Because MRSA is transmitted by contact, perioperative protocols should be used when caring for these patients. They should include the following:

- Segregate the patient, using Contact Precaution guidelines.
- Wear a gown and gloves whenever there is potential for contact with contaminated fluids or materials.
- Implement strict hand hygiene practices.
- Limit patient transportation to essential movement only.
- Clean and disinfect patient care equipment as close as possible to the time of use (AORN, 2009c).

In healthcare facilities, MRSA causes serious and sometimes fatal infections, including necrotizing fasciitis. MRSA resists almost every antibiotic except intravenous vancomycin. In 2005 the U.S. Food and Drug Administration (FDA) approved a new treatment for hospital patients with serious bacterial infections, including infections caused by MRSA. The drug tigecycline (Tygacil) is an antibiotic related to the tetracycline family that was first used in 2005. This drug is formulated to retain activity against some bacteria that are resistant to tetracyclines and provides an expanded broad spectrum of activity for patients with complicated SSIs. Minocycline and doxycycline are also used in the treatment of MRSA.

VANCOMYCIN-RESISTANT ENTEROCOCCI. Enterococci are intrinsically resistant to cephalosporins, semisynthetic penicillins, and clindamycin. Some strains also have acquired resistance to erythromycin, chloramphenicol, tetracycline, fluoroquinolones, and vancomycin (CDC, 2006c). The incidence of vancomycin-resistant enterococci (VRE) infections in the United States has increased rapidly in recent years and now is difficult or impossible to treat. Patients at the greatest risk of VRE infection are patients with a prolonged stay in the critical care unit, intraabdominal or cardiothoracic surgical procedures, presence of indwelling central venous catheters, presence of urinary catheters, extended hospital stays, multiple antimicrobial therapies, and proximity to infected individuals. Because the enterococcal plasmid carrying the resistant gene can be transferred to organisms such as *S. aureus,* VRE infections are of serious concern (Droboni et al, 2009; CDC, 2006c).

The CDC has issued recommendations regarding the use of vancomycin, including identifying situations in which vancomycin should and should not be used; establishing education programs for practitioners, susceptibility testing, isolation procedures, and dedication of equipment and devices; verifying procedures for cleaning and disinfecting the environment; and minimizing movement of personnel between patients with and without VRE (Droboni et al, 2009; CDC, 2006c).

VRE can be transmitted directly from patient to patient, through the hands of healthcare providers, or through contact with contaminated environmental surfaces and equipment used for patient care. As with MRSA, Contact Precautions should be followed when caring for patients infected with VRE. Perioperative protocols are similar to protocols for MRSA patients and should include the following:

- Segregate patients, using Contact Precaution guidelines.
- Wear a gown and gloves when in contact with contaminated materials.
- Implement strict hand hygiene practices.
- Limit patient transportation to essential movement only.
- Clean and disinfect patient care equipment as close as possible to the time of use (AORN, 2009c; CDC, 2007a).

Germicides commonly used for cleaning and disinfecting in hospitals are effective against VRE. Isopropyl alcohol and sodium hypochlorite (bleach) are highly effective. With a 10-minute exposure time, some phenolic and some quaternary ammonium compounds also are effective. These are less effective at shorter exposure times. Hydrogen peroxide has been found to be ineffective. No relationship seems to exist between microbial resistance to antibiotics and increased resistance to germicides (CDC, 2007a). Perioperative personnel should routinely consult the manufacturer's written instructions and follow Environmental Protection Agency (EPA) recommendations when selecting germicides for surface cleaning (AORN, 2009d).

VANCOMYCIN INTERMEDIATE–RESISTANT *STAPHYLOCOCCUS AUREUS*. In 1996 the first known incidence of vancomycin intermediate–resistant *S. aureus* (VISA) occurred in Japan when the organism was isolated from a surgical site infection and undrained abscess. The first occurrence of the organism in the United States was seen 1 year later. A patient that had been treated with vancomycin for multiple episodes of peritoneal MRSA developed bacterial strains moderately resistant to vancomycin, which was the treatment of choice for MRSA. Although the organism showed only intermediate levels of resistance, the CDC viewed this occurrence as an early warning that strains of *S. aureus* with full resistance to vancomycin may emerge (CDC, 2006c). Vancomycin is ineffective for the treatment of VRSA and VISA.

MULTIDRUG-RESISTANT *MYCOBACTERIUM TUBERCULOSIS* (MDR-TB). Outbreaks of TB have heightened concern about healthcare-associated transmission of this disease. The incidence of MDR-TB is increasing in the United States. Transmission is most likely to occur from patients with unrecognized pulmonary or laryngeal tuberculosis and those who do not take their TB medication regularly. Populations at greatest risk of

developing TB or MDR-TB are the elderly, indigent, minorities, immigrants from countries where TB and MDR-TB are prevalent, and HIV-infected individuals (CDC, 2006b). Transmission also occurs as a result of procedures such as bronchoscopy, endotracheal intubation, endotracheal suctioning, and open abscess irrigation, inclusive of inadequate equipment disinfection. Extensively drug-resistant TB (XDR-TB) is now a threat in many Asian countries and the former Soviet Union. This strain of TB is very difficult to treat because of its resistance to the primary medications used to treat TB (e.g., isoniazid and rifampin) as well as many of the secondary medications used (e.g., fluoroquinolone, amikacin, kanamycin, and capreomycin) (Neil, 2008).

The CDC's Guidelines for Preventing the Transmission *of Mycobacterium Tuberculosis in Health-Care Settings* emphasize the following:

- Importance of control measures, including engineering controls and personal respiratory protection, including fit-tested, personal respirators when indicated
- Use of risk assessment to develop a tuberculosis-control plan
- Early detection and treatment of patients with tuberculosis
- Screening programs for healthcare workers
- Training and education for healthcare workers
- Evaluation of the tuberculosis-control program (CDC, 2005b)

CREUTZFELDT-JAKOB DISEASE. Creutzfeldt-Jakob disease (CJD) is an infectious, human prion disease that is a fatal neurodegenerative disease of the central nervous system. CJD is one of a group of encephalopathies known as *transmissible spongiform encephalopathies (TSEs)*. Other human forms of TSE are Gerstmann-Sträussler-Scheinker syndrome and *new variant CJD (nvCJD)* or *variant CJD (vCJD)* (CDC, 2008b).

CJD is considered a slower viral infection caused by a self-replicating prion. Prions are a unique class of organisms that have no detectable DNA or RNA. These small, proteinaceous agents are abnormal isoforms of normal cellular proteins. The incubation period for CJD varies from months to years to decades. Symptoms include rapidly progressing dementia, memory loss, rapid physical and mental deterioration, and a distinctive electroencephalogram reading. Positive diagnosis can be made only by direct examination of affected brain tissue. Most cases occur randomly and for unknown reasons when the patient is between 50 and 75 years old. The average duration of illness after the patient becomes symptomatic is 6 months, always ending in death. In contrast, vCJD has an earlier onset (between 18 and 41 years of age). Patients exhibit initial psychiatric symptoms and then neurologic symptoms differing from those of CJD, and the course of illness averages 14 months. The disease is always fatal (CDC, 2008b). According to the CDC, there is strong epidemiologic and laboratory evidence to support a causal association between vCJD and bovine spongiform encephalopathy (also known as *mad cow disease*).

CJD can be familial (i.e., inherited in the form of a mutant gene) or sporadic (no family history and no known source of transmission). Approximately 90% of cases are sporadic. Only about 1% of cases result from person-to-person transmission, and those are primarily the result of iatrogenic (medically related) exposure. Exposures have occurred via transplantation of contaminated central nervous system tissue, such as dura mater or corneas; from injections of pituitary hormone extracts; and by use of contaminated surgical instruments or stereotactic depth electrodes (CDC, 2008b).

CJD and other TSEs are unusually resistant to conventional chemical and physical decontamination methods. The causative prions are resistant to steam autoclaving, dry heat, ethylene oxide gas, and chemical disinfection with formaldehyde or glutaraldehyde as normally used in the healthcare environment (AORN, 2009e). Glutaraldehyde and formaldehyde act as fixatives, causing the prions to become more stable and less susceptible to normal sterilization/disinfection protocols. Special protocols for instrument care after exposure to prions should be followed (AAMI, 2009a). Some institutions use disposable instrument sets for diagnostic brain biopsies to rule out CJD or TSE. A process using radiofrequency (RF) gas plasma to eliminate prions that cause CJD from surgical instruments has been developed. The technique removed contamination to levels 1000 times lower than that achieved by existing decontamination methods (AAMI, 2009a). Other processes being investigated include the use of an alkaline cleaning agent before sterilization and vaporized hydrogen peroxide (VHP) sterilization. Protocols for handling CJD are evolving as researchers learn more about prions and their destruction. Table 3-2 lists options from which an acceptable protocol for care of instruments and equipment exposed to the CJD prion can be developed.

CONTROLLING INFECTION

Asepsis

The term *asepsis* means the absence of infectious organisms. Asepsis is directed at cleanliness and the elimination of all infectious agents. Surgical asepsis is designed to exclude all microbes, whereas medical asepsis is designed to exclude microbes associated with communicable diseases. Practices that restrict microorganisms in the environment and on equipment and supplies and that prevent normal body flora from contaminating the surgical wound are termed *aseptic techniques*. The goal of each aseptic practice is to optimize primary wound healing, prevent surgical infection, and minimize the length of recovery from surgery (History box). For perioperative practitioners, surgical aseptic principles and practices are the foundation for infection control efforts in the perioperative arena.

Infection control practices should primarily focus on prevention. Transmission of infection involves a chain of events, including the presence of a pathogenic agent, reservoir, portal of exit, transmission, portal of entry, and host susceptibility. Prevention occurs when there is a break in the chain of transmission. Infection control practices involve personal and administrative measures. Personal measures should include fitness for work and application of aseptic principles. Administrative measures should include provision of adequate physical facilities, appropriate surgical supplies, and operational controls in the perioperative area.

As new organisms have emerged, and known organisms become more resistant, the importance of patient education as a risk reduction strategy cannot be minimized. In addition to practicing sound infection control practices, nurses partner with the patient through effective education about infection control measures to maximize the potential for perioperative safe care (Patient and Family Education).

Universal, Standard, and Transmission-Based Precautions

Universal Precautions. In 1985, in response to the growing number of individuals testing positive for HIV, the CDC published recommendations for the use of Universal Precautions

HISTORY

Influences on Infection Control through the Ages

FIRST CENTURY BC
It was believed that swampy land contained minute animals not visible to the naked eye. These invisible animals were thought to become airborne, enter humans through the mouth, and cause disease.

450 BC
Hippocrates, the father of surgery, used wine or boiled water to irrigate wounds, laying the foundation for the rudiments of aseptic technique and infection control.

SECOND CENTURY
Galen, a Roman, is reported to have boiled his instruments before use.

MIDDLE AGES
The practices of segregating lepers, avoiding areas of pestilence, and isolating the severely ill indicated an awareness that diseases were transmissible.

SIXTEENTH CENTURY
Thomas Moffett identified and described lice, fleas, and mites.

SEVENTEENTH CENTURY
Antony van Leeuwenhoek, inventor of the microscope, discovered previously unseen creatures in his microscopic observations.

EIGHTEENTH CENTURY
Agostino Bassi linked a disease of the silkworm with a fungal parasite; he then suggested that many contagious diseases, such as smallpox, typhus, and cholera, were the result of live organisms.

1850s
Louis Pasteur, founder of the science of microbiology, theorized that fermentation was caused by particles of living matter so small that they could not be seen but could be carried freely in the air. He referred to these microorganisms as germs and found that heat killed them. The relationship between the fermentation process and the putrefaction of tissue was not understood at that time.

1860s
Joseph Lister learned about Pasteur's work, recognized the analogous relationship between the two processes, and began to investigate the relationship of the germ theory to the process of infection. By 1867 Lister was advocating carbolic acid soaks and sprays for hands, wounds, dressings, sutures, and the OR itself. Although Lister's antiseptic methods and principles were crude and undeveloped, their use resulted in a decrease in surgical mortality from 45% to 15%.

Ignaz Semmelweis made a simple but momentous contribution to infection control by advocating that hands be washed between examinations of patients and that a clean gown be worn for each patient.

Florence Nightingale instigated radical changes in sanitation, resulting in reductions in mortality from contagious diseases.

1880-1890s
In 1889 Halstead, at the Johns Hopkins Hospital, asked the Goodyear Rubber Company to make rubber gloves for his scrub nurse because she was allergic to the corrosive hand rinse being used. Gradually the idea of wearing gloves to protect the patient emerged. White aprons and gowns replaced the usual morning coat worn by surgeons. Masks were added in 1897 as microbiologists measured the microbial shed that occurred during conversation. Before the use of masks, many procedures were performed in total silence to decrease the probability of surgical wound infection. Sterilizers completed the transition to a truly aseptic approach to surgery, with all items coming into contact with the patient being sterile.

Modified from Foster LG: *Robert Wood Johnson, the gentleman rebel,* State College, Pa, 1999, Lillian Press; Foster LG: *A company that cares—100 year illustrated history of Johnson and Johnson,* New Brunswick, NJ, 1999.

(CDC, 2006b). Reports of hospital personnel becoming infected with HIV after a needle stick or skin exposure to a patient's blood created an urgent need for new and better measures to protect personnel from patient transmission of infection. With knowledge that many patients with bloodborne infections are undiagnosed, Universal Precautions, for the first time, placed emphasis on applying Blood and Body Fluid Precautions (previously a category in the 1993 *Guidelines for Isolation Precautions in Hospitals*) universally to all individuals regardless of their presumed infection status. Universal Precautions expanded the Blood and Body Fluid Precautions by recommending masks and eye protection to prevent mucous membrane exposures in addition to the routine use of barrier protection, such as gowns and gloves. Universal Precautions also emphasized the prevention of needle-stick injuries and the use of ventilation devices when resuscitation was performed. The CDC continued to recommend the use of Universal Precautions until 1987, when a new system of isolation called *Body Substance Isolation* (BSI) was proposed. BSI directed isolation of *all* moist and potentially infectious body substances (e.g., blood, feces, urine, sputum, saliva, wound drainage, other body fluids) for all individuals regardless of their infection status. This was accomplished primarily with the use of gowns and gloves. Because of the similarities yet differences between Universal Precautions and BSI, confusion reigned. In 2007 the CDC further expanded the *Guidelines for Isolation Precautions*.

The Occupational Safety and Health Administration (OSHA) issued a rule for *Occupational Exposure to Bloodborne Pathogens* to address workplace safety. This document was based on the concept of Universal Precautions. OSHA subsequently revised its final rule to include a special focus on needle-stick and other percutaneous exposures to bloodborne pathogens (OSHA, 1991). The revised rule addressed "sharps with engineered sharps injury protections" (nonneedle devices or needle devices with built-in safety features to reduce the potential for injury) and "needleless systems" (alternative delivery devices using blunt cannulae, catheter ports or connectors, or other nonneedle devices). Other revisions focused on the review and updating of exposure control plans, solicitation of employee input, and improved record keeping. The

PATIENT AND FAMILY EDUCATION

Patient Education for SSI Prevention

The Joint Commission has established several National Safety Patient Goals (NPSGs) to provide organizational guidance for key patient safety issues. One of these goals, NPSG 7, focuses on how organizations reduce the patient's risk for developing a healthcare-associated infection (HAI). In addition to implementing hand hygiene measures and other evidence-based practices to prevent HAIs and surgical site infections (SSIs), organizations are also required to provide adequate education about SSI prevention to both patients having surgical procedures and also their families. Education can be provided by any means the organization chooses (e.g., printed materials, verbal teaching, classes), but there must be some documentation within the patient record that the education occurred. Items that might be included in a patient handout are included below.

Millions of people have surgery each year. Every surgery has risks, but we know there are some that can be prevented. One way you can help lower your risk for problems from your surgery is to learn about some of the things that can cause infection and talk with a member of your surgical care team before surgery about the type of care you should receive. Here are some questions that patients often ask about surgical site infections, which are also called SSIs.

What is a Surgical Site Infection (SSI)?

A surgical site infection is an infection that occurs after surgery in the part of the body where the surgery took place. Most patients who have surgery do not develop an infection. However, infections develop in about 1 to 3 out of every 100 patients who have surgery. The following are some of the common symptoms of a surgical site infection:

- Redness and pain around the area where you had surgery
- Drainage of cloudy fluid from your surgical wound
- Fever

Can SSIs be Treated?

Yes. Most surgical site infections can be treated with antibiotics. The antibiotic given to you depends on the bacteria (germs) causing the infection. Sometimes patients with SSIs also need another surgery to treat the infection.

What are Some of the Practices Performed by Hospitals to Prevent SSIs?

To prevent SSIs, doctors, nurses, and other healthcare providers:

- Clean their hands and arms up to their elbows with an antiseptic agent just before the surgery.
- Clean their hands with soap and water or an alcohol-based hand rub before and after caring for each patient.
- May remove some of your hair immediately before your surgery using electric clippers if the hair is in the same area where the procedure will occur. They should not shave you with a razor. Using a razor to remove hair before surgery can cause infections because of the risk of leaving small cuts on the skin.
- Wear special hair covers, masks, gowns, and gloves during surgery to keep the surgery area clean.
- Give you antibiotics before your surgery starts. In most cases, you should get antibiotics within 60 minutes before the surgery starts and the antibiotics should be stopped within 24 hours after surgery. Given properly, antibiotics can greatly lower your chances of getting an infection after surgery.
- Clean the skin at the site of your surgery with a special soap that kills germs.

What Can I Do to Help Prevent SSIs?

Before your surgery*:*

- Tell your doctor about other medical problems you may have. Health problems such as allergies, diabetes, and obesity could affect your surgery and your treatment.
- Quit smoking. Patients who smoke get more infections. Talk to your doctor about how you can quit before your surgery.
- Do not shave near where you will have surgery. Shaving with a razor can irritate your skin and make it easier to develop an infection.

At the time of your surgery:

- Speak up if someone tries to shave you with a razor before surgery. Ask why you need to be shaved and talk with your surgeon if you have any concerns.
- Ask if you will get antibiotics before surgery.

After your surgery:

- Make sure that your healthcare providers clean their hands before examining you, either with soap and water or with an alcohol-based hand rub. *If you do not see your providers clean their hands, please ask them to do so.*
- Family and friends who visit you should not touch the surgical wound or dressings.
- Family and friends should clean their hands with soap and water or an alcohol-based hand rub before and after visiting you. If you do not see them clean their hands, ask them to do so.

What Do I Need to do When I Go Home from the Hospital?

- Before you go home, your doctor or nurse should explain everything you need to know about taking care of your wound. Make sure you understand how to care for your wound before you leave the hospital.
- Always clean your hands before and after caring for your wound.
- Before you go home, make sure you know who to contact if you have questions or problems after you get home.
- If you have any symptoms of an infection, such as redness and pain at the surgery site, drainage, or fever, call your doctor immediately.

If you have additional questions, please ask your doctor or nurse.

Modified from The Joint Commission: Educating patients on SSI prevention, *OR Manager* 25(7):21-22, 2009; Surgical Care Improvement Project: Tips for safer surgery, available at www.ofmq.com/Websites/ofmq/Images/FINALconsumer_tips2.pdf. Accessed July 25, 2009; The Society for Healthcare Epidemiology of America: FAQs about surgical site infections, available at www.shea-online.org/Assets/files/patient%20guides/NNL_SSI.pdf. Accessed July 25, 2009.

TABLE 3-2

Care of Items Exposed to the Creutzfeldt-Jakob Disease Prion

Tissue Infectivity	Item/Device (Using Spaulding Classification System)	Cleanable	Heat/ Moisture Stable	Disposition
High infectivity	Critical/semicritical instruments/ devices	If easily cleaned	If yes	1. Thoroughly clean with detergent germicide 2. Autoclave at 134° C (272° F) immersed in water in prevacuum sterilizer for 18 min (extended cycle) *or* 3. Autoclave instruments immersed in water at 121° C (250° F) in gravity sterilizer for 20 min; 60 min if not immersed in water *or* 4. Immerse in 1N NaOH (1 normal sodium hydroxide) for 60 min at room temperature. After 60 min, remove items from NaOH, rinse, and steam sterilize at 121° C (250° F) in gravity sterilizer for 30 min 5. After processing according to one of above options, prepare instruments in usual fashion and sterilize for future use
			If no	Discard
	Critical/semicritical instruments/ devices	If difficult to clean	If yes	1. Discard *or* 2. Decontaminate initially by: a. Autoclave at 134° C (272° F) in prevacuum sterilizer for 18 min *or* b. Autoclave at 121° C (250° F) in gravity sterilizer for 60 min *or* c. Immerse in 1N NaOH for 60 min at room temperature. After 60 min, remove items from NaOH, rinse, and steam sterilize at 121° C (250° F) in gravity sterilizer for 30 min 3. After initial decontamination as explained above, thoroughly clean, wrap, and sterilize by conventional methods for future use
			If no	Discard
	Critical/semicritical instruments/ devices	If impossible to clean	NA	Discard
	Noncritical instruments/ devices	If cleanable	NA	1. Clean according to routine procedures 2. Disinfect with a 1:10 dilution of sodium hypochlorite (bleach) or 1N NaOH, choosing solution that would be least damaging to items 3. Continue processing according to routine procedures
		Noncleanable	NA	Discard
	Environmental surfaces	NA	NA	1. Cover surface with disposable, impermeable material 2. Incinerate material after use 3. Disinfect surface with 1:10 dilution of sodium hypochlorite (bleach) 4. Wipe entire surface using routine facility decontamination procedures for surface decontamination
Medium/ low/no infectivity	Critical/semicritical/ noncritical instruments/ devices	Cleanable	NA	1. Clean, disinfect, or sterilize according to routine procedures
		Noncleanable	NA	Discard

TABLE 3-2

Care of Items Exposed to the Creutzfeldt-Jakob Disease Prion—cont'd

Tissue Infectivity	Item/Device (Using Spaulding Classification System)	Cleanable	Heat/ Moisture Stable	Disposition
Medium/ low/no infectivity, cont'd	Environmental surfaces	NA	NA	1. Cover surface with disposable, impermeable material 2. Dispose of material according to facility policy 3. Disinfect surface with OSHA-recommended agent for decontamination of blood-contaminated surfaces (e.g., 1:10 or 1:100 dilution of sodium hypochlorite [bleach])

NA, not applicable; *OSHA,* Occupational Safety and Health Administration.
Modified from Favaro MS, Bond WW: Chemical disinfection of medical and surgical materials. In Block SS, editor: *Disinfection, sterilization, and preservation,* ed 5, Philadelphia, 2001, Lippincott Williams & Wilkins; Association for the Advancement of Medical Instrumentation (AAMI): *Sterilization in healthcare facilities,* Arlington, Va, 2009, The Association, available at www.aami.org. Accessed June 1, 2009; Rutala WA, Weber DJ: Creutzfeldt-Jakob disease: recommendations for disinfection and sterilization, *Clin Infect Dis* 32(9):1348-1349, 2001; Centers for Disease Control and Prevention: *Guideline for disinfection and sterilization in healthcare facilities,* 2008, Atlanta, 2008, available at www.cdc.gov/ncidod/dhqp/pdf/guidelines/Disinfection_Nov_2008.pdf. Accessed June 1, 2009.

following is a summary of the requirements of the *Final Rule: Occupational Exposure to Bloodborne Pathogens* (OSHA, 2001):

1. Each facility must develop and implement an exposure control plan that defines exposure and implements the requirements of the final rule. This plan is to be reviewed and revised annually with information provided to all employees. The plan must reflect changes in available technology to reduce exposure to bloodborne pathogens and implementation of appropriate technology to that end. Nonmanagerial employee input must be solicited in selecting technology to be implemented in the practice setting.
2. Engineering and work-practice controls must be used to eliminate or minimize employee exposure. Examples follow:
   a. The employer must provide everything necessary for proper hand hygiene.
   b. Contaminated needles must not be recapped or removed unless such action is required by a specific medical procedure. Such recapping or removal must be accomplished by the use of a mechanical device or one-handed technique.
   c. A clamp or other mechanical device should be used to disassemble a knife blade and handle.
   d. Sharps are to be placed in labeled or color-coded, puncture-resistant, leak-proof containers for disposal.
   e. Specimens of blood or body fluids must be placed in containers that prevent leakage and are labeled or color-coded. Warning labels must be affixed to containers of regulated waste, refrigerators and freezers containing blood or potentially infectious materials, and other containers used to transport blood or potentially infectious materials (Figure 3-2). The labels must be fluorescent orange or orange-red.
   f. Food and drink are not to be kept in the same storage area where blood or other potentially infectious materials are present.
   g. PPE must be provided by the employer at no cost to the employee. Appropriate PPE shall include but is not limited to gloves, gowns, face shields or masks, and eye protection. Protective eyewear must have solid side shields. Gloves are to be worn when contact with blood or body fluids is anticipated. Disposable gloves are to be replaced as soon as possible after contamination occurs. Disposable gloves are not to be washed or decontaminated for reuse. Some facilities may have educational signs posted to assist employees in recognition of appropriate PPE (Figure 3-3).
   h. Signs must be posted at the entrance to work areas of potential contamination. These signs are to bear the biohazard legend with the following information: name of infectious agent, special requirements for entering the area, and name and telephone number of the responsible individual.
   i. Housekeeping provisions are to ensure that the workplace is maintained in a clean and sanitary condition. A written schedule for cleaning and a method of decontamination must be established. All equipment and working surfaces must be cleaned and decontaminated after contact with blood or other potentially infectious materials.

FIGURE 3-2 Biohazard label.

FIGURE 3-3 Example of universal symbols for blood and body fluid protection.

j. Contaminated laundry must be placed in a labeled or color-coded container that is recognized by all employees.
k. All employees are to receive education and training about safe handling of hazardous substances and materials. Information must be provided to all occupationally exposed employees at no cost to them. Individuals must receive training at the time of employment and annually thereafter. Individual employee training records are to be maintained by the employer for the duration of employment plus 30 years. The healthcare worker is highly encouraged to receive the HBV vaccine after obtaining the required information about the risk of exposure and about the vaccine. If the employee chooses not to accept the vaccination, the employer must have the employee sign a letter of declination.
l. Employees should report all exposures to blood and body fluids for postexposure evaluation.
m. Employers who are required to maintain a log of occupational injuries and illnesses must maintain a sharps injury log that acts as a tool for identifying high-risk practice areas and for evaluating various devices in use. This log must protect the confidentiality of the injured employee. Log information should include the type and brand of the device, the practice area in which the injury occurred, and an explanation of how the incident occurred.

The bloodborne pathogen regulation is enforceable by OSHA at the federal and state levels. This regulation is based on the concept of Universal Precautions to serve and protect healthcare providers and to minimize the transfer of pathogens from one patient to another. Surveyors for OSHA may engage in on-site visits to healthcare facilities. Unannounced visits may occur at any site where an employee exposure occurs. The visit may be a result of a verbal or written employee concern, referral from another regulatory agency, or random inspections of facilities.

Standard Precautions. By the early 1990s the controversy regarding Universal Precautions and Body Substance Isolation (BSI) had escalated. There was considerable confusion about which body fluids required special care under either Universal Precautions or BSI. There were also concerns about the need for additional precautions to prevent airborne, droplet, and contact transmission of other infectious agents. With this need in mind, the CDC developed a single set of precautions incorporating the major features of Universal Precautions and BSI (CDC, 2007b). These precautions are called *Standard Precautions,* and they are designed to reduce the transmission risk of bloodborne and other pathogens. Additional precautions based on routes of transmission for patients known or suspected to be infected or colonized with highly transmissible or epidemiologically significant pathogens are included in the document.

Standard Precautions are intended to reduce the transmission of microorganisms from recognized and unrecognized sources of infection. Standard Precautions should be applied to all patients receiving care regardless of their diagnosis or presumed infection status. They are considered the first, and most important, tier of precautions and as such are a primary strategy for successful infection prevention and control. Standard Precautions apply to (1) blood, (2) all body fluids and secretions and excretions (except sweat) regardless of whether they contain visible blood, (3) mucous membranes, and (4) nonintact skin. Standard Precautions include the following:

1. *Hand hygiene.* Hand hygiene is the most important factor in preventing the spread of infection. Hands are to be washed whenever they are in contact with blood, body fluids, secretions, excretions, and contaminated items, whether or not gloves are worn. Hands are washed immediately after gloves are removed, between patient contacts, and when otherwise indicated to avoid transfer of microorganisms to other patients or environments. Sometimes it is necessary to wash hands between tasks and procedures on the same patient to prevent cross-contamination of different body sites. A plain (nonantimicrobial) soap should be used for routine handwashing. When special circumstances such as hyperendemic conditions occur, an antimicrobial soap or an antiseptic hand rub (waterless antiseptic agent) should be used. The hand rub antiseptic agent is most effective if the hands are clean before the antimicrobial agent is applied. For effectiveness,

RESEARCH HIGHLIGHT

Handwashing Compared with Alcohol-Based Hand Rubs

Hand hygiene is recognized as a primary method of decreasing healthcare-associated infections. Prevention of infection is a priority for all healthcare providers inclusive of the perioperative team. Compliance with handwashing has been less than 50% in numerous studies. The introduction of waterless alcohol-based hand products increased compliance with hand hygiene, and in 2005 JCAHO (now named TJC) required healthcare organizations to comply with the CDC Category I recommendations for hand hygiene. Alcohol-based hand rubs are easy to use and fast-acting, and provide activity against most bacteria, viruses, and fungi. These recommendations require monitoring healthcare workers' compliance with recommended hand hygiene practices, making hand hygiene an institutional priority, and providing easier methods for hand hygiene, such as alcohol-based hand rubs.

One of the objectives of this study was to evaluate the comparative microbial efficacy of handwashing with an unmedicated soap to hand rubbing. Before and after handwashing or hand rubs, imprints of the participants' palms and fingertips were taken, and then colony counts and identification of transient flora were determined. Handwashing was considered to be satisfactory if both hands were washed together for 30 seconds (±5 seconds), rinsed under running water, and dried with a paper towel. Hand rubs were considered satisfactory if 2 to 3 ml of the alcohol-based agent was applied to both hands, and all surfaces of the hands were rubbed together until the alcohol was dry. Observation was used for this part of the study.

Before hand hygiene procedures, the mean colony counts were 87 ppm for the palms and 85 ppm for the fingertips. During the study, it was observed that hand rubbing was performed more vigorously than handwashing. Transient flora levels were 4% after handwashing and 0% after hand rubbing. The results of this study support the CDC Category I recommendations, indicating that hand rubbing with a waterless, alcohol-based hand hygiene product is more effective than handwashing with an unmedicated soap.

Modified from Kac G et al: Microbial evaluation of two hand hygiene procedures achieved by health care workers during routine patient care: a randomized study, *J Hosp Infect* 60:32-39, 2005; Gupta C et al: Comparison of two alcohol-based surgical scrub solutions with an iodine-based scrub brush for presurgical antiseptic effectiveness in a community hospital, *J Hosp Infect* 65(1):277-278, 2007.

a sufficient amount of the agent must be used for the hand rub. Manufacturers' written instructions should be followed. An additional amount of hand rub agent may be necessary (Research Highlight).

2. *Gloves.* Clean, nonsterile gloves should be worn when touching blood, body fluids, secretions, excretions, and contaminated items. Freshly donned gloves should be worn when touching mucous membranes and nonintact skin. Gloves should be changed between tasks and patient procedures and after contact with material that may contain high concentrations of organisms. Gloves should be removed immediately after use and hands washed before engaging in another task or giving care to another patient.
3. *Masks, eye protection, face shields.* A mask and eye protection or a face shield is to be worn at any time patient care activities are likely to generate sprays or splashes of blood or body fluids, secretions, and excretions. These protective devices help protect the mucous membranes of the nose, mouth, and eyes.
4. *Gowns.* Clean, nonsterile gowns are to be worn at any time patient care activities are likely to generate sprays or splashes of blood or body fluids, secretions, and excretions. Gowns help protect the skin and prevent soiling of clothing. The activity to be performed and the amount and type of fluid likely to be encountered dictate the degree of protective barrier necessary in the gown. Gowns should be removed immediately after use and hands washed before engaging in other activities or giving care to another patient.
5. *Sharps.* Needles, scalpels, and other sharps should be handled in a manner to avoid injury. Needles should never be recapped using any technique that directs the point of the needle toward any body part. If recapping is necessary, it should be done using a mechanical device or a one-handed scoop technique. Used needles should not be removed from disposable syringes, and they should not be bent, broken, or otherwise manipulated by hand. Used disposable sharps should be placed in puncture-resistant containers located as close as possible to the point-of-sharps use. Reusable sharps should be contained in a puncture-resistant container for transport to the point of decontamination.
6. *Patient care equipment.* Single-use items should be discarded after use. Reusable equipment must be cleaned and reprocessed to ensure safe use for another patient. Equipment soiled with blood, body fluids, secretions, and excretions should be handled carefully to prevent exposure of skin and mucous membranes, contamination of clothing, and transfer of organisms to patients, personnel, and the environment.
7. *Linens.* Linens soiled with blood, body fluids, secretions, or excretions should be handled in a manner to avoid skin and mucous membrane exposure, clothing contamination, and transfer of microorganisms to other patients, personnel, and the environment.
8. *Environmental control.* Adequate procedures for routine care and cleaning of environmental surfaces, beds, and associated equipment are to be developed, and the use of these procedures is monitored on a regular basis.
9. *Patient placement.* Patients who contaminate the environment or who are unable to maintain appropriate hygiene or environmental control are to be housed in a private room with appropriate air handling and ventilation. If a private room is unavailable, the infection-control professional may determine a method for cohorting patients with similar infectious organisms (CDC, 2007b).

Transmission-Based Precautions. Transmission-based precautions are the second tier of infection prevention, designed for patients known or suspected to be infected by epidemiologically important pathogens spread by airborne or droplet transmission or by contact with dry skin or contaminated surfaces. They may be used singly or in combination with one another if the patient has a disease that has multiple routes of transmission and are to be used in addition to Standard Precautions.

AIRBORNE PRECAUTIONS. Airborne transmission occurs by dissemination of droplet nuclei from evaporated droplets that can remain suspended in the air for long periods or by dissemination of dust particles that contain the infectious agent.

Droplet nuclei are particles 5 μm or smaller in size. Airborne microorganisms can be dispersed widely depending on air currents and can be inhaled by or deposited on a susceptible host. In addition to Standard Precautions, Airborne Precautions include the following:

1. Patients are to be placed in private, negative-pressure rooms. The air exchange should be at a rate of 6 to 12 exchanges per hour with air discharged to the outdoors or circulated through high-efficiency particulate-arresting (HEPA) filters before being circulated to other areas of the facility.
2. Caregivers must wear OSHA-specified respiratory protection when caring for patients with known or suspected tuberculosis. If susceptible personnel care for patients with rubeola (measles) or varicella (chickenpox), respiratory protection should be worn. If the caregiver is immune to rubeola and varicella, respiratory protection is unnecessary.
3. All precautions for preventing transmission of tuberculosis should be implemented if the patient is known or suspected to have tuberculosis.
4. A surgical mask should be placed over the patient's nose and mouth for Airborne Infection Isolation Precautions when the patient must be transported from one location to another. Patient transport should be limited to essential purposes only.

DROPLET PRECAUTIONS. Droplet Precautions are used for patients known or suspected to be infected with microorganisms that are transmitted by large droplets (>5 μm). These droplets can be generated when the patient sneezes, coughs, or talks. Droplet Precautions are used in addition to Standard Precautions. Droplet Precautions include the following:

1. Patients are to be placed in private rooms when available. If this is not possible, the patient should be placed in a room with another patient who is infected with the same organism and with no other infection. If this is not possible, a 3-foot spatial separation should be maintained between the infected patient and other patients in the same room. For Droplet Precautions, no special air handling is required.
2. Caregivers should wear a mask when working within 3 feet of the patient.
3. Patients should be transported only for essential purposes. When transport is necessary, a mask should be placed over the patient's nose and mouth to minimize dispersal of droplets (CDC, 2007b).

CONTACT PRECAUTIONS. In addition to Standard Precautions, Contact Precautions should be used for patients known or suspected to be infected or colonized with epidemiologically important organisms that can be transmitted by (1) direct contact, as occurs when the caregiver touches the patient's skin, or (2) indirect contact, as occurs when the caregiver touches patient care equipment or environmental surfaces in the patient's room. Contact Precautions include the following:

1. Patients should be placed in a private room. If this is not possible, the patient should be placed in a room with another patient who is infected with the same organism and with no other infection. If this is not possible, patient placement must be determined on an individual basis, depending on the organism involved.
2. Gloves should be worn on entering the patient's room. Gloves should be changed after handling infective material that might contain a high concentration of microorganisms. When patient care activities have been completed, gloves should be removed before leaving the patient's room. Hands should be washed after glove removal. To avoid transferring microorganisms to others, no environmental surfaces in the patient's environment should be touched after the hands have been washed.
3. Gowns should be worn on entering the patient's room if there is a probability that the caregiver's clothing will be in contact with the patient or the environmental surfaces or if the patient is incontinent, has diarrhea, or has an ileostomy or colostomy. The gown should be removed before leaving the patient's room, and care should be exercised to avoid contact with environmental surfaces.
4. Patient transportation should be limited to essential transport only and Contact Precautions maintained to avoid contamination of personnel, visitors, or the environment.
5. Patient care equipment should be dedicated to a single patient and not be shared between patients. If this is impossible, equipment must be cleaned and disinfected thoroughly before being used for another patient (CDC, 2007b).

PROTECTIVE ENVIRONMENT. The purpose of creating a protective environment for allogeneic HSCT (hematopoietic stem cell transplantation) patients is to minimize fungal spore counts in the environment. These immunocompromised patients are highly susceptible to environmental fungi, and such an infection can cause morbidity. Implementation of the following helps create a protective environment:

- Place patients in specifically designated private rooms.
- Filter incoming air using HEPA filters.
- Maintain a positive air-pressure gradient in relation to surrounding areas. Rooms should be well sealed to prevent air leakage into rooms.
- Maintain unidirectional airflow with air entry on one side of the room, across the patient, and exit on the opposite side of the room.
- Maintain more than 12 air exchanges per hour.
- Lower dust levels by using smooth, washable surfaces as opposed to textured surfaces.
- Prohibit dried or fresh flowers and potted plants.
- Place N95 respirators on patients during transport.

Perioperative staff members traditionally have relied on numerous types of precautions to protect themselves and others from bloodborne pathogens and other infectious diseases. Implementing these precautions within the surgical environment requires critical thinking skills and sound nursing judgment. Consistent application of these precautions by all members of the perioperative team serves to protect the healthcare provider and to minimize cross-infection of pathogens among patients (AORN, 2009f).

Infection Control and Bioterrorism. The potential for bioterrorism is a reality in today's world. The CDC has identified agents that may pose a risk to the national security because of their (1) easy dissemination or transmission from person to person, (2) potential to cause high mortality and have a major public health impact, (3) potential to cause public panic and social disruption, and (4) necessity for special action for public health preparedness (CDC, 2009) (Table 3-3). Other emerging infections have been identified as problematic (Box 3-2). Although it is unlikely that patients with these infectious diseases would be among the surgical population except in an

TABLE 3-3

Bioterrorism Agents*

Agent	Transmission	Incubation	Symptoms	Management
Anthrax *(B. anthracis)*	Cutaneous: direct contact Inhalation: droplet, aerosolization	Cutaneous: 1-7 days Inhalation: 1-6 days on average, may be as late as 43 days	Cutaneous: Itching, progressing to papular and vesicular lesions, eschar, edema, ulceration, and sloughing. If untreated may spread to lymph nodes and bloodstream. Fatality: 5%-20%. Inhalation: Influenza-like with progression to high fever, dyspnea, stridor, cyanosis, and shock. Chest wall edema and hemorrhagic meningitis may be present. Death is universal in untreated cases and may occur in 95% of cases not treated in first 48 hr.	Standard Precautions. Special attention should be given to protection and containment of any draining wounds, inclusive of cutaneous lesions.
Smallpox (variola major/ variola minor viruses)	Inhalation of droplets, droplet nuclei, aerosols, and direct or indirect contact	Typically 12-14 days	High fever, malaise, abdominal pains, and, in some cases, delirium. Rash develops over face and spreads to extremities. Rash soon becomes vesicular and then pustular. All lesions progress at same rate. Fever continues throughout course of disease, and growing and expanding pustules are very painful. In 5%-10% of patients, a rapidly progressive disease develops, which is almost always fatal within 5-7 days.	Standard, Droplet, Airborne, and Contact Precautions for patients with vesicular rash pending diagnosis. Avoid contact with organism while handling contaminated bedding. Wear protective attire to include gloves, gown, and N95 respirator. Vaccine does not give reliable lifelong immunity. Previously vaccinated persons are considered susceptible. After exposure, initiate Airborne Precautions and observe for unprotected contact (from days 10-17). Vaccinate within 2-3 days of exposure. One case is a public health emergency because of highly communicable nature of this disease. Consult CDC and local health agencies at earliest opportunity.
Plague *(Y. pestis)*	Pneumonic plague: aerosolized bacteria carried on respiratory droplets from infected person Bubonic plague: bites from fleas or infected rodent	Pneumonic plague: 1-3 days Bubonic plague: 2-8 days	Pneumonic: Fever, headache, and weakness, with rapid progression to pneumonia with dyspnea, chest pain, cough, and bloody or watery sputum. Respiratory failure and shock may follow within 2-4 days. Bubonic: Symptoms include swollen, tender lymph nodes (buboes), fever, headache, chills, and weakness.	Standard and Droplet Precautions. Patients should be placed in private rooms or cohorted with "like" patients. Transport should be limited to essential movement only, and patient should wear mask during transport. Contact Precautions until decontamination is complete.
Tularemia *(F. tularensis)*	Bites of ticks, deerflies, and other arthropods that have eaten infected animal tissue; by handling infected animal carcasses; by eating or drinking contaminated food or water; or by inhaling infected aerosols	1-14 days (average 3-5 days)	Depending on route of exposure, skin ulcers, inflamed eyes, sore throat, oral ulcers, swollen and painful lymph nodes, and pneumonia. When bacteria are inhaled, symptoms include sudden fever, chills, headache, muscle aches, joint pain, cough, and progressive weakness. Symptoms may progress to chest pain, dyspnea, bloody sputum, and respiratory failure.	Standard Precautions

Continued

TABLE 3-3

Bioterrorism Agents—cont'd

Agent	Transmission	Incubation	Symptoms	Management
Botulism *(C. botulinum)*	Foodborne: ingestion of preformed toxin Wound: when wounds are infected with *C. botulinum* that secretes toxin; injection drug users are at risk for wound botulism	Foodborne: within hours of ingesting food, but can occur up to 8 days later	Early symptoms of botulism include gastrointestinal distress, nausea, and vomiting. Symptoms progress to diplopia, blurred vision, drooping eyelids, slurred speech, difficulty swallowing, dry mouth, and muscle weakness. If not treated, the disease progresses to respiratory paralysis and paralysis of arms and legs. Botulinum toxin is most poisonous substance known.	Standard Precautions

*The information about bioterrorism and the identified biologic weapons presented in this table represents current knowledge at the time of publication. The CDC is updating their website with the most current information from throughout the world. Practitioners are encouraged to update their knowledge continually by consulting the CDC website (www.cdc.gov) and other experts in the field. The Health Alert Network (HAN) is the CDC's surveillance system. It connects local, state, and national public agencies with high-speed and satellite Internet access. The extent of precautions necessary can be quickly determined by using this system.

Modified from Centers for Disease Control and Prevention, Disease Information: *Anthrax, 2003,* available at www.bt.cdc.gov/agent/anthrax/anthrax-hcp-factsheet.asp. Accessed April 25, 2009; Centers for Disease Control and Prevention, Disease Information: *Smallpox, 2007,* available at www.emergency.cdc.gov/agent/smallpox/overview. Accessed June 10, 2009; Centers for Disease Control and Prevention, Disease Information: *Plague, 2008,* available at www.cdc.gov/ncidod/dvbid/plague. Accessed June 10, 2009; Centers for Disease Control and Prevention, Disease Information: *Tularemia, 2003,* available at www.emergency.cdc.gov/agent/tularemia. Accessed June 10, 2009; Centers for Disease Control and Prevention, Disease Information: *Botulism, 2008,* available at www.cdc.gov/nczved/dfbmd/disease-listing/botulism. Accessed April 25, 2009; Ignatavicius DD: Care of patients with infection. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, St Louis, 2010, Saunders.

BOX 3-2

Emerging Infectious Diseases in the United States

RECENTLY EMERGING DISEASES

- Severe acute respiratory syndrome (SARS)
- West Nile virus
- Avian influenza
- H1N1 influenza
- Viral hemorrhagic fevers (e.g., Ebola, Marburg)
- Monkeypox
- Chagas' disease

Modified from Ignatavicius DD: Care of patients with infection. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, St Louis, 2010, Saunders.

extreme circumstance, it is likely that, given a national crisis or epidemic, perioperative personnel could and would be mobilized to serve in a variety of locations and roles as part of the national, state, and local emergency preparedness plan. Perioperative personnel should have a basic knowledge and understanding of the agents most likely to be encountered and the levels of precautions required for patient and personnel safety. Communication, collaboration, and coordination are required in the face of any bioterrorist event or natural disaster. Communities need emergency plans for such matters, such as guarding patient data and protecting information systems, linking quickly and easily with state and federal resources, ensuring culturally competent communication and care, accessing mental health resources, and identifying agencies that can partner with one another to provide services. Each institution must be compliant with The Joint Commission's requirements for periodic testing of emergency management systems and their associated plans.

Engineering Practices to Control Infection

Environment of Care. The surgical suite should be designed in such a way as to minimize and control the spread of infectious organisms. Either a central-core, race track, or a single-corridor design may be used. With the central-core design, sterile equipment and supplies should be contained within the central-core area, which is surrounded by ORs and a peripheral corridor. The single-corridor design places the ORs on either side of a single corridor, with separate storage rooms, usually along the corridor, to house sterile equipment and supplies. If a single-corridor design is used, sterile and contaminated items must be separated by either space or time. That is, sterile, wrapped, or containerized items can pass contaminated items in the corridor when the contaminated items are covered or otherwise contained (Figure 3-4).

Floors in the ORs should be hard, seamless, easily cleaned, and contiguous with the walls. This design eliminates the sharp angle where the floor and walls meet, where bacteria can become lodged and proliferate. If floors must be seamed, all seams should be heat-sealed. Walls may be constructed of any hard surface that is easily cleaned and hard enough to withstand the impact of surgical equipment that may accidentally be pushed into the wall during transport. If ceramic tile is used, smooth-surface grouting mortar should be used. This grout provides a surface nearly as smooth as the tile itself, eliminating concerns that surface roughness may attract and retain bacteria. Painted walls are less desirable because the paint flakes and peels, particularly in areas of higher humidity.

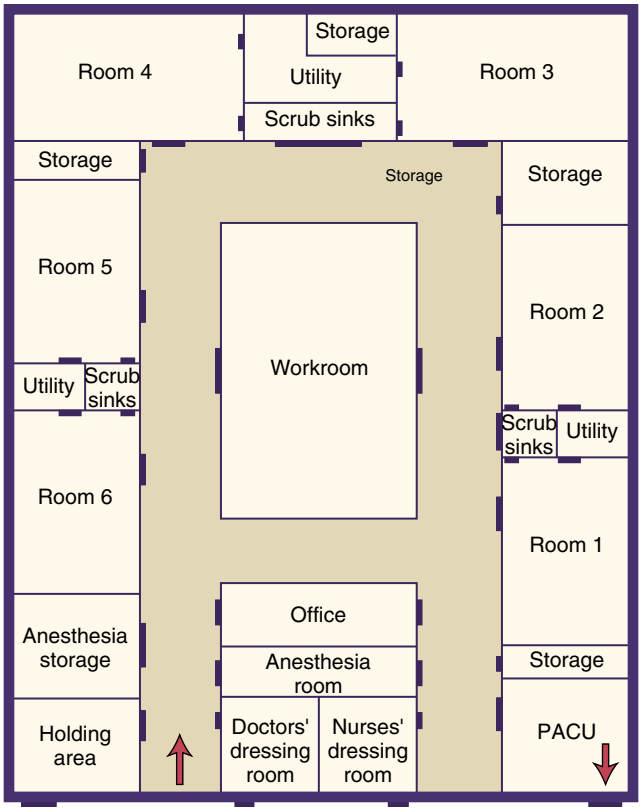


FIGURE 3-4 Racetrack floorplan.

If a hard-finish, epoxy paint is used, it is only as good as the surface beneath it. Equipment banged into a wall may cause damage and expose construction material to the environment. A soft-colored, matte-finished wall may be preferred to reduce reflectance and glare (AIA, 2006).

Doors in the ORs may swing or slide. If sliding doors are used, they should not recess into the wall but should slide over the adjoining wall to facilitate housekeeping. Cabinets should be recessed into the wall if possible. This configuration allows for maximum use of open floor space in ORs. Size and configuration of ORs are discussed in detail by the American Institute of Architects Academy of Architecture (AIA) for Health. Stainless-steel cabinets are preferred because the surfaces remain smooth and are easily cleaned. Wooden cabinets quickly become damaged with cracks and crevices where bacteria can collect and proliferate. Wooden cabinets are difficult to clean and disinfect and should be avoided in ORs. Cabinet doors may be of either the swinging or the sliding type. A cleaning protocol should be established for the tracts if sliding doors are used. For noncabinet shelving, open wire shelves are preferred because dust and bacteria do not accumulate, and air can circulate freely around shelf contents (AIA, 2006).

Scrub sinks should be located adjacent to each OR, with a single area serving two ORs if possible. Ideally, scrub sinks are located in a room or alcove adjacent to the peripheral or single corridor of the OR. Scrub sinks should not be within the central-core area because aerosolization and splashing may occur where sterile items are stored, contaminating the environment.

Each surgical suite must contain an enclosed soiled workroom exclusive for its own use. The workroom should contain a flushing hopper, receptacles for waste and soiled linen, a handwashing sink, and a work counter. If the area is used as a holding area as part of a larger system for collection and disposal of soiled materials, the flushing hopper is not required (AIA, 2006).

Heating, Ventilation, Air Conditioning. To control bioparticulate matter in the OR environment, ventilating air should be delivered to the room at the ceiling and exhausted near the floor and on walls opposite to those containing inlet vents. Airflow should be in a downward directional flow, moving down and through the location with a minimum of draft, to the floor and exhaust portals (AIA, 2006).

Air pressure in the OR should be greater than that in the surrounding corridor; this is called "positive pressure" in relation to corridors and adjacent areas. This positive pressure helps maintain the unidirectional airflow in the room and minimizes the amount of corridor air (less clean area) entering the OR (more clean area). Each OR should have a minimum of 15 total air exchanges per hour, with the equivalent of at least 3 replacements being of outside air to satisfy exhaust needs of the system. No recirculating devices, such as cooling fans or room humidifiers or dehumidifiers, are to be used. These units create a turbulent airflow and may recirculate settled bacteria. Doors to ORs should be kept closed to maintain correct ventilation, airflow, and air pressure. To minimize static electricity and to reduce the potential for bacterial growth, relative humidity in the OR should be maintained between 30% and 60%. A lower relative humidity may support accumulation of static electricity, whereas the presence of a higher humidity may cause condensation of ambient moisture, which may result in damp materials and supplies. This dampness supports bacterial growth. Temperatures in ORs should be maintained at 68° F (20° C) to 73° F (23° C) (AIA, 2006).

Practices to Prevent Infection

Sterilization. *Sterilization* is defined as the complete elimination or destruction of all forms of microbial life. The concept of what constitutes "sterile" is measured as the *probability* of sterility for each item to be sterilized. This probability is known as the *sterility assurance level* (SAL). For terminal steam sterilization processes, 10^{-6} is the recommended probability of survival for microorganisms on a sterilized device. A probability of microorganism survival of 10^{-6} means that there is less than or equal to a 1 in 1 million chance that an item is contaminated or unsterile. The SAL of 10^{-6} is considered appropriate for items to be used on compromised body tissue. For items not intended to come into contact with compromised tissue, an SAL of 10^{-3} is sometimes accepted. An SAL of 10^{-3} represents a 1 in 1000 chance of a surviving microorganism (AAMI, 2009a).

STEAM STERILIZATION. Steam sterilization is the oldest, safest, most economical, and best understood method of sterilization available in healthcare. It is the preferred method of sterilization for items that are heat and moisture sensitive. The efficacy of steam sterilization depends on lowering and limiting the bioburden on the item to be sterilized, using effective sterilization cycles, and preventing recontamination of sterile items before delivery to the point of use (AAMI, 2009b).

Theory of Microbial Destruction. Microorganisms are believed to be destroyed by moist heat through a process of denaturation and coagulation of the enzyme-protein system

within the bacterial cell. Microorganisms are killed at a lower temperature when moist heat is used as opposed to when dry heat is used. This fact is based on the theory that all chemical reactions, including coagulation of proteins, are catalyzed by the presence of water.

Principles and Mechanisms. At standard atmospheric pressure (sea level) when water is heated, the water temperature increases as heat energy is added. After the boiling point of 100° C (212° F) is reached, additional heat energy evaporates the water to form steam. At this point, the steam and the water are at the same temperature, but the steam has more energy than the water. This difference in energy is known as the *latent heat of vaporization*. When a cold item is introduced into the steam, some of the steam releases its latent energy to the object and changes back to liquid water. This phenomenon allows items to be heated much more rapidly in steam than in dry heat. The phenomenon of steam changing to liquid water is called *condensation,* and the steam and the liquid water are at a temperature of 100° C (212° F) when this occurs. At this point, the steam is said to be saturated. This 100° C (212° F) temperature is insufficient to kill microorganisms, however. To achieve a saturation temperature sufficient to kill microorganisms (250° F [121° C]), it is necessary to have a sealed container. When water is boiled in a vessel from which the steam cannot escape, a higher temperature is reached. As more steam is generated with no escape route, pressure in the vessel increases. The higher the steam pressure, the higher the temperature. The steam is the sterilizing agent. Any compressed air remaining in the vessel mixes with the steam and lowers the steam temperature. This reduced-temperature steam is incapable of sterilization. Air acts as a barrier to steam sterilization (AAMI, 2009c).

Steam entering the sterilizer chamber should contain little or no entrapped liquid water. The term *steam quality* describes the amount of steam vapor and liquid water in the mixture. A steam quality of 100% indicates that no liquid water is present in the steam. A steam quality of 97% or greater (i.e., <3% of the mixture is liquid water) is recommended to achieve an efficient sterilization process. Causes of low steam quality include improper boiler operation and inadequate or poorly maintained steam distribution lines to the sterilizer (AAMI, 2009c; AORN, 2009g).

Presterilization Preparation. The efficacy of the sterilization process depends in part on lowering or limiting the amount of bioburden present on the item to be sterilized. Items to be sterilized should be precleaned to lower the bioburden to the lowest possible level.

To prevent infection, all items that come into contact with the patient or sterile field should be systematically decontaminated after a surgical procedure. Handling, transport, and cleaning methods must be selected to prevent cross-contamination to other patients, exposure of personnel to bloodborne pathogens, and damage to instruments. The cleaning and decontamination methods chosen should be economic and of demonstrated effectiveness. Items may be cleaned by hand, by mechanical means, or by a combination of the two (AAMI, 2009a). Increased productivity, greater cleaning effectiveness, and increased employee safety may result from use of mechanical cleaning methods. Some mechanical cleaning equipment is designed to remove microorganisms through a cleaning and rinsing action, whereas others destroy specific types of microorganisms by thermal or chemical means. Types of mechanical cleaning equipment include washer-sterilizers, washer-disinfectors/washer-decontaminators, or washer-sanitizers; ultrasonic cleaners; utensil washers; and cart washers.

All workers handling soiled surgical instruments, whether in the OR, the substerile room, or a central decontamination area, must wear PPE sufficient to prevent contact with any blood or other body fluid. This generally means scrub attire covered with a liquid-proof gown, coverall, or sleeved apron; hair covering; surgical face mask; eye protection; and gloves suitable to the task. In the event that fluids may pool on the floor, liquid-proof boots or shoe covers are recommended.

Instruments should be kept as free as possible from gross soil and other debris during the surgical procedure. Throughout the surgical procedure, the scrub person should wipe used instruments with sponges moistened with sterile water. When blood is allowed to dry on the instrument, it may cause pitting, rusting, or corrosion. Sterile water is preferred to saline solution, which can cause pitting and damage to instrument surfaces. Initial decontamination should begin immediately on completion of the surgical procedure (AAMI, 2009c; AORN, 2009e). All instruments that can be immersed are disassembled, and box locks are opened to allow solution to contact all soiled surfaces. These instruments should be placed in a basin, solid-bottom container system, or bin with a lid. Scissors and lightweight instruments should be placed on top. Heavy retractors should be placed in a separate tray. An enzyme solution, foam, or spray can be added to the instruments to begin the process of breaking down any proteinaceous materials that may remain on the instruments.

Some instruments have sharp or pointed edges, such as scissors, forceps with teeth, perforating towel clamps, curettes, and rongeurs. These items can penetrate the gloves and skin, creating a portal of entry for infectious organisms. A different process is used for these instruments. Sharp instruments must not be placed in a basin or tray in such a way that a worker would have to reach into the container to retrieve the instrument, risking injury. Instead, they are placed with points down in a basin small enough that the handles are outside the basin, allowing individual instruments to be grasped. An alternative is to place all instruments together and not handle them until after they have been through an automated cleaning process.

Soiled instruments should be within leak-proof containers or trays inside plastic bags when they are transported from the OR for cleaning and decontamination. If sharps are being transported, the container should be puncture-resistant. Means of containing instruments include plastic, rubber, or metal bins with lids; solid-bottom sterilization container systems with the lids in place and filters in place; or simply placement of the instrument tray in a plastic bag. All soiled containment packages should be labeled with the biohazard symbol to warn handlers as to the nature of the contents. Transporting instruments while they are soaking is discouraged because of the possibility of a liquid spill and its associated clean-up problems as well as the difficulty of safely disposing the contaminated liquid unless a flushing hopper is available (AAMI, 2009a).

In the decontamination area, an initial cold water rinse with tap water or a soak in cool water with a protein-dissolving and blood-dissolving enzyme helps remove blood, tissue, and gross debris from device lumens, joints, and serrations. After completion of this pretreatment, the instruments should be

processed in an automated device, and washed by hand if an automated device is not available (AAMI, 2009a).

Automated processing is completed with the use of washer-sanitizers or washer-decontaminators. In most facilities, these units have replaced manual washing of instruments and the use of washer-sterilizers. They may have a single chamber where several phases of a rinsing, cleaning, rinsing, and drying process occur. Alternatively, they may have multiple chambers, each specialized for a specific function in the cleaning process, including initial cool water rinse to remove protein debris, enzymatic-solution soak, washing with detergent, ultrasonic cleaning, sustained hot water (80° C to 95° C) rinse, perhaps a liquid chemical germicide rinse (e.g., sodium hypochlorite solution), a lubrication cycle, and drying. Soiled utensils such as basins and trays similarly should pass through a utensil washer, a washer-disinfector-sanitizer, or a washer-sterilizer. When laparoscopic items or other items with a lumen are cleaned, a cleaning apparatus for these items can be attached to the newer washer-sanitizers/decontaminators (AAMI, 2009a; CDC, 2008a).

If instruments are manually cleaned, they should be submerged in warm water with an appropriate detergent and then cleaned and rinsed while submerged. Cleaning in this fashion helps protect personnel from aerosolization or splashing of infectious material and from injury caused by sharp objects. Harsh abrasives should not be used for manual cleaning because they damage the protective surfaces of instruments, contribute to corrosion, and impede sterilization (AORN, 2009e).

If a washer-sterilizer is to be used, gross debris should be removed with a cold water rinse before the instruments are placed in the washer-sterilizer, with care used to minimize splashing during rinsing. Instruments are placed in perforated or meshed-bottom trays or baskets and positioned so that the cleaning portion of the washer-sterilizer cycle can reach all parts of the instrument. The two types of washer-sterilizers are (1) those configured like a tunnel, with doors at each end and rotating spray arms on the sides, top, and bottom of the chamber; and (2) those that cover the instruments with water and blow steam and air through the water to cause agitation that produces the cleaning effect (Figure 3-5). The former machines are generally found in central decontamination areas and may be connected to an automatic or manual conveyer. The second type of machine is generally small (about 16 to 20 inches in diameter) and located in the instrument-processing room of the surgery suite (AAMI, 2009c).

After the instruments are cleaned with detergent and water and rinsed, the washer-sterilizer begins a steam sterilization cycle. The exposure time for this cycle depends on the temperature at which the cycle is run. Some washer-sterilizers of the tunnel type operate at 285° F (140° C) for less than 1 minute. Others, including all of the second type of washer-sterilizers, operate at 270° F (132° C) for 10 minutes. All rely on gravity displacement to remove air from the chamber. Debris remaining on the instruments because of possible inefficiencies of the cleaning process is baked on by the sterilization portion of the process and may be difficult to remove. Instruments processed through a single cycle of a washer-sterilizer are safe to handle and may be sterile, depending on presterilization bioburden. They are not suitable, however, for immediate use in another surgical procedure. They must be inspected, arranged in a manner convenient for the surgical team to use, and steam-sterilized again (AAMI, 2009c).

Not all instruments tolerate this process, and not all hospitals have access to mechanical washers that incorporate hot water or chemical decontamination as part of the cleaning cycle. Some instruments do not tolerate immersion in water or cannot tolerate the heat or pressures involved in mechanical processes. These items must be handwashed using an appropriate detergent for the type of material and the type of soil on the item. If protein or other organic soil is present, the detergent should have an alkaline pH (>7). If inorganic soil is present, the detergent should have an acid pH (<7). The degree of alkalinity or acidity should be selected so that the instrument or item itself is not damaged in the cleaning process. Stainless-steel instruments with organic soil are best cleaned by alkaline detergents with a pH range of 7 to 10, according to most U.S. surgical instrument manufacturers. Using acidic or harshly alkaline solutions can remove the protective passivation layer from the instrument, resulting in irreparable pitting and other corrosive activity. This advice regarding detergent selection applies to mechanical washing also. Although a neutral pH detergent is often selected for the foregoing reasons, written instructions from the instrument manufacturer should be consulted to determine appropriate cleaning products and procedures (AAMI, 2009c).

Items that were soiled with blood or body fluids and that have been cleaned only may not have been sufficiently decontaminated to allow handling by workers not wearing protective attire. If such an item tolerates steam sterilization, it can be decontaminated further by processing through an unwrapped steam-sterilization cycle (flash sterilized). It is then safe to handle. The item also can be soaked in a liquid chemical germicide, such as 2% alkaline glutaraldehyde or ortho-phthalaldehyde (OPA) to disinfect it; the manufacturer's written recommendations for immersion time must be followed. If none of these methods is suitable for the item, because of damage to the item, cost, or unavailability, workers in the preparation area should wear protective gloves when handling, inspecting, assembling, and packaging these items for sterilization.

The ultrasonic cleaning process is designed to remove fine soil from crevices and box-lock areas of instrumentation. It should be used only after instruments have had gross debris removed. Ultrasonic energy occurs in waveforms and is generated by transducers on the sides or bottom of a specially constructed chamber that is filled with water or a water and detergent solution. The ultrasonic waves pass through the water, creating tiny bubbles that collapse or implode. This creates a negative pressure, which pulls debris away from surfaces. This process is known as *cavitation*. Ultrasonic cleaning is not biocidal, and after the cleaning process is done, the instruments should be rinsed to remove the loose debris. Some ultrasonic consoles have chambers for rinsing and drying instruments.

Not all items tolerate the energy waves of the ultrasonic process. Chromium-plated instruments should not be cleaned ultrasonically because the energy waves can loosen the chromium from the base metal underneath. Dissimilar metals, such as stainless steel, titanium, copper, and lead, should not be ultrasonically processed at the same time. The energy waves, combined with the heat and detergent solution, can cause electrolysis to occur, plating one metal onto others, potentially ruining the instruments. Some manufacturers recommend that microsurgery instruments not be placed in the ultrasonic cleaner because of their delicate design and the fact that they

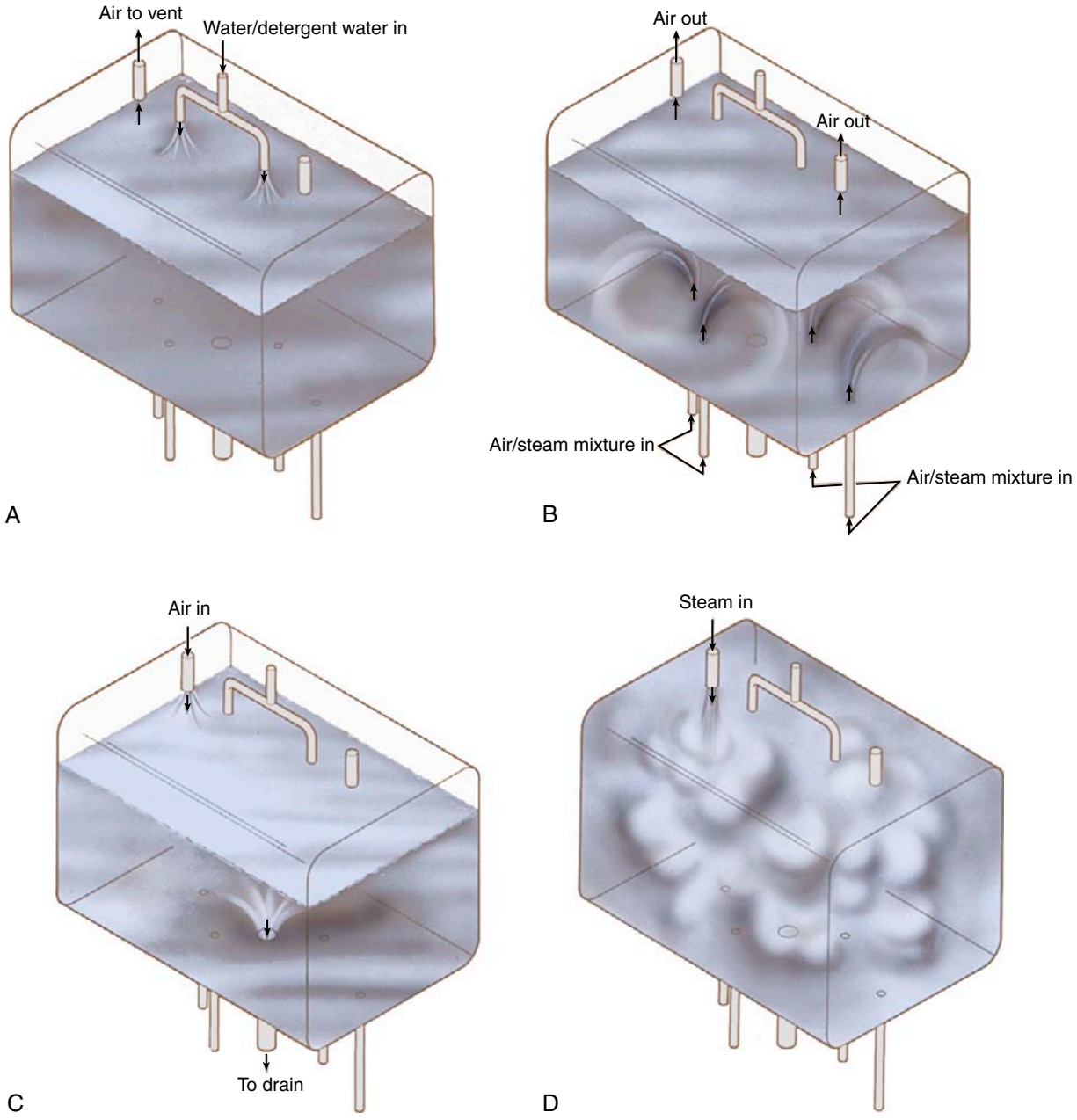


FIGURE 3-5 Automatic washer-sterilizer. **A**, The cycle in this machine begins with a cold water rinse entering through the top of the chamber to loosen and remove gross soil, such as blood and tissue, without coagulating proteinaceous material, which would cause it to adhere to instruments. Then warm water and detergent enter the chamber to a level to cover the instruments. **B**, Next, jets of steam and air are injected into the filled chamber through ports in the floor of the chamber. Violent turbulence in the detergent-water solution removes any debris remaining on the instruments after the initial rinse. **C**, At the conclusion of the wash time, the water drains out of the chamber. Newer models of washer-sterilizers may have microprocessor controls that allow the user to set the duration of wash time based on the nature of soil on the instruments. A final rinse coming in through the top of the chamber carries any detergent residues and soil away from the instruments and out the drain. **D**, Finally, saturated steam begins to fill the chamber. Air in the chamber and load is heavier than the steam and, because of gravity, is displaced downward and out the drain. As pressure builds in the chamber from the incoming steam, the temperature rises to 132° C (270° F), the chamber drain closes, and the temperature is held for the duration of the sterilization exposure time selected by the user. Then steam is exhausted through the automatic condenser exhaust. Some machines have the capability of selecting drying times for the instruments. At the conclusion of the cycle, an audible signal indicates that the unit is ready for unloading. Instruments and the inside of the sterilizer are very hot, and if no dry time was used, the instruments and trays are also wet. Use extreme caution in handling.

may contain several types of metal. The detergent or enzyme cleaner used in the ultrasonic machine should be selected carefully. The corrosiveness and overall effectiveness of some solutions can be dramatically affected by the combination of heat and ultrasonic energy in such a machine.

The final step before sterilization for reuse includes instrument preparation and packaging. These activities occur in a clean area, separate from the area where decontamination occurred. Instruments are inspected carefully for cleanliness and functionality. Soiled instruments are returned for further cleaning. Instruments with movable parts are treated with a water-soluble lubricant solution that contains an antimicrobial agent to retard growth in the lubricant solution. Broken or worn instruments are set aside for repair. Instruments are assembled into sets according to set content lists prepared by perioperative nursing staff.

Packaging and Sterilizer Loading. Packaging of surgical supplies and their arrangement in loads in the sterilizer are factors that govern the effectiveness of steam sterilization. The prime function of a package containing a surgical item is to permit sterilization of the contents and to ensure the sterility of the contents up to the time the package is opened. Provision must be made for the contents to be removed without contamination. To be effective, packaging material should have the following characteristics:

- Allows for adequate air removal and steam penetration
- Provides an adequate microbial barrier
- Resists tearing or punctures
- Has proven seal integrity (i.e., does not delaminate when opened and does not allow a reseal after opening)
- Allows for aseptic delivery of package contents
- Is free of toxic ingredients and nonfast dyes
- Is low-linting
- Is cost-effective by cost and value analysis (AORN, 2009h)

Sterilization container systems are one method of packaging instrumentation. Rigid packaging systems can be sterilized, stacked, and stored and offer a simple, effective packaging method. Because of the rigid material of the container, they cannot be punctured, abraded, or easily contaminated by environmental microbes. Properly initiated, container systems are a cost-effective packaging method. Recommendations and written instructions for sterilizing should be obtained from the container manufacturer. Performance testing should be carried out in the sterile processing department of the healthcare facility to ensure that all conditions essential for sterilization and drying are effectively achieved. Before opening a container, the perioperative nurse should check for evidence of integrity and sterility, and the lid should be carefully removed. The perioperative nurse should examine the contents to verify that the indicator or integrator has changed and that steam or ethylene oxide has reached the interior. When the scrub person removes the inner basket, he or she should ensure that the inner basket does not touch the outer container (AORN, 2009h).

If textile wrappers are used, they must be laundered between sterilization exposures to ensure sufficient moisture content of the fibers. This prevents superheating and absorption of the sterilizing agent. Rehydrated materials also deteriorate at a slower rate. All wrappers must be checked for holes or tears before use. Many in-hospital packaging materials—woven and nonwoven, reusable and disposable—are marketed today. Materials should be evaluated carefully before a product is chosen.

The size and density of woven textile packs must be restricted to ensure uniform steam penetration. The pack should not exceed 12 × 12 × 20 inches (30 × 30 × 50 cm) and should not weigh more than 12 lb (5.4 kg). When the items in the pack are being assembled, the lighter materials should be placed near the center of the pack. Each succeeding layer of dry goods should be placed crosswise on the layer below to promote free circulation of steam and removal of air. Pack density should not exceed 7.2 lb per cubic foot. A chemical indicator or integrator that accurately reflects one or more of the physical parameters of sterilization should be inserted into the center of each pack. These parameters are time, temperature, and steam saturation.

The pack should be wrapped sequentially in two barrier-type wrappers, which may be disposable or reusable. A single-textile reusable wrapper is defined as one layer of 270- to 280-thread count woven fabric. Cross-stitching and raw edges are unacceptable. Sequential double-wrapping creates a package within a package, providing for ease in presenting the wrapped item to the sterile field. Wrappers are made in suitable dimensions for the various items that must be packaged. The familiar envelope wrap is made by placement of the article diagonally in the center of the wrapper. The near corner, which should point toward the worker, is brought over the item, and the triangular tip is folded back to form a cuff. The two side flaps are folded to the center in like manner. The far corner of the wrapper is then folded on top of the other three. The process is repeated with the second wrapper, and the package is secured with autoclave indicator tape.

When the pack is opened for use, the flaps at the corners are used to form a protective cuff over the person's hands during dispensing of the sterile contents. When the items are wrapped, the wrappers should be folded securely about the contents. The package should be firm and sealed securely to prevent contamination in handling and storage. Single, disposable, nonwoven wrappers composed of fused material layers are available and widely used to wrap surgical supplies. These single wrappers provide a bacterial barrier at least equivalent to the sequential double wrap and allow for safe and easy presentation of the package contents to the sterile field, providing an alternative to the sequential double-wrapping procedure. Careful wrapping to prevent tenting and gapping of the package is essential (Figure 3-6). Nonwoven, single-use wrappers should not be reused (AAMI, 2009a).

Sterilization process (chemical) indicator tape should be used to hold wrappers in place on packages and to indicate that the packages have been exposed to the physical conditions of a sterilization cycle. When packages are opened, these tapes should be first torn so that the package cannot be retaped and then removed from reusable wrappers because they create laundry problems, such as occluding screens and filters. In some cases, the tapes leave a dye on the wrappers that may cause deterioration of the material. Tapes also may leave an adhesive residue that can interfere with future sterilizations of the fabric.

Sterilization pouches, commonly manufactured from a combination of paper and plastic films, provide an option for the packaging of single (or small groups) or lightweight instruments or other objects (e.g., medicine cups) for steam or gas sterilization. Double pouching is generally used with this method. A chemical indicator appropriate to the sterilization method is placed in the pouch and the pouch is sealed either with heat lamination or with a self-adhesive strip (Figure 3-7).

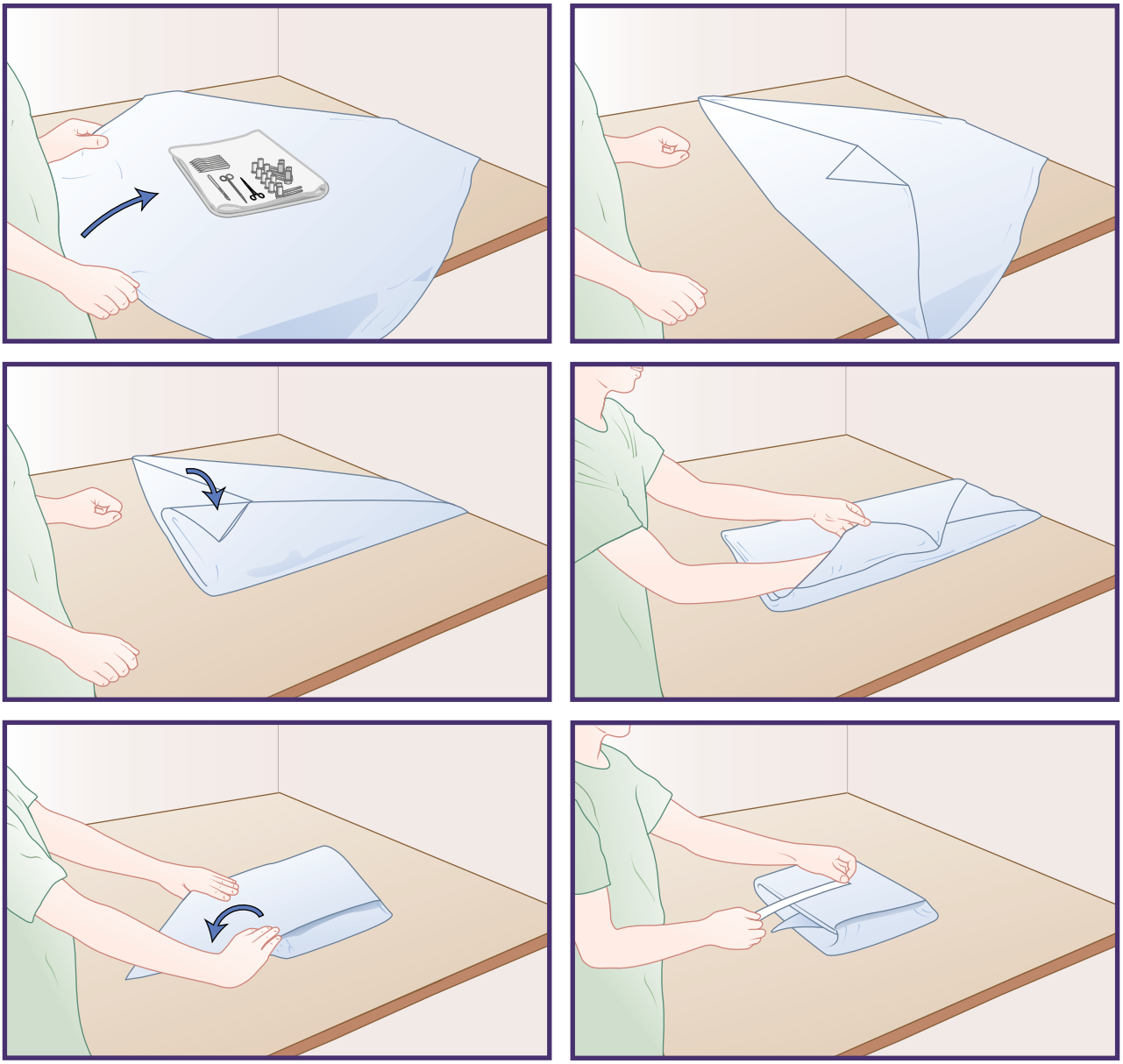


FIGURE 3-6 Envelope style wrapping.

Every package intended for sterile use should be imprinted or labeled with a load-control number that identifies the date of sterilization, the sterilizer used, and the cycle or load number. Load-control numbers facilitate identification and retrieval of supplies, inventory control, and appropriate rotation to ensure that dated packages are used first (AAMI, 2009a). Additional information to be noted on the label includes the initials of the person who prepared the item(s) and the package contents.

Some instruments or packaging systems may present challenges to the sterilization process. Special preparation or loading procedures may be necessary to meet these challenges. Hinged instruments must be arranged so that the steam can contact all surfaces of the instrument, including the tips, hinged surfaces, and ratchets. To accomplish this, these instruments must be sterilized in the open position. If the instruments have ringed handles for the fingers, the instruments may be placed on a "stringer," which is a U-shaped metal rod made especially for this purpose. When using closed container systems for sterilization, basket attachments may be used to immobilize instruments in the proper position for sterilization. Tubular instruments with lumens can trap air, which interferes with the sterilization process. To avoid this problem, lumens should be moistened with water immediately before sterilization. As the instrument is heated, the water turns to steam and forces the air out of the lumen. Instruments with concave or other surfaces that can hold water must be carefully placed on-edge to facilitate removal of air, which may become trapped in the concave surface. Placing the instrument on-edge also facilitates drainage of condensate. Items such as basins, which may be stacked for sterilization, should be stacked with sufficient space between all surfaces so that steam can contact all surfaces (AAMI, 2009a; CDC, 2008a).

When packaging is complete and the sterilizer chamber is loaded, the bundles and packages should be arranged to minimize resistance to steam, which must pass through the load

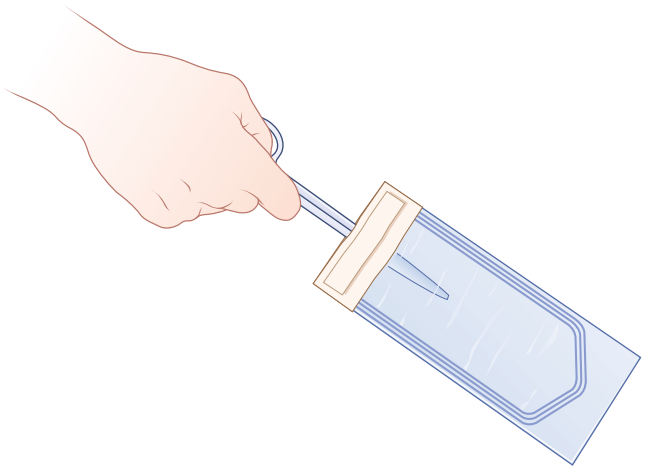


FIGURE 3-7 Sterilization pouch.

from the top of the chamber toward the bottom of the sterilizer. All packages should be placed on a vertical edge in the sterilizer in a loose-contact position. This allows free circulation and penetration of steam, enhances air elimination, prevents entrapment of air or water, and precludes excessive condensation. A second or upper layer may be placed crosswise on the first or lower layer. All jars, tubes, canisters, and other nonporous objects should be arranged on their sides with their covers or lids removed to provide a horizontal path for the escape of air and the free flow of steam and heat. To guard against superheating, surgical packs and supplies should not be subjected to preheating in the sterilizer with steam in the jacket before sterilization.

Rigid container systems should be placed flat on the sterilizer shelf. These containers should not be stacked during sterilization unless the manufacturer specifically recommends this practice. Containers should be stacked only in the manner recommended by the manufacturer's written instructions. Stacking may interfere with air removal and steam penetration. In addition, condensation from upper containers may drip down and contaminate lower containers when the sterilizer door is opened and the cooler room air contacts the containers (AAMI, 2009a; CDC, 2008a).

Sterilizing. When steam enters the autoclave, it is at the same pressure as the atmosphere. As the valves and doors to the outside close, steam pressure rises inside the chamber, increasing the temperature of the steam. Evacuation of air from the sterilizer is necessary to permit proper permeation of steam. If a sterilizer is improperly loaded, mixing of air with steam acts as a barrier to steam penetration and prevents attainment of the sterilization temperature.

The three factors necessary to achieve steam sterilization are *time, temperature,* and *moisture.* The microbial destruction period is based on the known time and temperature necessary to accomplish sterilization in saturated steam. Authorities have shown that definite laws determine the order of death in a given bacterial population subjected to a sterilizing process. If the temperature is increased, the time may be decreased.

To provide a safety margin, the minimum estimated exposure is extended to cover the lag between the attainment of the selected temperature in the chamber and the temperature of the load. The length of exposure varies with the type of sterilizer, cycle design, altitude, bioburden, packaging, and size and composition of items to be sterilized. Written instructions for sterilization parameters should be obtained from the sterilizer manufacturer. If a closed container system is used as packaging for items to be sterilized, the container manufacturer's written instructions for exposure times should be consulted and reconciled with those of the sterilizer manufacturer (AAMI, 2009a).

Sterilizers vary in design and performance characteristics. Use of rigid container systems may alter the come-up and exposure times in steam sterilizers. The configuration of some instruments or medical devices may hinder air removal and steam penetration, making sterilization more difficult. In such circumstances, the device manufacturer must be able to specify the necessary parameters to achieve steam sterilization. Typical minimum cycle times for gravity-displacement steam sterilization and typical minimum cycle times for dynamic air-removal steam sterilization are provided in Table 3-4. Certain instruments and implants require extended time cycles, however. The manufacturer's written instructions for extended time cycles must be followed.

The recording thermometer, not the pressure gauge, is the important guide to the sterilizing phase. The recording clock on the sterilizer gives information about the run of the load and to what temperature the goods were exposed and the exposure time. The temperature inside the chamber must be maintained throughout the determined time of exposure. The sterilization printout documents the come-up time, exposure time, and exhaust time (AAMI, 2009a).

Drying, Cooling, and Storing. On completion of the sterilization cycle, the steam inside the chamber is removed immediately so that it does not condense and produce wet packs. To assist in the drying process, the jacket pressure should be maintained to keep the walls of the chamber hot as the steam from the chamber is exhausted. When the chamber pressure has been exhausted, the door may be opened slightly to permit vapor to escape. Another method is to introduce clean, filtered air by means of a vacuum dryer (ejector) device in conjunction with the operating valve on the sterilizer. The minimum drying time for all methods is approximately 15 to 20 minutes.

After removal from the sterilizer, freshly sterilized packs should be left untouched on the loading carriage until they have cooled to room temperature. This is usually accomplished in 30 to 60 minutes, depending on the load contents. If freshly sterilized packages are placed on cool surfaces such as metal tabletops, vapor still inside the essentially dry package may condense to water. This water may dampen the package from the inside to the outside. When the outside is wet, bacteria may follow the moist tract into the contents of the package. Because bacteria are capable of passing through layers of wet material, any packages that are wet must be considered unsterile.

A written record of existing conditions during each sterilization cycle should be maintained. It should include the sterilizer number, the cycle or load number, the time and temperature of the cycle, the date of sterilization, the contents of the load, and the initials of the operator. These records should be retained for the length of time designated by the statute of limitations in each state.

Sterile packages must be handled carefully and only as necessary. They should be stored in clean, dry, limited-access areas that are well ventilated and have controlled temperature and humidity. Closed cabinets are preferred to open shelves for sterile storage. If open shelves must be used, the lowest shelf should be 8 to 10 inches from the floor to avoid floor contamination.

TABLE 3-4

Common Time-Temperature Parameters for Steam Sterilization

Type of Sterilizer	Load Configuration	Temperature, in °C (°F)	Time, in Minutes
Gravity displacement	Porous or nonporous	121-123 (250-254)	15-30
		132-135 (270-275)	10-25
Prevacuum	Porous or nonporous	132-135 (270-275)	3-4 or manufacturer's instructions
Steam flush/pressure pulse	Porous or nonporous	121-123 (250-254)	20
		132-135 (270-275)	3-4

The highest shelf should be at least 18 inches from the ceiling to allow for circulation around the stored items. All shelves should be at least 2 inches from outside walls to facilitate air circulation and avoid any condensation that might accumulate on the walls during periods of severe temperature change. Shelving should be smooth and well spaced, with no projections or sharp corners that might damage the wrappers. Sterilized packs should never be stacked in close contact with each other. Their arrangement on the shelves should provide for air circulation on all sides of each package. Excessive handling, crowding, dropping, and stacking of sterile packs tend to force particles through the mesh or matrix of the wrapping material, which might contaminate the contents. Sterile items should not be stored near or under sinks or in any area where they can become wet.

Shelf life refers to the length of time a pack may be considered sterile. Loss of package sterility is event-related as opposed to time-related; that is, what happens to the package after sterilization determines its continued sterility—not the length of time the package remains on the shelf ready for use. Variables that must be considered in determining shelf life are the type and number of layers of packaging material used, the presence or absence of impervious protective covers, the number of times a package is handled before use, and the conditions of storage. Impervious protective covers known as *dust covers* may extend shelf life by protecting the sterile package from a contaminating event. When used to protect sterilized items, impervious covers should be designated as such to prevent their being mistaken for a sterile wrap. They should be applied only to thoroughly cooled, dry packs at the time of removal from the sterilizer cart, after the required cooling period (AORN, 2009h).

Supply standards should be planned to maintain adequate stock with prompt turnover. Appropriate volume and proper rotation of supplies reduce the need for concern about shelf life. The longer an item is stored, the greater the chances of contamination. For proper rotation, the most recently dated sterile packages should be placed behind those already on the shelves.

Quality Control Practices: Physical Monitoring. Physical monitoring includes checking items such as time, temperature, and pressure recorders; digital printouts; and gauges. All mechanical parts of sterilizers, including gauges, steam lines, and drains, should be checked periodically by the engineering department within the facility. The individual responsible for the sterilizers should keep reports of these inspections. Temperature, humidity, and vacuum should be measured with control equipment, independently of the fixed gauges. There are several methods of keeping a constant check on the proper functioning of a sterilizer and ensuring the efficiency of the sterilizing process. *Mechanical, chemical,* and *biologic* controls assist in identifying and preventing sterilizer malfunction and operational errors made by personnel (Table 3-5). Automatic controls are a type of mechanical control that, by a predetermined program, controls all phases of the sterilizing process. The controls allow the steam to enter, monitor the time of the sterilizing cycle, exhaust the steam, and initiate drying. Some lock the door so that it cannot be opened until the cycle is complete.

On older sterilizers, recording thermometers (a dial on the front of the sterilizer) were the mechanical control that indicated and recorded the temperature throughout the sterilizing cycle. Sterilizers today provide a digital readout as opposed to a graphic depicter of the sterilizing cycle. The digital readout records a decrease in temperature when and if it occurs; this can warn of sterilizer failure. The digital readout records the time the sterilizer reaches the desired temperature and the duration of each exposure. It can be determined if a decrease in temperature occurred, warning of sterilizer failure. These recordings are proof that the exposure time of loads has been correct and proper temperature limits have been maintained. The daily record should show the number of the sterilizer, the number of cycles run, the time, and the date. Mechanical monitoring devices provide real-time assessment of sterilizer-cycle conditions and permanent records by means of either chart recordings or computer printouts. This evidence can be used for detection of malfunctions as soon as possible so that alternative procedures can be implemented while the cause of the malfunction is identified and corrective action is taken. Recordings cannot detect air pockets within the load or pack, however. Air is a poor conductor of heat; it is one of the most common causes, other than human error, of sterilization failure (AAMI, 2009a).

Chemical controls, also commonly known as *chemical indicators* or *integrators,* include devices such as pellet-containing, sealed glass tubes; sterilizer indicator tapes; color-change cards or strips, which may or may not provide a line of demarcation to indicate use or nonuse of the sterilizer load; and indicators containing color-changing enzymes, which mimic or provide a representation of bacterial kill. Some enzyme indicators contain a biologic component; others do not. Chemical indicators are used to detect failures in packaging, loading, or sterilizer function, such as presence of cool air pockets inside the sterilizing chamber. Chemical indicator cards or strips that are impregnated with a material that changes color or moves up a gauge when steam initiates a chemical reaction are placed in instrument trays or other packages. No chemical monitor verifies that an item is actually sterile. Integrators are so named for their ability to integrate time, temperature, and the presence of steam. They reduce the risk of using an unsterile pack and may be used with numerous types of sterilization processes. Because they vary in color changes for each type of sterilizer

TABLE 3-5

Mechanical, Chemical, and Biologic Sterilization Monitors

Type	Classification	Application
Temperature and pressure recording devices Time recording devices Digital recording devices	Physical monitors	Steam EO Low-temperature: • H_2O_2 plasma • Ozone • Peracetic acid
External strips/tape	Chemical monitors	Used on outside of packages
Bowie-Dick type indicators		Used for dynamic air removal in steam sterilizers
Internal chemical indicator strips (CIs)		Used for: • Steam • EO • Low-temperature H_2O_2 • Ozone
Geobacillus stearothermophilus	Biologic monitors (indicator)	Used for routine load release, efficacy monitoring, qualification testing, product quality assurance, etc. Used for: • Steam • Low-temperature H_2O_2 gas plasma sterilizers • Ozone sterilizers • Liquid peracetic acid sterilizers Should be done weekly, preferably daily, and according to sterilizer manufacturer's written instructions Each load that contains implantable devices should be monitored with a BI; load should be quarantined until BI test results are obtained
Bacillus atrophaeus (formerly *Bacillus subtilis*)	Biologic monitor	Ethylene oxide monitoring devices that should be performed on every load to be sterilized

Modified from Association for the Advancement of Medical Instrumentation (AAMI): *Sterilization in healthcare facilities,* Arlington, VA, 2009, The Association, available at www.aami.org. Accessed July 24, 2009; Association of periOperative Registered Nurses (AORN): Recommended practices for sterilization in the perioperative practice setting. In *Perioperative standards and recommended practices,* Denver, 2009, The Association.
EO, Ethylene oxide.

and because they may have different wording on the integrator to denote that an instrument set or other item is acceptable for use, perioperative nurses and scrub persons should always refer to the manufacturer's written instructions when relying on indicators and integrators (AORN, 2009h).

An external chemical indicator should be used on all packages to be sterilized except those that allow direct visualization into the package, where an internal indicator is used (e.g., paper or plastic pouches). The primary purpose of the external indicator is to differentiate between processed and nonprocessed packages. This indicator should be checked after the sterilization process and before a package is opened to determine that the package has been exposed to a sterilization process.

Each package requiring sterilization should have an internal chemical indicator or integrator placed within the area of the package believed to be least accessible to steam penetration. The indicator or integrator should be located and interpreted by the user at the time the package is opened and before use of the contents (AORN, 2009h).

A biological indicator (BI) is the most accurate method of checking sterilization effectiveness. Commercially prepared biologic indicators should be stored and used according to the manufacturer's written instructions. They contain a known population of *Geobacillus stearothermophilus,* a highly heat-resistant, spore-forming microorganism that does not produce toxins and is nonpathogenic. Rapid-action indicators are available commercially for certain types of sterilizers. These indicators provide a preliminary enzymatic reaction that is highly correlated to biologic kill. Reaction times range from 20 seconds to 3 hours. The length of time necessary for an initial reading depends on the type of sterilizer, type of indicator used, and the cycle used. For a true indication of biologic kill, only indicators having a biologic component should be used, and the indicator should be incubated after the initial reading according to the manufacturer's instructions to ensure accurate results (AAMI, 2009a).

Biologic testing should be done after initial installation of steam sterilizers, after any major repair of the sterilizer, and with all loads of implantable devices. Whenever possible, implantable devices should be quarantined until the results of the biologic testing are available.

Biologic testing for steam sterilizer loads should be conducted weekly and preferably daily on the first run of the day. The BI should be placed in a test pack that is positioned on-edge in the front, bottom section of a routinely loaded steam sterilizer. This area of the sterilizer provides the greatest challenge for the test pack. AAMI (2009a) has defined the contents of the test pack. Commercially prepared test packs are also available.

After the sterilization cycle, the BI is removed from the pack and incubated according to the manufacturer's instructions. Negative reports (failure to recover any spores from the indicators in the test pack) indicate that the sterilizer is functioning properly. Results of these tests should be filed as a permanent record. A positive report does not indicate sterilizer failure

FIGURE 3-8 General-purpose gravity air displacement steam sterilizer. This type of sterilizer can be used to sterilize wrapped or unwrapped instruments and utensils, linen packs, and solutions in specially designed vented flasks. These units are available in several sizes, from the small unit similar in size to the washer-sterilizer described in Figure 3-5 to large, floor-loading units. A medium-size unit is pictured here. Some units have sophisticated microprocessor controls that allow maximum flexibility in selecting sterilization and drying times and help in troubleshooting if a problem occurs during a cycle. Digital readouts and heat-sensitive paper printouts have replaced the round chart and pen found on older models. These changes have helped the operator more easily determine and document that the conditions needed for proper sterilization were met.

because false-positive results sometimes occur. The sterilizer should be retested immediately, however, and taken out of service until it is operationally inspected and the results of retesting are negative. If a sterilizer malfunction is found, all items prepared in the suspect load should be considered unsterile. They should be retrieved if possible and washed, repackaged, and resterilized in another sterilizer. All items in any load processed since the last negative result also should be considered suspect and should similarly be retrieved if possible (AAMI, 2009a)

When a prevacuum sterilizer is used, a test designed to detect residual air in the chamber should be run daily. The test, generally known as a *Bowie-Dick* test, is run with an otherwise empty chamber so that residual air is not forced into other packs or materials, degrading the test results. The Bowie-Dick test determines the efficacy of the vacuum system of the sterilizer. The Bowie-Dick test is *not* a sterility-assurance test.

Types of Steam Sterilizers. For sterilization to occur, steam must contact all surfaces of the item to be sterilized. To accomplish this, the air in the sterilizer chamber must be evacuated. The terms *gravity displacement* and *dynamic air removal* describe the methods by which air leaves the sterilizer chamber. Dynamic air removal sterilizers use preconditioning techniques to remove air from the sterilizing chamber. This may be through a vacuum pump (prevacuum) or by an above atmospheric pressure process, such as the steam-flush pressure-pulse process.

At the beginning of the cycle in a gravity displacement sterilizer, steam begins to enter the chamber after the door is closed and locked (Figures 3-8 and 3-9). An initial burst of steam enters the chamber and forces out much of the free air in the chamber. Air is heavier than steam, and the two do not mix well. As more steam enters the chamber, the air that is held by gravity at the bottom of the chamber exits down the drain, which is at the bottom of the sterilizer—hence the name *gravity displacement sterilizer.*

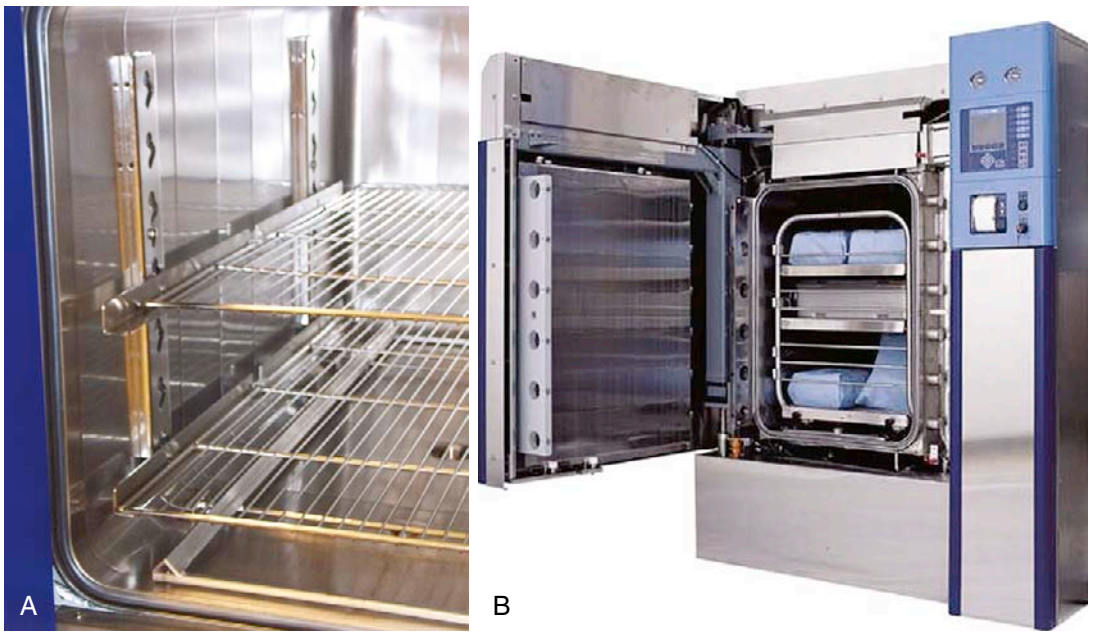


FIGURE 3-9 **A**, Adjustable racks are designed to permit maximum loading efficiency. **B**, Instrument baskets or trays should have either wire-meshed bottoms or a sufficient number of perforations in the sheet metal to allow for air removal and drainage of condensate during the sterilization cycle.

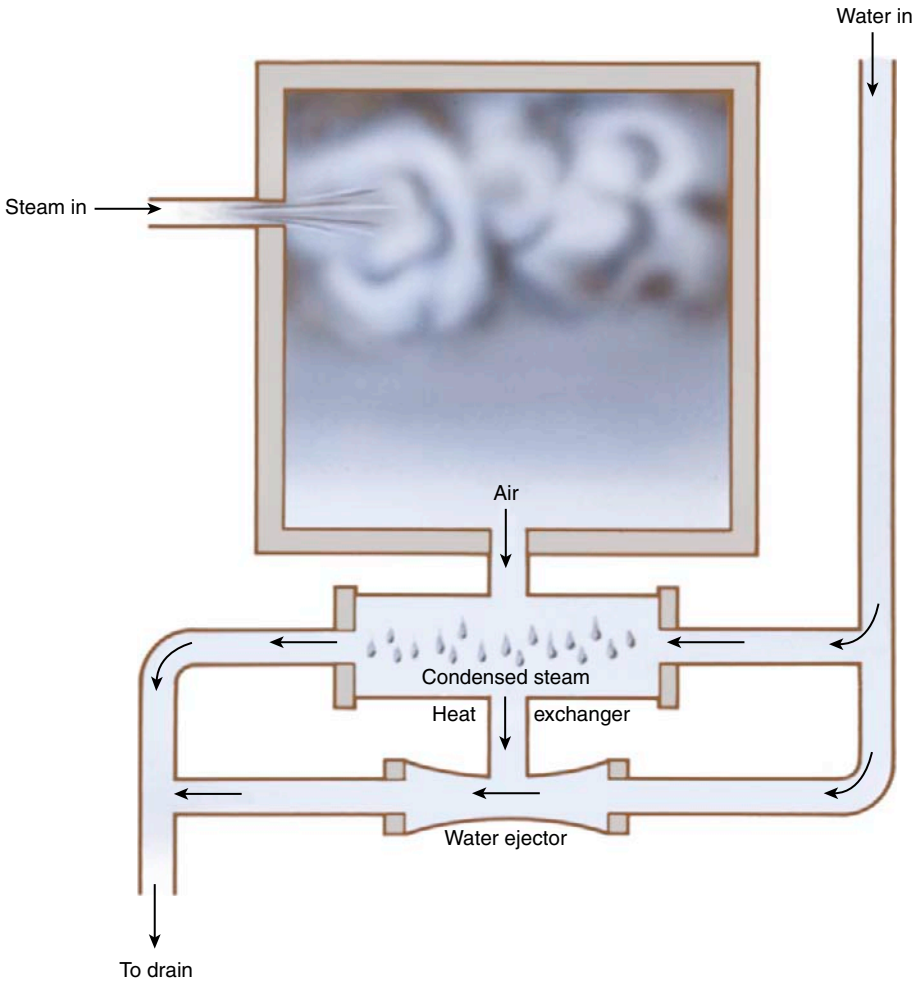


FIGURE 3-10 Prevacuum steam sterilizer. This type of sterilizer features active, aggressive removal of air rather than relying on the passive action of gravity. When the cycle is initiated, steam is injected with force into the chamber. At the same time, the drain at the bottom of the chamber is automatically closed. As more steam enters the chamber, pressure increases and the steam and air form a turbulent mixture. When a specific pressure is reached, the drain opens, and the pressurized steam and air rush from the chamber, aided by a water ejector or a vacuum pump. This sudden rush of gas from the chamber creates a vacuum within the chamber. This process is repeated several times and deepens the level of vacuum drawn with each pulse. The effect of this pulsing cycle is to displace any air in the load and rapidly increase the chamber and load temperatures. At the conclusion of this conditioning phase, steam flows into the chamber and raises the temperature to sterilization levels, usually 132° C (270° F). The temperature is maintained for at least 3 minutes for unwrapped, nonporous materials and 4 minutes for wrapped or porous items. Steam is removed from the chamber to draw a partial vacuum again. Heated, filtered air is introduced into the chamber to dry the load. Drying times are selected and set by the user, depending on the nature of the load. Some units have a special cycle designed for rapid sterilization of an instrument tray in a single wrapper. This express cycle has fewer conditioning pulses, a 4-minute exposure time, and 1 or 2 minutes of dry time, for a total cycle time of approximately 12 minutes. Although the wrapper feels warm and dry to the touch, the contents may not be totally dry. This package should be handled by individuals wearing sterile gloves and using sterile towels for protection from burns. The instruments sterilized in this express cycle must be used immediately. Because the contents are not dry, the package is not suitable for storage

In a prevacuum cycle, rather than passive air removal as is the case with the gravity sterilizer, air is actively removed from the sterilizer (Figure 3-10). When the cycle is initiated, steam is injected with force into the chamber. At the same time, the drain at the bottom of the chamber is automatically closed. As more steam enters the chamber, pressure increases, and the steam and air form a turbulent mixture. When a specific pressure is reached, the drain opens, and the pressurized steam and air rush from the chamber, aided by a water ejector or a vacuum pump. This sudden exit of gas from the chamber creates a vacuum within the chamber. This is the basis for the name *prevacuum sterilizer.* The sterilizer repeats this injection and vacuum process four times in succession in an effort to evacuate all air from the chamber (AAMI, 2009c; CDC, 2008a).

Some prevacuum sterilizers have the capability of providing an *abbreviated prevacuum cycle.* In this cycle, there are two rather than four pulses of the steam injection-vacuum process. This cycle may be used only for simple metal or glass instruments. No instruments with a lumen should be sterilized using this cycle (AAMI, 2009c; CDC, 2008a).

The *high-speed steam sterilizer,* commonly referred to as a *flash sterilizer,* can be adjusted to operate at 132° C (270° F) and 27 psi of pressure for shortened cycles with no accompanying drying cycle. Flash sterilization can be accomplished in either a gravity displacement or a dynamic air-removal sterilizer. Flash sterilization is most frequently used in the OR for sterilizing urgently needed unwrapped instruments. AORN's *Recommended Practices for Sterilization in the Perioperative Practice Setting* recommend that the use of flash sterilization should be kept to a minimum. Flash sterilization should be used only in selected clinical situations and in a controlled manner. This method of sterilization is intended for use with unwrapped items or sterilizing trays or container systems developed specifically for the flash cycle. Flash-sterilized items are to be used immediately after sterilization; they may not be stored for future use. Flash sterilization should not be used for implantable devices except in cases of emergency when no other option is available (AORN, 2009g). In an emergency, when flash sterilization of an implant is unavoidable, a rapid-action BI with a chemical integrating indicator should run with the load (AORN, 2009g). The BI should continue to be incubated for the full time. Documentation should reflect patient follow-up if the final biologic test indicates a failure. Appropriate perioperative planning along with communicating and working with implant manufacturers may help decrease unplanned flash sterilization of implantable devices (AORN, 2009g). Although flash sterilizing is considered a rapid method of sterilization for unwrapped items, some pulsing gravity and the abbreviated prevacuum cycles have been designed with a brief drying cycle intended to dry the single wrapper. Flash sterilization containers should be used, cleaned, and maintained according to the manufacturer's written instructions. Flash sterilization containers should be opened, used immediately, and not stored for later use. Flash sterilization containers should be differentiated from other types of containers (AORN, 2009g). Routine cycle parameters for flash sterilization are shown in Table 3-6. Meticulous recordkeeping must be implemented for flash sterilization. At minimum, facilities should document the patient's name, surgery or procedure performed, item(s) and number flashed, and exposure time and temperature (Stanton, 2008). Additional information to document includes the operator information and reason for flash sterilization. Analysis of the frequency of flash sterilization, the number of objects flashed, and the reason for using flash sterilization can be used as an impetus for process improvements.

CHEMICAL STERILIZATION. Materials that cannot be heat-sterilized are continually being introduced for use in healthcare. These materials require the use of other methods of sterilization. Chemical agents provide an effective alternative to steam sterilization. Chemical sterilization is frequently referred to as *low-temperature sterilization.* This term refers to maximum temperatures of 54° to 60° C (130° to 140° F) for gaseous sterilization compared with temperatures of 121° to 132° C (250° to 270° F) for steam sterilization.

Sterilization can be achieved by many agents when only vegetative cells are present. If the microbial population is unknown, however, a sporicidal agent must be employed to ensure sterilization. An antimicrobial agent must exhibit a wide microbiologic spectrum and sporicidal activity to qualify as a chemosterilant.

Ethylene Oxide. *Ethylene oxide (EO)* is an alkylating agent that results in microbial death under controlled parameters. EO has had application for heat-labile and moisture-sensitive items, such as intricate, delicate surgical instruments; large pieces of equipment; and electrical instruments. EO should be used if alternate methods of sterilization are not available or compatible with the medical devices being processed. EO is colorless at ordinary temperatures, has an odor similar to that of ether, and has inhalation toxicity similar to that of ammonia gas. EO is a known carcinogen and must be used carefully because of its toxicity. It is highly explosive and very flammable in the presence of air. These hazards are greatly reduced by dilution of EO with inert gases such as carbon dioxide and hydrochlorofluorocarbons (HCFCs). Neither of these two inert gases seems to affect the bactericidal activity of EO, serving only as inert diluents that reduce the flammability hazard.

There are several theories on how EO kills bacteria. The killing rate of bacteria is generally believed to be relative to the

TABLE 3-6

Time-Temperature Parameters for Flash Steam Sterilization

Type of Sterilizer	Load Configuration	Temperature, in °C (°F)	Time, in Minutes
High-speed gravity displacement	Metal or nonporous items only (no lumens)	132-135 (270-272)	3 (follow manufacturer's instructions for express cycle)
	Metal items with lumens and porous items (e.g., rubber, plastic), which are sterilized together	132-135 (270-272)	10
Prevacuum (dynamic air removal)	Metal or nonporous items only (no lumens)	132-135 (270-272)	3
	Metal items with lumens and porous items, which are sterilized together	132-135 (270-272)	4 or manufacturer's instructions
Pulsing gravity	All loads	Manufacturer's instructions	Manufacturer's instructions should be followed for time and temperature
Abbreviated prevacuum	All loads	Manufacturer's instructions	Manufacturer's instructions should be followed for time and temperature

rate of diffusion of the gas through the bacterial cell walls and the availability or accessibility of one of the chemical groups in the bacterial cell walls to react with EO. The killing rate also depends on whether the bacterial cell is in a vegetative or spore state. Destruction takes place by alkylation through chemical interference and probably inactivation of the reproductive process of the cell. In the process of alkylation, a hydrogen atom within the microbial cell is replaced with a portion of the EO molecule (e.g., an alkyl group). This process alters the structure of the microbial molecule and renders it nonfunctional. When sufficient molecules within the microbial cell are subjected to this process, the microbial cell is rendered unable to metabolize or produce infection.

Items to be sterilized with EO must be thoroughly cleaned and dried so that no visible droplets remain. Drying inhibits the formation of ethylene glycol during the sterilization cycle. Lumens should be dry and open at both ends. Caps, plugs, valves, and stylets should be removed from instruments or equipment to permit the gas to circulate through the items. The packaging material used should possess the characteristics described previously in this chapter.

Items to be sterilized should be placed in a loose configuration within the confines of metal baskets or sterilizer carts. Packages should not touch the chamber walls when loaded into the sterilizer. An excessively large load or a load that is tightly packed interferes with proper air removal, load humidification, sterilant penetration, and sterilant evacuation at the conclusion of the cycle. Penetration of gas throughout the load is essential. Compression of packages prevents penetration of the gas. If packages are wrapped in plastic, compression hinders evacuation of air and causes packages to open during the decrease in chamber pressure when a vacuum is drawn. Proper loading is essential so that sterilized items do not fall from the container or cart after sterilization, requiring personnel to handle them before aeration. Because metal baskets or carts do not absorb ethylene oxide, they can be handled before aeration. An EO-sensitive chemical indicator should be used with each package to indicate that the package was exposed to the gas. The chemical indicator does not indicate achievement of sterility (AORN, 2009g).

Factors affecting sterilization with EO are time of exposure, gas concentration, temperature, humidity, and penetration. The exposure time required depends on temperature, humidity, gas concentration, the ease of penetrating articles to be sterilized, and the type of microorganisms to be destroyed (Table 3-7). Gas concentration is affected by the temperature and humidity inside the sterilizing chamber. If the concentration of gas is doubled, the exposure time may be shortened. Temperature and humidity have a pronounced influence on the destruction of microorganisms. They are important in gaseous sterilization with EO because they affect penetration of the gas through bacterial cell walls and through wrapping and packaging material.

TABLE 3-7

Common Parameters for Ethylene Oxide Sterilization

Time, in Minutes	Temperature, in °C (°F)	Humidity, in %	Gas Concentration, in mg/L
105-300	37-63 (99-145)	45-75	450-1200

Dry spores are the most difficult to kill, but when such spores are moistened their resistance to gas penetration is lowered. Dehydration makes some microorganisms nearly immune to EO sterilization, whereas droplets of moisture can inhibit the action of the gas by protecting the organism. EO sterilizers with automatic controls provide for moisture injection to increase the relative humidity within the chamber. Manufacturers of gas sterilizers have developed recommended exposure periods for various EO concentrations in relation to the material to be sterilized. Exposure time is set for absolute destruction of the most resistant microorganisms, which is a very slow process.

The adequacy of every EO cycle should be verified by the use of biologic monitors that contain *Bacillus atrophaeus* (*formerly Bacillius subtilis*). AAMI (2009a) has defined two standard test packs for use in monitoring the EO sterilization cycle. The sterilizer manufacturer's written recommendations regarding cycle parameters should be followed.

EO-sterilized items must be aerated to make them safe for personnel handling and patient use. At the conclusion of the sterilization cycle, items may be removed safely from the chamber to a separate aerator. Certain models of sterilizers may have an internal aeration cycle. The sterilizer manufacturer's recommendations relating to opening the sterilizer door after completion of the sterilization cycle and subsequent transferring of items to the aerator must be followed closely. Excessive exposure to EO represents a health hazard to personnel. It is a known carcinogen and has been linked to reproductive problems and other disorders in animals. Inhalation of EO should be avoided or minimized, and direct contact with items sterilized by EO should be avoided during transfer to the aerator. Various safety features, such as a purge system, an audible alarm at the end of the sterilization cycle, and automatic door-locking and door-sealing mechanisms, are used on EO sterilizers to protect personnel. Opening the sterilizer door within the capture zone of the scavenging hood for a period of 5 to 10 minutes can reduce operator exposure to the sterilizing gas. If the sterilizer contents are not removed at that time, they begin to "outgas," resulting in increased EO concentration within the chamber.

Aeration is accomplished in a mechanical aerator. The length of aeration for each item should be based on the manufacturer's written recommendations. Typical aeration times when a mechanical aerator is used are 8 to 12 hours at 50° to 55° C (122° to 131° F) or 12 to 16 hours at 38° C (100.4° F). When moving items from the sterilizer to the aerator, they should be handled minimally. Personnel should not breathe the air that passes over baskets or carts containing EO-sterilized items. To avoid breathing this air, carts should always be pulled as opposed to pushed. Depending on the sterilization-cycle temperature used, items may be warm to the touch at the end of the cycle. Butyl rubber gloves are recommended to protect personnel from contact with liquid EO and from thermal injury (AORN, 2009g).

Because of the highly explosive and flammable nature of EO, the sterilizer and aerator should be installed in a well-ventilated room and should be vented to the outside atmosphere as recommended by the manufacturer and by the requirements of the National Institute for Occupational Safety and Health (NIOSH). Only authorized personnel are allowed access, and hazard signs should be posted. Compliance with other administrative controls to ensure safety is essential.

EO is carcinogenic and carries potential as a reproductive hazard; therefore OSHA has issued standards regulating personnel

exposure to EO. These standards set the permissible exposure level (PEL) (the amount of EO in the air) at 1 part per million (ppm) and the action level (AL) (monitored value at which corrective action should occur) at 0.5 ppm. These are calculated as time-weighted averages (TWAs) over an 8-hour period. OSHA requires that monitoring and surveillance be performed to ensure that exposure levels do not exceed 1 ppm over an 8-hour period (OSHA, 1984). In addition, occupational exposure level to EO may not exceed 15 ppm in any 15-minute period. This is known as the *excursion level* (EL). EO-monitoring badges are available and required. Adherence to these guidelines helps protect patients and personnel from problems associated with EO sterilization (AAMI, 2009c; OSHA, 1984, 1988).

In general, EO sterilization should be used *only* if the materials are heat-sensitive and unable to withstand sterilization by saturated steam under pressure. EO's advantages are that it is easily available; it is effective against all types of microorganisms; it easily penetrates through masses of dry material; it does not require high temperatures, humidity, or pressure; and it is noncorrosive and nondamaging to items. Sterilization with EO also has numerous disadvantages. The long exposure and aeration periods make it a lengthy process. Compared with other methods of sterilization, EO sterilization is expensive. Liquid EO may produce serious burns on exposed skin if not immediately removed; insufficiently aerated materials can cause skin irritation, burns of body tissue, and hemolysis of blood; and diluents used with EO cause damage to some plastics. Human error and mechanical breakdown can enhance these disadvantages (AAMI, 2009c; OSHA, 1984).

Aqueous Glutaraldehyde. When used properly, liquid chemosterilants can destroy all forms of microbial life, including bacterial and fungal spores, tubercle bacilli, and viruses. Although formaldehyde is one of the oldest chemosterilants known to destroy spores, it is rarely used in the United States because it takes 8 to 24 hours to be effective, its pungent odor is objectionable, and it may cause irritant or allergic reactions. Glutaraldehyde works more rapidly and is less irritating than formaldehyde solutions.

Activated aqueous glutaraldehyde 2% is recognized as an effective liquid chemosterilant. It is most useful in the disinfection of lensed instruments, such as cystoscopes and bronchoscopes, because it has minimal deleterious effects on the lens cement and is noncorrosive. Its low surface tension permits easy penetration and rinsing.

Instruments must be free from bioburden and completely immersed in activated aqueous glutaraldehyde solution for 10 hours to achieve sterilization. Any period of immersion less than 10 hours does not kill spores that may be present and must be considered as only a disinfection procedure. During immersion, all surfaces of the instrument must be in contact with the liquid chemosterilant. After immersion, instruments must be rinsed thoroughly with sterile distilled water before being used.

Peracetic Acid. Liquid peroxyacetic (peracetic) acid is a biocidal oxidizing agent. Peracetic acid sterilization is a system that uses a chemical formulation of 35% peracetic acid and water. Peracetic acid is an effective biocide at low temperatures and is effective in the presence of organic material. It has a chemical formula of acetic acid plus an extra oxygen atom. This extra oxygen atom is highly reactive; it reacts with most cellular components and causes cellular death. The ability of peracetic acid to inactivate many different critical cell systems is responsible for its broad-spectrum antimicrobial activity. As peracetic acid is changed to acetic acid and the oxygen decomposes, it is rendered nontoxic and environmentally safe. Because peracetic acid is highly corrosive to instruments, it must be used in combination with anticorrosive additives (AORN, 2009g). Commercially available sterilization systems using peracetic acid have found increasing use in recent years because of their relatively short cycles and subsequent ability to ready items for use quickly. These systems should be maintained and used according to the manufacturer's instructions. Although peracetic acid does not leave toxic residues on items that have been adequately rinsed, the agent may cause serious injury if not handled, neutralized, and rinsed properly. Items processed in peracetic acid systems should be used immediately after processing because the item containers are wet and are not sealed from the environment. Some controversy regarding internal-process monitors has existed with peracetic acid sterilization systems. *Bacillus atrophaeus* indicators should be used on installation of a peracetic acid sterilization unit and after any major repairs. Manufacturer recommendations should be sought and carefully followed for routine sterilizer monitoring.

Low-Temperature Hydrogen Peroxide Gas Plasma Sterilization. Low-temperature hydrogen peroxide gas plasma sterilization should be used for moisture-sensitive and heat-sensitive items and when indicated by the device manufacturer. Plasma is the fourth state of matter, the sequence being solid, liquid, gas, and plasma. Gas plasmas are highly ionized gases composed of ions, electrons, and neutral particles. In this process, microbial life is disrupted when free radicals created from hydrogen peroxide gas plasma interact with microbial cell membranes, enzymes, or nucleic acids (AORN, 2009g). To create gas plasma for sterilization, a precursor solution, such as hydrogen peroxide, is introduced into a closed area in the sterilizer under low-vacuum conditions. In this process, microbial life is disrupted when free radicals created from hydrogen peroxide gas plasma interact with microbial cell membranes, enzymes, or nucleic acids. Hydrogen peroxide vapor is charged with radiofrequency, and plasma is created that removes hydrogen peroxide residuals from the sterilized items. The byproducts of this process are oxygen and water (in the form of humidity). Packages are dry at the end of the cycle (AAMI, 2009c; AORN, 2009g).

Plasma sterilization is displacing ethylene oxide sterilization for most applications. It is designed to provide nontoxic, dry, low-temperature sterilization in a shorter turnaround time than that of ethylene oxide. The hydrogen peroxide gas plasma process rapidly destroys a broad spectrum of microorganisms, including gram-negative and gram-positive vegetative bacteria, *Mycobacterium,* yeasts, fungi, lipophilic and hydrophilic viruses, and highly resistant aerobic and anaerobic bacterial spores. Cycle times for gas plasma sterilization vary depending on the model of sterilizer being used. At the completion of the sterilization process, no toxic residues remain on the sterilized items. No aeration is necessary, making it a safe process for patients and healthcare workers. Preparation of instrumentation for sterilization includes cleaning and decontaminating procedures, drying, reassembly, and wrapping with nonwoven polypropylene wraps or Tyvek/Mylar pouches (Figure 3-11). Cellulosic-based products, such as paper and linen, are not recommended for use with plasma systems because they tend to absorb the vapor and cause the sterilization cycle to abort.

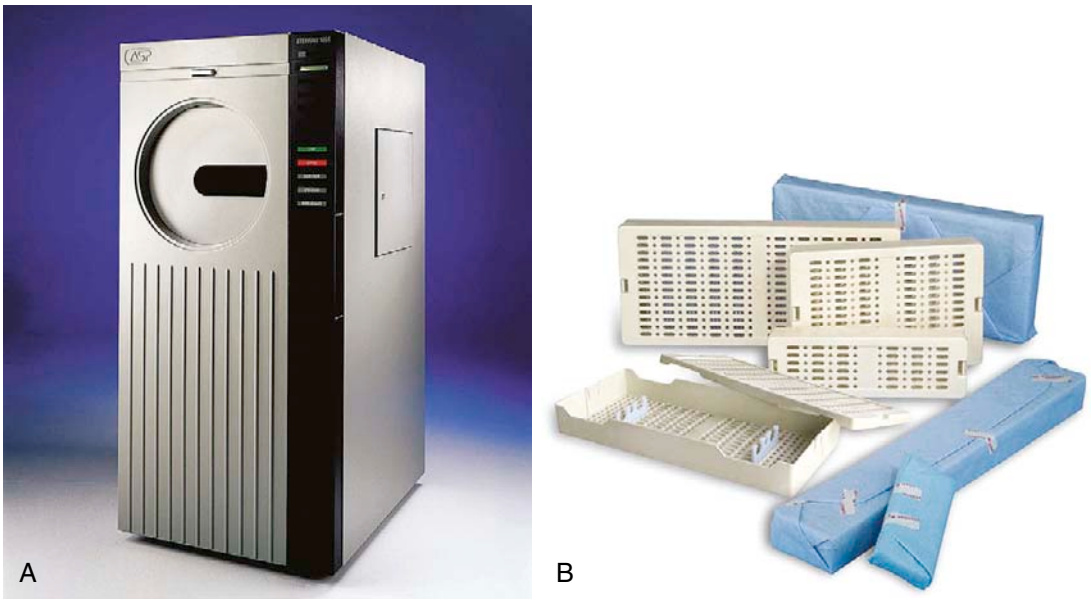


FIGURE 3-11 **A**, Gas plasma sterilizer. **B**, Supplies for use in low-temperature, gas plasma sterilization systems.

Manufacturer's written instructions for use should always be followed (AAMI, 2009c; AORN, 2009g).

Biologic and chemical indicators for process verification are used in the same manner as indicators for steam and ethylene oxide sterilization procedures. Plasma sterilization processes should be tested with biologic indicators at intervals similar to the intervals used for steam and ethylene oxide sterilization. Manufacturer recommendations should be followed in determining the specific monitor to be used. For hydrogen peroxide plasma sterilization systems, *Geobacillus stearothermophilus* spores show the greatest resistance to kill. The importance of consulting the system manufacturer for specific instructions cannot be overemphasized (AAMI, 2009c; AORN, 2009g).

DRY HEAT STERILIZATION. Dry heat sterilization should be used only when the materials cannot be sterilized by other methods, when the moisture of other processes would damage the materials, or when the materials would be impermeable to the process. These materials include grease, anhydrous oils, powders, and some glassware. Dry heat is not a suitable sterilization method for fabrics and rubber goods because the high temperatures necessary for sterilization cause deterioration of these materials. There are two kinds of dry heat (also known as *hot air*) sterilizers—the gravity convection type and the mechanical convection type. Both heat by electricity to achieve accurate and dependable temperature control.

In the *gravity convection sterilizer,* convection is created by the temperature differences within the sterilizing chamber. The heating apparatus present in the bottom of the chamber warms the air within the chamber. The warmed air rises, contacting the items in the chamber to be sterilized. At contact, heat is transferred from the air to the items. With this loss of heat, the cooled air descends toward the bottom of the chamber where it is warmed again by the heating coils.

In the *mechanical convection sterilizer,* the heating apparatus is outside the chamber, in a compartment separated from the chamber by a diffusing wall placed in front of a motor-driven turbine blower. Through an internal process, air is heated and forced into a chamber on the opposite wall. From this chamber, the air is discharged into the chamber uniformly over the vertical plane of the chamber. This system provides for uniform delivery of heated air and equal transfer of heat to all regions of the chamber. This system offers the maximum functional efficiency at a minimum cost and is the system most often used in hospitals (AAMI, 2009c).

Because of the variation in items to be sterilized and packaging methods and materials, parameters for dry heat sterilization vary. Temperature parameters refer to the temperature of the load, not sterilizer chamber temperature.

Spore tests may be used with dry heat sterilization. *Bacillus atrophaeus* is the most commonly used challenge microorganism. The sterilizer manufacturer's instructions should be carefully followed for sterilizer monitoring (AAMI, 2009a).

Disinfection. High-level disinfectants play a key role in the processing of semicritical medical devices. They must be practical, fast, safe, and easy to use. Appropriate cleaning, disinfecting, and sterilizing of reusable devices are crucial to ensure their safe use and to maintain equipment integrity. Advances in instrument processing, specifically in the area of high-level disinfectants, continue to support better patient care in the clinical setting.

Disinfection is defined as the process of eliminating many or all pathogenic organisms, except bacterial spores, from inanimate objects. In healthcare facilities, equipment is usually soaked in liquid chemicals for a specified period to achieve disinfection of the equipment or item. The disinfection process may destroy tubercle bacilli and inactivate hepatitis viruses and enteroviruses but usually does not kill resistant bacterial spores. The term *disinfection* also may refer to treatment of body surfaces that have been contaminated with infectious material. Chemicals used to disinfect inanimate objects are referred to as *disinfectants*. Chemicals used for body surfaces are known as *antiseptics*. The term *germicide* refers to any solution that destroys microorganisms. Some germicides are disinfectants and antiseptics.

Disinfectants are categorized as high-level, intermediate-level, or low-level, depending on their disinfecting capability. High-level disinfectants kill all microorganisms except high numbers of bacterial spores. Intermediate-level disinfectants may kill tubercle bacilli, vegetative bacteria, and most viruses and fungi but not bacterial spores. Low-level disinfectants kill most vegetative bacteria and some viruses and fungi.

As with sterilization, an item must be cleaned properly before it can be disinfected. Thorough cleaning removes all foreign substances, such as soil or organic material, from a device. This is usually accomplished by the use of soap and water or an enzymatic detergent. The term *decontamination* refers to the removal of pathogenic organisms from an object, making the object safe to handle.

Items to be sterilized or disinfected have been classified as critical, semicritical, and noncritical, based on the risk of infection for the patient. This classification system, known as the *Spaulding classification system* and named for its developer, Earle Spaulding (Banerjee et al, 2008), has withstood the passage of time and continues to be used today to determine the correct processing method for preparing instruments and other items for patient use. According to the Spaulding system, the level of disinfection required is based on the nature of the item and the manner in which it is to be used.

Critical items are items that enter sterile tissue or the vascular system. These items should be subjected to a sterilization process and be sterile at the time of use. Many critical items are purchased from the manufacturer as sterile. Unsterile critical items should be steam-sterilized if they are heat-stable and moisture-stable. If the items cannot withstand heat or moisture, they may be sterilized by one of the other methods discussed earlier. Examples of critical items include surgical instruments, needles, implants, and certain types of catheters (Banerjee et al, 2008).

Semicritical items are items that contact nonintact skin and mucous membranes but do not ordinarily penetrate the blood barrier. Examples of semicritical items include anesthesia breathing circuits, fiberoptic endoscopes, and laryngoscopes. Semicritical instruments require high-level disinfection; that is, these items must be free of microorganisms other than bacterial spores. Examples of high-level disinfecting agents include glutaraldehyde, *ortho*-phthalaldehyde, stabilized hydrogen peroxide, peracetic acid, and chlorine or chlorine compounds (Banerjee et al, 2008).

Noncritical items are items that come into contact only with intact skin. Because skin is an effective barrier to most microorganisms, most noncritical, reusable items can be cleaned at the point of use. Intermediate-level or low-level disinfectants may be used to process noncritical items. Examples of noncritical items include blood pressure cuffs, bedpans, linens, utensils, furniture, and floors. Although it is unlikely that infection will be transmitted to patients with intact skin by means of noncritical items, noncritical items can contaminate the hands of healthcare workers or medical equipment that will be used on other patients, which may pose a greater risk for infection. Examples of low-level disinfectants include alcohols, sodium hypochlorite, phenolic solutions, iodophor solutions, and quaternary ammonium solutions (Banerjee et al, 2008).

TYPES OF DISINFECTANTS. Many disinfectants are used alone or in combinations, such as hydrogen peroxide and peracetic acid, in healthcare settings. These include alcohols, chlorine and chlorine compounds, formaldehyde, glutaraldehyde, ortho-phthalaldehyde, hydrogen peroxide, iodophors, peracetic acid, phenolics, and quarternary ammonium compounds. In healthcare the commercial products are considered unique and must be registered with the EPA or cleared by the FDA. In most cases, a given product is designed for a specific purpose and should be used accordingly. Disinfectants are not interchangeable, and incorrect use can cause occupational diseases among personnel who are associated with their use. Written instructions for use should be followed and precautions should be taken to minimize exposure to these products. The following are various types of disinfectants that are used in today's healthcare facilities (CDC, 2008a).

Alcohols. For disinfection in healthcare, the term *alcohol* refers to either 70% or 90% isopropyl alcohol. Both of these compounds are water-soluble and have a high degree of germicidal activity. They are bactericidal as opposed to bacteriostatic against vegetative forms of bacteria. They also are tuberculocidal, fungicidal, and virucidal. Isopropyl alcohol (*n*-propanol) and ethyl alcohol (*n*-ethanol) at concentrations of 60% to 80% are potent virucidal agents that can inactivate lipophilic viruses such as herpes and the influenza virus along with many hydrophilic viruses such as rhinovirus and rotaviruses. Studies have demonstrated the ability of ethyl and isopropyl alcohol to inactivate the hepatitis B virus (HBV) and to inactivate the human immunodeficiency virus (CDC, 2008a). The alcohols do not destroy spores or kill certain hydrophilic viruses. Alcohols are flammable and must be stored in a well-ventilated area. Because they evaporate rapidly, extended contact time is difficult to achieve unless items are immersed. Alcohols lack residual effect and are easily inactivated by protein material. Alcohols tend to damage the coating on lensed instruments and may cause hardening of certain rubber and plastic tubing after repeated exposure to the compound. Alcohols are considered intermediate-level disinfectants. They are often used to disinfect thermometers and rubber stoppers on medication vials. Alcohol also is used in processing flexible endoscopes. After high-level disinfection and a tap water rinse, alcohol is effective in inactivating water contaminants. Its speed of evaporation also assists in rapid drying of the endoscope channels. Guidelines from the Association of Practitioners in Infection Control (APIC) should be followed (AORN, 2009i; CDC, 2008a).

Chlorine Compounds. In healthcare facilities, hypochlorites are the most widely used of the chlorine compounds. Hypochlorites are available in a liquid form (sodium hypochlorite [liquid household bleach]) and in a solid form (calcium hypochlorite). Hypochlorites have a broad-spectrum of antimicrobial activity. They are inexpensive and fast-acting. Low concentrations of free chlorine (50 ppm) are effective against vegetative bacteria and *Mycoplasma*. Free chlorine at 50 ppm inactivates HIV, whereas a 500-ppm concentration is needed to inactivate HBV. Concentrations of 1000 ppm are recommended for inactivation of bacterial spores. Household bleach contains 5.25% sodium hypochlorite. A dilution of 1:1000 provides 50 ppm of available chlorine. A dilution of 1:50 provides 1000 ppm of available chlorine, which is considered adequate to achieve high-level disinfection. The CDC recommends a 1:10 solution, which provides 5000 ppm of available chlorine. Hypochlorite solutions are stable for 30 days in opaque containers. Beyond that time, a new solution should be prepared. Hypochlorites are inactivated in the presence of organic matter. All organic material should be removed before application of the disinfecting solution. Hypochlorites are used sparingly on instruments because of the corrosive action of the compound.

Hypochlorites are most often used for countertops, floors, and other surfaces to be disinfected. Other chlorine compounds that may be used include chlorine dioxide and chloramine-T. Chlorine compounds are the preferred disinfectant in water treatment (CDC, 2008a; AORN, 2009i).

Glutaraldehyde. Glutaraldehyde is a saturated dialdehyde that has gained wide acceptance as an overall effective high-level disinfecting agent and chemical sterilant. Aqueous solutions of glutaraldehyde are acidic and in this state not sporicidal. The solution is said to be "activated" when alkalizing agents are added to make the solution alkaline. Glutaraldehyde has a broad antimicrobial range, being effective against vegetative bacteria, *M. tuberculosis,* fungi, and viruses. Although glutaraldehyde is effective against most bacteria in 10 minutes, some species of mycobacteria require a longer exposure time. To achieve high-level disinfection, a minimum exposure time of 20 to 45 minutes is recommended, based on the manufacturer's written instructions (AORN, 2009g). Glutaraldehyde is noncorrosive to endoscopic equipment, thermometers, rubber, and plastic. Glutaraldehyde phenate is a related compound that has been shown to lose efficacy against certain organisms in the recommended dilution. Another compound, glutaraldehyde with *ortho*-phenylphenol and *para-tert*-amylphenol, provides a wide range of antimicrobial activity similar to that of 2% glutaraldehyde. The compound is odorless and minimizes irritation and allergic reactions in users (AORN, 2009g; CDC, 2008a).

***ortho*-Phthalaldehyde (OPA).** *ortho*-Phthalaldehyde is a 0.55% *ortho*-phthalaldehyde solution in an aqueous buffer with a pH of 7.5 and is considered a high-level disinfectant. Studies have demonstrated excellent microbicidal activity and mycobacterial activity. The solution is bactericidal, virucidal, and fungicidal. It is tuberculocidal at a minimum exposure time of 12 minutes at room temperature. It has several potential advantages over glutaraldehyde. It has excellent stability over a wide pH range and is odorless, and it is not known to irritate the eyes or nasal passages. As with any high-level disinfectant, PPE should be employed when using *ortho*-Phthalaldehyde. *ortho*-Phthalaldehyde can be used for most applications for which glutaraldehyde is used and has broad materials' compatibility. The manufacturer's written instructions should be read before use (AORN, 2009g; CDC, 2008a).

Hydrogen Peroxide. Hydrogen peroxide is active against a wide range of microorganisms, including bacteria, yeasts, fungi, viruses, and spores (CDC, 2008a). Unstable and low concentrations of hydrogen peroxide (<3% solution) may be used as low-level disinfectant for work-surface cleaning and disinfection. Stabilized 6% hydrogen peroxide is sporicidal and can be used as a liquid sterilant with sufficient exposure time. The solution is corrosive, however, to copper, zinc, and brass. It also can damage rubber and plastic. As with other chemicals, dilution of hydrogen peroxide must be monitored by regularly testing the minimum effective concentration. Hydrogen peroxide is not used widely as a disinfectant in today's healthcare environment (AORN, 2009g; CDC, 2008a).

Iodine and Iodophors. Iodine solutions have been used widely by health professionals, primarily as antiseptics on skin or tissue. An iodophor is a water-soluble combination of iodine and a solubilizing agent or carrier that allows for a slow but continuous release of free iodine over time. Iodophors may be used as disinfectants or antiseptics, depending on the concentration of free iodine. The most widely used iodophor is povidone-iodine (Betadine). As disinfectants, iodophors have the advantage of having the germicidal efficacy of iodine without the disadvantages of toxicity and surface irritation. Iodophors are usually nonstaining and effective against vegetative bacteria, *M. tuberculosis,* and most viruses and fungi. Iodophors are not considered suitable for high-level disinfection or for use as hard-surface disinfectants because they have no sporicidal capability (CDC, 2008a).

Phenolics. Phenol (carbolic acid) was first used by Lister in the mid-1800s. Since that time, many phenol derivatives (phenolics) have been developed. Phenolics are assimilated by porous material, making their removal difficult. Residual disinfectant can cause tissue irritation. Most phenolic formulations are tuberculocidal, bactericidal, virucidal, and fungicidal. Certain viruses, including echovirus, are resistant to phenolics. Phenolics are not sporicidal, and they are not considered effective as high-level disinfectants. They are used primarily as intermediate-level and low-level disinfectants for environmental cleaning. They are known to have toxic effects, however, and their use has been associated with depigmentation and hyperbilirubinemia in newborns. Because of this, phenolics are not recommended for cleaning incubators or infant bassinets (CDC, 2008a).

Quaternary Ammonium Compounds. Quaternary ammonium compounds ("Quats") have been used for many years as a result of a reputation for microbicidal activity, good detergent action, and low-level toxicity. In more recent times, it has been noted that environmental factors, such as hard water, soap residues, and protein soils, reduce or nullify the efficacy of these compounds. Quaternary ammonium compounds are ineffective against *M. tuberculosis* and lipophilic viruses. These compounds are not considered to be sporicidal. Quaternary ammonium compounds are not recommended for high-level, intermediate-level, or low-level disinfection. They are good cleaning agents and are used most often for noncritical surfaces such as floors, walls, and furniture (AORN, 2009d; CDC, 2008a).

CLEANING AND PROCESSING ENDOSCOPES AND ACCESSORIES. In today's technologically advanced environment, flexible fiberoptic endoscopes and their associated instrumentation allow for a myriad of minimally invasive surgical procedures. The list of these procedures grows daily. Current technology allows not only for direct visualization of internal structures, but also for diagnostic biopsies and therapeutic procedures to be performed with reduced pain and shorter recovery time and hospital length of stay. Along with advances in technology, complications also have occurred. Some complications, such as bleeding or tissue perforation, are immediately obvious. Infectious complications may be more difficult to identify.

Endogenous and exogenous microorganisms can cause infections related to endoscopic procedures. When an infection occurs from endogenous sources, organisms normally present in the procedure area gain access to the bloodstream. Examples of endogenous infections resulting from endoscopy include localized infections, pneumonia, endocarditis, brain abscess, and subdural empyema. Infections also can be caused by organisms introduced into the patient via the endoscope (exogenous organisms). Organisms commonly associated with exogenous infection include *Pseudomonas, Klebsiella, Enterobacter, Salmonella,* and *M. tuberculosis*. Because HAV, HBV, HCV,

and HIV are inactivated by commonly used chemical germicides, documented endoscopic transmission of these viruses is uncommon. HBV transmission via the endoscope has been reported, as has the transmission of tuberculosis via a contaminated bronchoscope (CDC, 2008a).

For an endoscope to be thoroughly disinfected, the disinfecting agent must contact all internal and external surfaces of the endoscope for the prescribed length of time. Organic soil, such as blood, feces, or respiratory secretions, harbors embedded microorganisms and prevents penetration of the disinfecting agent. Some disinfectants are inactivated by organic material. Rigorous mechanical cleaning is essential to remove soil and debris from the outside of the scope and from the lumens of all accessible channels (CDC, 2008a).

Endoscopes and their accessories should be cleaned immediately after use to prevent drying of secretions or other organic soil. They should be cleaned with a nonabrasive enzymatic detergent as recommended by the endoscope manufacturer (AORN, 2009j; CDC, 2008a). If a powdered detergent is used, all granules must be dissolved completely before washing begins. Undissolved granules can block the internal channels of the instrument. To soften, moisten, and dilute organic debris, endoscope channels should be flushed with copious amounts of water and detergent. The external surfaces of the endoscope should be washed with a detergent solution and rinsed. Internal channels should be brushed to loosen and remove organic matter. The detergent solution should be suctioned or pumped through all channels to remove loosened debris. Special attention should be given to convoluted areas and crevices where contaminated organic material may lodge. The tip of the endoscope should be gently wiped or brushed to remove any debris or tissue that may be lodged around the air and water outlets. Brushes used for cleaning should be disposable or be thoroughly cleaned and sterilized daily. Detachable parts of the endoscope, such as hoods and suction valves, should be removed and soaked in a detergent solution. They should be thoroughly cleaned with a detergent, using a brush to remove any organic material (AORN, 2009j; CDC, 2008a).

Before immersion in any liquid, endoscopes should be pressure tested (leak tested) to determine the integrity of seals and minimize the potential for damage to the head of the scope. If damage is detected, the scope should not be immersed or reused. The endoscope should be removed from service and returned to the manufacturer for repair. An endoscope sent for repair is considered a contaminated item and must be labeled as such for shipping.

Immediately after endoscopes are decontaminated and cleaned, they should be rinsed of residual debris and cleaning agents. After a tap-water rinse, endoscopes should be rinsed with 70% or 90% alcohol and forced–air-dried. Alcohol inactivates organisms normally found in tap water and helps dry the internal channels of the scope. After being cleaned, endoscopes and accessories should be sterilized or high-level disinfected before being stored. Care must be taken to dry internal channels of the scopes after being processed and before being stored. Endoscopes should be stored in a vertical position in an area in which recontamination is unlikely. Endoscopes should be processed immediately before patient use, including first use of the day, to preclude the possibility that the scope may have been recontaminated during storage or handling or both. Endoscopes should be sterilized or high-level disinfected, depending on their intended use (see discussion of the Spaulding classification system earlier in this chapter). Because of pressure and heat sensitivity, for many years the sterilization method of choice for endoscopes was EO. More recently, other technologies and liquid peracetic acid with anticorrosive buffers and Sterrad NX also have been used to process endoscopes. As the utilization of endoscopic surgery expands, and the need for sterile endoscopes increases, additional processing methodologies are expected to become available (AORN, 2009j; CDC, 2008a)

Activated glutaraldehyde was long considered the agent of choice for high-level disinfection of endoscopes. A manual or an automated system may be used. Regardless of whether a manual or automated system is used, meticulous manual cleaning must precede the disinfection process. The solution manufacturer's written instructions should always be followed (CDC, 2008a).

The facility should maintain a log for each procedure with the patient's name, medical record number (if available), and type of procedure being performed; the endoscopy physician's name; and the serial number or other identifier of the scope. If an automatic endoscope reprocessor is used, identification of this device should be included in the record. This documentation assists in the tracking and investigation in the event of an outbreak or safety concern (AORN, 2009g).

PASTEURIZATION. Pasteurization is a process that uses hot water at temperatures between 65.5° C (150° F) and 76.6° C (170° F) for 30 minutes to achieve high-level disinfection. The actual time/temperature relationship depends on the items to be disinfected. Contact time is inversely related to temperature. For equivalent microbial destruction, longer exposure times are required when the temperature is decreased. Controversy exists as to whether pasteurization results in high-level or intermediate-level disinfection. The CDC definition of high-level disinfection requires destruction of all microbial life except for large populations of bacterial spores. Because pasteurization, by definition, does not kill bacterial spores, some would consider the process to result in only intermediate-level disinfection. Some semicritical items, such as respiratory therapy and anesthesia devices, are ready for patient use after cleaning and pasteurization. High numbers of bacterial spores are not found often on these devices after use. Cleaning before pasteurization reduces the bioburden, and the low number of spores that might be present on a properly pasteurized device of this type would not represent an infective dose when contacting intact mucous membranes. Advantages of pasteurization include absence of toxic residues and the associated need for postprocess rinsing. Disadvantages of pasteurization include the lack of sporicidal activity and the potential for splash burns to personnel involved with the process (AAMI, 2009a).

Reprocessing/Reuse of Items Labeled for Single-Use Only. Healthcare trends reflect cost-driven market forces and consumer-driven demands for quality, safety, and effectiveness. Facilities in today's marketplace are reprocessing and reusing devices labeled for single use (Ambulatory Surgery Considerations). The practice of reprocessing and reusing single-use items is controversial and some facilities choose this process as a cost containment effort and to reduce the amount of waste. Each facility must decide whether to reprocess and to what

extent the practice should be instituted. Three basic tenets must be included in any reprocessing/reuse program, as follows:

- If a device cannot be cleaned, it cannot be reprocessed and reused.
- If sterility of a postprocessed device cannot be shown, the device cannot be reprocessed and reused.
- If the integrity and functionality of a reprocessed single-use device cannot be shown and documented, the device cannot be reprocessed and reused (AORN, 2009k).

AMBULATORY SURGERY CONSIDERATIONS

Ambulatory Surgery Centers and the Device Reprocessing Debate

According to the *AORN Guidance Statement: Reuse of Single-Use Devices,* it is noted that this process may realize some operational savings. The authors further elaborate on the fact that a cost-benefit ratio analysis should be completed before any unit or organization enters into this practice.

In the May 2009 issue of *OR Manager,* the author discusses the reprocessing debate as it affects ambulatory surgery centers (ASCs). The three ways to handle used single-use medical and surgical devices are currently identified in the following manner:

- Dispose of them after use.
- Reprocess the device according to the stringent Food and Drug Administration (FDA) guidelines.
- Contract with a reprocessing specialty company to collect, reprocess, and reship the product to the center.

The FDA publishes an extensive listing of single-use devices that have been identified for reprocessing. The FDA has been monitoring this situation since 2001, with vigorous oversight and the development of stringent guidelines and their subsequent enforcement. They have clearly identified those devices that penetrate the mucosa as high risk and do not endorse reprocessing of these devices. The FDA became involved in the debate when they were alerted by the original manufacturers of devices that facilities were reprocessing devices without ensuring the efficacy, effectiveness, and sterility of the original product.

Can Devices be Reprocessed in the Ambulatory Surgery Setting Effectively?
Yes. The ASC needs to engage in a course of identifying the devices based on the FDA listing and requirements along with developing a cost-benefit ratio to determine if the devices meet the needs of their center. The May 2009 *OR Manager* article clearly points out that in some centers this policy works well, some centers have room for improvement, and in other ASCs the practice does not function well for the organization.

SUMMARY
Even with strong oversight by the FDA, the debate will continue as the issues surrounding surgical site infections (SSIs), the economy, and the associated costs remain front and center. The end-users, usually the surgeon and the perioperative nurse, will need to be aware of issues such as cost, efficacy, and associated changes to the FDA's and the manufacturer's recommendations. The issues of universal healthcare coverage and the cost to the public for the plan, along with such issues surrounding documentation from the original manufacturer over concerns of efficacy and sterility after reprocessing by a third party, will expand and need to be monitored.

Modified from Device reprocessing makes inroads in ASCS: *OR Manager* 25(5):28-29, 2009; Association of periOperative Registered Nurses: AORN guidance statement: Reuse of single-use devices. In *Perioperative standards and recommended practices,* Denver, 2009, The Association.

Although some savings may be realized by reusing certain single-use devices, any cost-benefit analysis necessarily would include consideration of the labor costs associated with reprocessing; program costs, including quality systems requirements such as sterility and postprocessing testing, documentation, and record-keeping costs; and the cost of device failure. The results of this cost analysis are helpful when making a decision about reprocessing/reusing single-use devices (Research Highlight).

The FDA views any reprocessor as a manufacturer and subject to federal regulations governing manufacturers. Hospitals and third-party reprocessors are subject to the same regulations as the original equipment manufacturer. These requirements include the following:

- Registration and listing
- Medical device tracking
- Medical device reporting
- Corrections and removals
- Device labeling
- Quality system regulation
- Premarket notification requirements (AORN, 2009k; AAMI, 2009b)

Each requirement has associated resource needs. An in-depth discussion of these requirements is beyond the scope of this textbook. Details of the FDA requirements for reprocessors can be found in the *Code of Federal Regulations*.

If a user facility chooses to engage a third-party reprocessor as opposed to conducting the program at the facility, it is the user facility's responsibility to assess the quality of the services provided under the contractual arrangement with the third-party reprocessor. The user facility must review the processes used by the contracted agency and determine whether correct procedures are being followed (CDC, 2008a; AORN, 2009b).

ASEPTIC PRACTICES TO CONTROL INFECTION

Surgical Aseptic Principles

Asepsis has been defined as the absence of infectious organisms. Surgical aseptic practices are based on the premise that most infections are caused by organisms exogenous to the surgical patient's body. To avoid infection, surgical procedures must be done in a manner that minimizes or eliminates the patient's exposure to exogenous organisms. Opening sterile supplies as close to the time of their use as possible, using sterile drapes to create a sterile field around the incision site, using sterile instruments for the surgical procedure, and placing the operative team in sterile attire after their hands and arms have been cleansed of surface bacteria aid in avoiding infection.

Aseptic technique stems from the principles of asepsis derived over time from microbiologic and epidemiologic concepts. Although some investigators may believe that current aseptic practices and techniques have become too ritualistic or lack scientific research to support their use, present-day infection-control statistics support the application of aseptic principles for safe perioperative nursing practice. Until empiric research shows that a technique is unnecessary or ineffective, the basic aseptic principles should be followed. These principles follow:

1. Only sterile items are used within the sterile field. Individuals dispensing sterile items to the sterile field must look at the sterilization indicator on or visible in the package, check

RESEARCH HIGHLIGHT

Reprocessing Single-Use Devices

The practice of reprocessing single-use, disposable devices has been controversial since the 1970s. Authors favoring the practice cite substantial cost savings and the absence of adverse patient outcomes. Authors who oppose the practice cite concerns about cleaning and sterilizing the devices and concerns about product integrity. Other authors cite the ethical issues of multiple charging for the same device. The purpose of this study was to determine whether reprocessed single-use devices could be sterilized and whether the devices would meet the same standards as a new device.

Single-use and reusable biopsy forceps and papillotomes and a reusable stone-retrieval basket were selected for the study. Eleven instruments, including a sterile control device, were used for the cleaning test. Devices were first contaminated with a radionuclide product and then cleaned under running tap water at 30° to 35° C (86° to 95° F) for 3 minutes. The inner lumens were flushed using a 10-ml syringe filled with enzymatic cleaner. The instrument was submerged in the same enzymatic cleaner for 10 minutes. After the enzymatic soak, the devices were placed in an ultrasonic bath of tap water at 30° to 35° C (86° to 95° F) for 5 minutes. After this ultrasonic treatment, lumens were flushed again by using a syringe, and external surfaces were cleaned under running water at 30° to 35° C (86° to 95° F) for 3 minutes. Lumens were dried by blowing air through them using a dry syringe, and the outer surfaces of the devices were dried. After processing, cleaning results were measured using a gamma camera to determine the distribution and intensity of radioactivity of the radionuclide-contaminating product used before cleaning.

To evaluate disinfection of the devices, channels were filled with 2% glutaraldehyde solution, and the devices were submerged in the glutaraldehyde solution for 20 minutes at a temperature of 20° to 25° C (68° to 77° F). After this treatment, lumens were flushed, using a syringe with tap water; the outside was cleaned under running tap water. Water was blown from the lumens with a dry syringe, and the outer surface of the devices was dried. Disinfection was measured in terms of log reduction factors calculated from the difference in colony-forming units before and after processing.

To evaluate sterilization, devices were placed in appropriate packaging materials and exposed to a half-cycle in either a steam sterilizer or an ethylene oxide sterilizer. After sterilization, devices were placed in appropriate culture media and incubated for the designated length of time. Sterilized devices were evaluated for the presence or absence of bacterial growth. Finally, scanning electron microscopy and x-ray photoelectron spectroscopy were used to evaluate device surfaces and the microstructure of materials after processing.

Results of this study showed that all devices remained contaminated after being cleaned, although the level of contamination differed according to type of device. Testing after disinfection and sterilization indicated that reusable devices were adequately disinfected using the described protocol, but single-use devices were not. Sterilization reduced the number of spores on devices, but spores could not be totally eliminated. Finally, single-use and reusable devices were physically damaged during sterilization. Compared with unused devices, surfaces of soiled and reprocessed devices showed increased concentrations of carbon and nitrogen, which were explained as traces of residual peptides from blood or other body materials.

The authors of this study concluded that when using the described standards for cleaning, disinfection, and sterilization, none of the reprocessed single-use devices in this study were suitable for use with subsequent patients. Disinfection and sterilization of disposable devices could not be accomplished to the required levels, and reprocessing procedures resulted in material changes that added to degradation and reduced functional integrity of the devices.

SUMMARY

According to the AORN (2009) *Guidance Statement: Reuse of Single-Use Devices,* reusing some single-use devices may realize some operational savings. However, it is critical to evaluate the cost-benefit ratio for a specific unit and/or organization. AORN believes that as licensed perioperative practitioners we must demonstrate accountability both to the nursing profession and to patients for ensuring the efficacy of any reprocessing program.

Modified from Heeg P et al: Decontaminated single-use devices: an oxymoron that may be placing patients at risk for cross-contamination, *Infect Control Hosp Epidemiol* 22:539-542, 2001; Association of periOperative Registered Nurses: AORN guidance statement: Reuse of single-use devices. In *Perioperative standards and recommended practices,* Denver, 2009, The Association.

for package integrity, and check for the package expiration date (or appropriate marking for event-related shelf life) before dispensing the item to the field.

2. Items of doubtful sterility must be considered unsterile. Examples include sterile items found in unsterile work areas, sterilized packages wrapped in pervious materials that have become wet, sterilized items without an integrator or other internal indicator, and sterilized packages wrapped in pervious materials that are dropped. If a package wrapped in an impervious material is dropped, and the area of contact is dry, the package may be opened and the contents used. The package should not be returned to sterile storage for future use.
3. Whenever a sterile barrier is permeated, it must be considered contaminated. This principle applies to packaging materials and to draping and gowning materials. Obvious contamination occurs from direct contact between sterile and unsterile objects. Other less apparent modes of contamination are the filtration of airborne microorganisms through materials, passage of liquids through materials, and undetected perforations in materials. Moisture soaking through a drape, gown, or package is considered a strikethrough, and the item must be considered contaminated.
4. Sterile gowns are considered sterile in front from shoulder to level of the sterile field and at the sleeves from 2 inches above the elbow to the cuff. The cuff should be considered unsterile because it tends to collect moisture and is not an effective bacterial barrier. The sleeve cuffs should always be covered by sterile gloves. Other areas of the gown that must be considered unsterile are the neckline, shoulders, axillary area, and back. These areas may become contaminated by perspiration or by collar and shoulder surfaces rubbing together during head and neck movements. Wraparound gowns that completely cover the back may be sterile when first put on.

The back of the gown must not be considered sterile, however, because it cannot be observed and protected from contamination. The sterile area of the front of the gown extends to the level of the sterile field because most scrub personnel work adjacent to a sterile table. For this reason, the scrub person should avoid changing levels, as would occur while moving from footstool to floor. To maintain sterility, scrub persons should not allow their hands or any sterile item to fall below the level of the sterile field. Scrub persons should neither sit nor lean against unsterile surfaces because the threat of contamination is great. The only time scrub persons may be seated is when the entire surgical procedure is performed at that level. Self-gowning and gloving should be done from a sterile surface separate from the sterile field. This method eliminates reaching over the sterile field to retrieve the sterile towel and then the sterile gown. It also eliminates the potential for water to be dripped on sterile items or on any part of the sterile field, preventing inadvertent contamination. When prepared, the scrub person's hands should be kept in sight at or above waist level. Elbows should be kept close to the body, and the hands should be kept away from the face. Hands should not be folded under the arms because axillary perspiration may permeate the bacterial barrier of the gown.

5. Tables are sterile only at table level. Sterile drapes are used to create a sterile field. Only the top surface of a draped table is considered sterile. Although the drape extends over the sides of a table, the sides cannot be considered sterile. Any portion of the drape that falls below the top edge of the table cannot be returned to table level. When placed, a drape should not be shifted or moved. Items should be dispensed to a sterile field by methods that preserve the sterility of the items and the integrity of the sterile field. Good judgment must be used when dispensing items by presenting them to the scrub person or by placing them securely on the sterile field. A sterile field should be created as close as possible to the time of use. Sterile drapes also are used to create a sterile field when placed over the patient and operative bed. Any item that extends beyond the sterile boundary is considered contaminated and cannot be returned to the sterile field. A contaminated item must be lifted clear of the operative field without contacting the sterile surface and must be dropped with minimal handling to a nonscrubbed surgical team member, an unsterile area, or a designated receptacle. Interpretation of sterile areas versus unsterile areas on a draped patient requires astute observation and use of good judgment.
6. The edges of a sterile enclosure are considered unsterile. Items should be dispensed to the field in a manner that preserves the sterility of the item and the integrity of the sterile field. After a sterile package or container is opened, the edges are considered unsterile. Sterile and unsterile boundaries are often intangible. A 1-inch safety margin is usually considered standard on package wrappers, whereas the sterile boundary on a wrapper used to drape a table is at the table edge. When opening a sterile wrapper, the top flap is first opened away from the operator; the side flaps then follow. The inside or proximal flap is opened last. All flaps are secured in the hand by the operator, so as not to dangle and contaminate other items. When removing items from a sterile package, the scrub person should lift it straight up from the package. On peel-pack pouches, the inner edge of the heat seal is the line of demarcation. Peel-pack edges should be pulled back as opposed to being torn. The contents of the package should be flipped on the sterile field by the nonscrubbed person or lifted directly upward by the scrub person. Its contents should not be allowed to slide over the side of the package. Interpreting sterile boundaries requires good judgment based on an understanding of aseptic principles.
7. Sterile individuals touch only sterile items or areas; unsterile individuals touch only unsterile items or areas. All members of the surgical team must understand which areas are considered sterile and which are considered unsterile. All must maintain a continual awareness of these areas. Scrubbed individuals must guard the sterile field to prevent any unsterile item from contaminating the field or the individuals themselves. Unsterile individuals must not touch or reach over a sterile field or allow any unsterile item to contaminate the field. When a perioperative nurse opens a package, hand and arm motions are always from unsterile to sterile objects. The nurse avoids contact with the sterile area by placing the hands under the cuff to provide a protected wide margin of safety between the inside of the pack (sterile) and the hands (unsterile) (Figure 3-12). As the unsterile nurse opens a sterile article that is wrapped sequentially in two wrappers with the corners folded toward the center of the article, the corner farthest from the body is opened first and the corner nearest the body opened last. When a scrub person opens a sterile wrapper, the side nearest the body is opened first. This portion of the wrapper then protects the gown and enables the individual to move closer to the table to open the opposite side (Figure 3-13). If

FIGURE 3-12 The perioperative nurse is shown opening the cover of a pack containing sterile drapes for surgery. The cover is cuffed to provide protection for the sterile contents. The nurse avoids contact with the sterile area by keeping all fingers under the cuff as the cover is drawn back over the table to expose the pack contents.

a solution must be poured into a sterile receptacle on a sterile table, the scrub person holds the receptacle away from the table or sets it near the edge of a waterproof-draped table (Figure 3-14). This procedure eliminates the need for the unsterile nurse to reach over the sterile field. Maintaining a safe margin of space can reduce accidental contamination when items are passed between sterile and unsterile fields. An instrument may be used as an extension of a team member's hands to ensure a safe margin between fields. The use of transfer forceps is unacceptable, however. Maintaining the sterility of these forceps is questionable because of many variables, such as sterilization method, type of container, and type and amount of soaking solution used. Incorrect handling of soaked forceps results in contamination. The preferred procedure is for single use of a packaged, sterile ring forceps, which is discarded into a container for reprocessing.

8. Movement within or around a sterile field must not contaminate the field. The patient is the center of the sterile field during an operative procedure; additional sterile areas are grouped around the patient. If contamination is to be prevented, patterns of movement within or around this sterile grouping must be established and rigidly practiced. Scrub persons stay close to the sterile field. If they change positions, they turn face to face or back to back with another individual while maintaining a safe distance between themselves and other objects. Accidental contamination is a threat to any scrub person who wanders into a traffic pathway or out of the clean area of the OR. Perioperative nurses approach sterile areas facing them and never walk between two sterile fields. Keeping sterile areas in view during movement around the area and maintaining a safe distance from the sterile field assist in preventing accidental contamination. Bacterial fallout from the body or clothing is a source of contamination when an unsterile individual leans over a sterile field. All perioperative personnel must maintain vigilance over sterile areas and identify contamination immediately. Movement within and around a sterile area should be kept to a minimum to avoid contamination of the field or the sterile members of the surgical team (AORN, 2009l).

Close adherence to principles of asepsis and consistent observance of the boundaries established in the principles provide protection against infection. Application of the basic principles of aseptic technique depends primarily on the individual's understanding and conscience. Every person on the surgical team must share the responsibility for monitoring aseptic practice and initiating corrective action when a sterile field is compromised.

Traffic Control

The surgical suite should be designed to minimize the spread of infectious organisms and to facilitate movement of patients and personnel within that framework (AORN, 2009m). Ideally, the suite is divided into three areas, each defined by the

FIGURE 3-13 The scrub person opens the near side of the wrapper first, providing protection for the sterile gown. The scrub person protects his or her gloves with the cuff of the drape as the drape is opened to provide the sterile table cover.

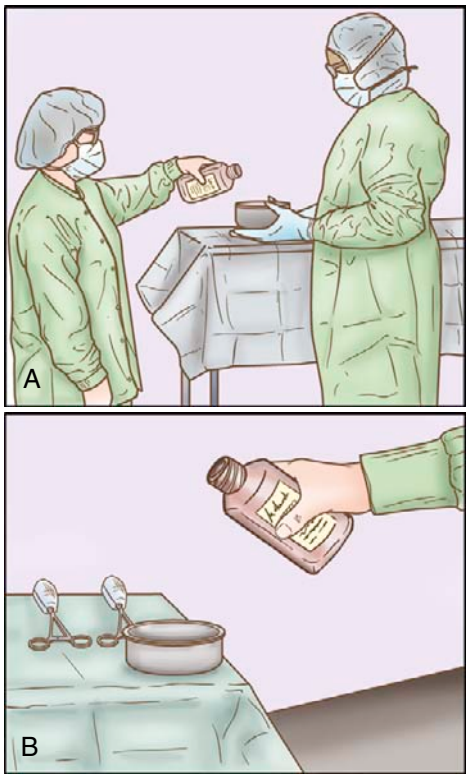


FIGURE 3-14 **A**, When pouring solution into the receptacle held by the scrub person, the perioperative nurse maintains a safe margin of space to avoid contamination of sterile surfaces. **B**, Care must be used when pouring solution into a receptacle on a sterile field to avoid splashing fluids onto the sterile field. Placement of the receptacle near the edge of the table permits the nurse to pour solution without reaching over any portion of the sterile field.

activities occurring within the area. The *unrestricted* area includes areas outside of the surgical suite and a control point to monitor the entrance of patients, personnel, and materials. Street clothes are appropriate attire in this area, and traffic is not limited, but provisions must be made for isolation of patients with communicable conditions (Risk Reduction Strategies). The *semirestricted* area comprises the peripheral support areas within the surgical suite. These may include storage areas, work areas, and corridors leading to restricted areas of the surgical suite. Traffic in the semirestricted area is limited to appropriately attired personnel and patients. Personnel must wear surgical attire and cover all head and facial hair when in this area. Patients should have their hair covered, wear clean hospital attire, and be covered with clean hospital linens. The *restricted* area includes the OR, procedure rooms (if any), the central core, and the scrub sink area. Personnel must wear surgical attire including hair coverings when in the restricted area. Masks are worn where open sterile supplies or scrub persons may be present. Masks are not required for patients because a mask could hinder access to the patient's face and airway and cause additional patient anxiety (AORN, 2009m).

Personnel entering semirestricted or restricted areas of the surgical suite should do so through prescribed routes. These routes contain vestibular areas, which serve as transition zones between the outside and inside of the suite. Offices, holding rooms, and locker rooms act as transition zones. Personnel entering the OR should access the locker room via the unrestricted area. After donning clean, hospital-laundered surgical attire, personnel should exit directly into the OR suite without retracing steps through the unrestricted area.

Air is a potential source of microorganisms that can result in a surgical site infection. Airborne contamination increases with movement of the surgical team. This movement should be kept to a minimum during operative procedures. Each OR door should remain closed except during movement of patients, personnel, supplies, and equipment. The positive-pressure gradient of air in the OR is disrupted if the door remains open. The turbulent flow occurring as the pressure equalizes can increase airborne contamination (Anderson et al, 2008; AORN, 2009m).

Surgical equipment and supplies also are potential sources of contamination. Clean and sterile supplies should be separated from contaminated items by space, time, or traffic

RISK REDUCTION STRATEGIES

H1N1—World Health Organization (WHO) Patient Safety: Clinical Checklist

Influenza A is the most common cause of influenza (flu) in humans. H1N1 is a subtype of influenza A. In June 2009 the World Health Organization (WHO) declared that a new strain of swine-origin H1N1 (commonly called "swine flu" by the public) was responsible for the 2009 flu pandemic. In response to the H1N1 threat, a team from the WHO consisting of experts in the areas of infection control, clinical management of pandemic influenza, and healthcare began developing a patient safety checklist. The checklist was designed to be utilized by healthcare personnel who will care for suspected or confirmed cases of influenza A (H1N1) virus.

Checklists are a practical approach to action and easy to use in the practice setting. They are not meant to be comprehensive documents or to replace routine patient care, but should be flexible on the basis of specific local and institutional needs. The checklist provides guidance regarding the clinical management of the individual patient and infection control measures to minimize and limit the spread of the virus.

The checklist was evaluated for effectiveness by several health centers throughout the world. The utilization of this process will continually need to be evaluated based on the health status of both patients and citizens throughout the world. The checklist does not replace clinical guidance or clinical judgment. Its users should also familiarize themselves with the relevant WHO guidance documents.

How to Use the Checklist

- Staff can use the checklist in a variety of ways. The objective is to ensure that no critical patient care items are missed during or immediately following care. The checklist can do any of the following:
  - It can be used as part of the patient's clinical record.
  - It can be reproduced as wall posters for hospitals or clinics.
  - It can be printed on cards for staff members to carry and use as a reference when treating patients.
- Parts of the checklist can also be extracted for use in any of these formats.

PATIENT CARE CHECKLIST

Upon Arrival to Clinical Setting/Patient Care Area

- Direct patient with flulike symptoms to designated waiting area.
- Provide instruction and materials to patient on respiratory hygiene/cough etiquette.
- Put medical/surgical mask on patient, if available and tolerable to patient.

Before Patient Entry to Designated Area (Isolation Room or Cohort)

- Post restricted entry and infection control signs.
- Provide dedicated patient equipment if available.
- Ensure at least 3 feet between patients in cohort area.
- Ensure local protocol for frequent linen and surface cleaning is in place.

Before Entering Designated Area (Isolation Room or Cohort) (Healthcare Workers and Visitors)

- Put on medical/surgical mask.
- Clean hands (handwashing or alcohol-based hand rub).

Before Every Patient Contact

- Put on medical/surgical mask.
- Clean hands (handwashing or alcohol-based hand rub).
- Put on eye protection, gown, and gloves if there is risk of exposure to body fluids/splashes.
- Clean and disinfect personal/dedicated patient equipment between patients.
- Change gloves (if applicable) and clean hands between patients.

Upon Initial Assessment

- Record respiratory rate over 1 full minute and oxygen saturation if possible.
- If respiratory rate is high (e.g., for the following age groups: <2 months, ≥60/minute; 2-11 months, ≥50/minute; 1-5 years, ≥40/minute; >5-12 years, ≥30/minute; ≥13 years, ≥20/minute) or oxygen saturation is below 90%, alert senior care staff for action.

Continued

RISK REDUCTION STRATEGIES

H1N1—World Health Organization (WHO) Patient Safety: Clinical Checklist—cont'd

- Record history, including flulike symptoms, date of onset, travel, contact with people who have flulike symptoms, co-morbidities.
- Consider specialized diagnostic tests (e.g., reverse transcription polymerase chain reaction [RT-PCR]).
- Use medical/surgical mask, eye protection, gloves when taking respiratory samples.
- Label specimen correctly and send as per local regulations with biohazard precautions.
- Consider alternative or additional diagnoses.
- Report suspected case to local authority.

Initial and Ongoing Patient Management

Supportive therapy for new influenza A (H1N1) patient as for any influenza patient including:

- Give oxygen to maintain oxygen saturation above 90% or if respiratory rate is elevated (when oxygen saturation monitor is not available).
- Give acetaminophen if considering an antipyretic for patients less than 18 years old.
- Give appropriate antibiotic if there is evidence of secondary bacterial infection (e.g., pneumonia).
- Consider alternative or additional diagnoses.
- Decide on need for antivirals* (oseltamivir or zanamivir), considering contraindications and drug interactions.

Before Leaving Designated Area (Isolation Room or Cohort) (Healthcare Workers and Visitors)

- Remove any personal protective equipment (gloves, gown, mask, eye protection).
- Dispose of disposable items as per local protocol.
- Clean hands (handwashing or alcohol-based hand rub).
- Clean and disinfect dedicated patient equipment and personal equipment that has been in contact with patient.
- Dispose of viral-contaminated waste as clinical waste.

Before Patient Transport/Transfer

- Put medical/surgical mask on patient if available and tolerable to patient.

If Performing Aerosol-Generating Procedures (e.g., Intubation, Bronchoscopy, CPR, Suction)

- Allow entry of essential staff only.
- Put on gown.
- Put on particulate respirator (e.g., EU FFP2, U.S. NIOSH-certified N95) if available.
- Put on eye protection, and then put on gloves.
- Perform planned procedure in an adequately ventilated room.

Before Discharge of Confirmed or Suspected Case

- Provide instruction and materials to patient/caregiver on respiratory hygiene/cough etiquette.
- Provide advice on home isolation, infection control, and limiting social contact.
- Record patient address and telephone number.

After Discharge

- Dispose of or clean and disinfect dedicated patient equipment as per local protocol.
- Change and launder linen without shaking.
- Clean surfaces as per local protocol.
- Dispose of viral-contaminated waste as clinical waste.

*Currently there is a lack of data on the clinical effectiveness of antivirals for this disease. Antiviral drugs are to be used according to national pandemic influenza preparedness plans. If antivirals are prescribed, oseltamivir or zanamivir should be used for influenza A (H1N1) patients because of increased risk of resistance with other antivirals. Where antiviral drugs are available for treatment, clinicians should make decisions based on assessment of the individual patient's risk. Risks versus benefits should also be evaluated on a case-by-case basis.

Modified from World Health Organization (2009): *Patient safety, clinical checklist influenza A (H1N1),* available at www.who.int/patientsafety/activities/ah1n1_checklist/en/. Accessed July 28, 2009; *Clinical management of human infection with new influenza A (H1N1) virus* (May 21, 2009), available at www.who.int/entity/csr/resources/publications/swineflu/clinical_managementH1N1_21_May_2009.pdf. Accessed July 30, 2009.

patterns. Clean and sterile items delivered to the surgical suite should be transported in a manner that preserves package integrity and protects the packaged items from contamination along the travel route. Because external shipping containers may collect dust, debris, and insects during shipment, these containers should be removed in the unrestricted area and the contents brought into the surgical suite. Within the suite, supplies should move from the clean core or storage area through the OR to the peripheral or semirestricted corridor. Soiled instruments, supplies, and equipment should not reenter the clean core. Instead, soiled items should be covered or contained in closed carts or containers and transported to an area designated for decontamination. This decontamination area, as well as the soiled linen and trash collection areas, should be separate from personnel and patient traffic areas (AORN, 2009m).

Surgical Attire

Every surgical department should have a written policy and procedure regarding proper attire in the surgical suite. According to OSHA regulations and institutional policy and to prevent transmission of organisms from the patient to personnel, it is required that personnel wear personal protective equipment (PPE) when it can be reasonably anticipated that the individual may come in contact with blood or other potentially infectious materials. PPE—which includes protective eyewear, gloves, and fluid-resistant gowns, aprons, and shoe covers—must be included as part of the surgical attire policy as determined by OSHA regulations (AORN, 2009b; OSHA, 1991).

People are a major source of bacteria in the surgical setting. To reduce bacterial and skin shedding (scurf) and promote environmental control and cleanliness, all persons entering the semirestricted and restricted areas of the surgical suite should wear clean, facility-laundered, surgical attire (Figure 3-15) made of multiuse fabric or limited-use nonwoven material (AORN, 2009b). Home laundering of surgical attire that is not visibly soiled is controversial, and there is no concrete research to support or refute this practice. Surgical attire becomes soiled or contaminated during normal wear. Taking worn, soiled, or contaminated surgical attire into the home can result in the spread of contamination to the home environment (AORN, 2009b). Surgical attire, also known as *scrub attire,* should be constructed of a low-linting material that minimizes bacterial shedding, is comfortable, and provides

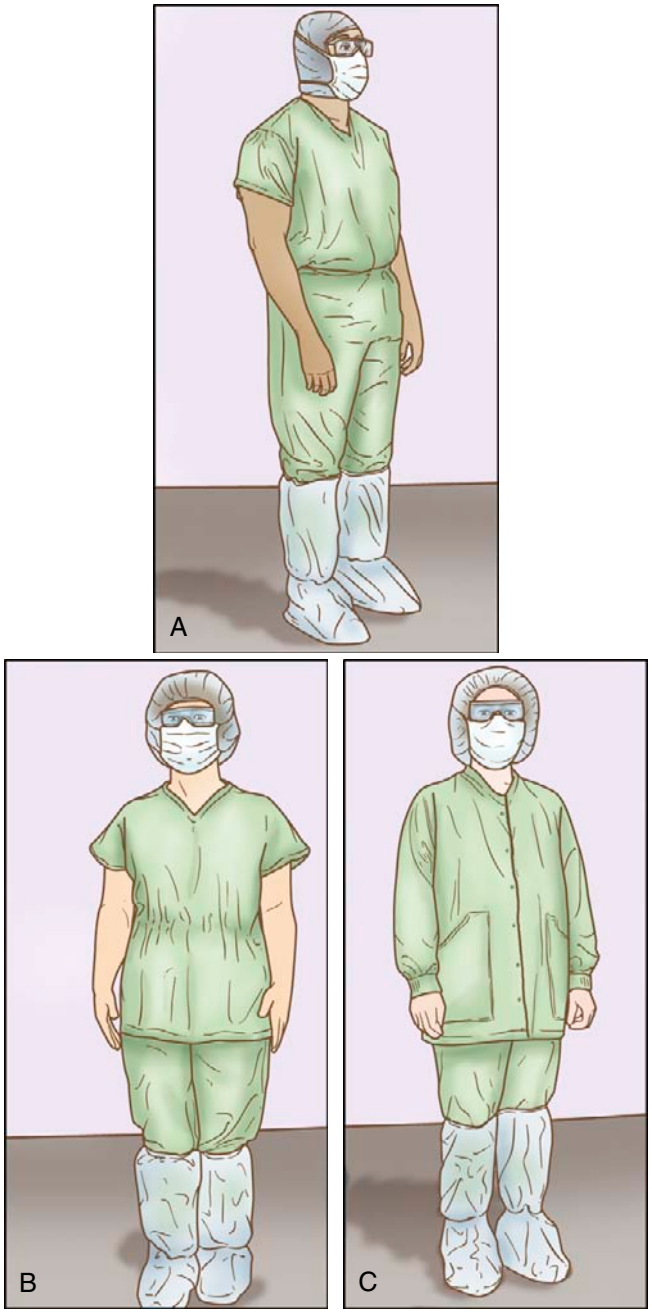


FIGURE 3-15 Proper surgical attire consists of a two-piece pantsuit, a scrub dress, or a one-piece coverall suit. Shoe covers should be worn when it is reasonably anticipated that spills or splashes will occur. If worn, they should be changed whenever they become wet, torn, or soiled. In semirestricted and restricted areas, all head and facial hair should be covered. In restricted areas, all personnel should wear masks. Jewelry should be removed or totally confined. Artificial nails should not be worn. **A**, When a two-piece scrub suit is worn, loose-fitting scrub tops should be tucked into pants. **B**, Tunic tops that fit close to the body may be worn outside of pants. **C**, Nonscrubbed personnel should wear long-sleeved jackets that are buttoned or snapped closed.

a professional appearance. If a two-piece pantsuit is worn, the top of the pantsuit should be tucked into the trousers or fit close to the body. Care should be taken when donning scrub pants to avoid dragging the pant legs on the floor. If nonscrubbed perioperative personnel wear long-sleeved shirts, the sleeves of the warm-up jackets should cover the shirtsleeves. Long sleeves are not appropriate for scrub personnel because the surgical scrub extends beyond the edge of the long sleeves (AORN, 2009b). A head cover, mask, and, if required, shoe covers complete the surgical attire ensemble. Shoe covers are required if there is a risk of blood or body fluid contamination, as described in OSHA regulations (OSHA, 1991). To protect the patient and the healthcare worker, surgical attire must be changed whenever it becomes soiled or wet with blood, any body fluid including perspiration, or food. Nonscrubbed personnel should wear long-sleeved jackets that are buttoned or snapped closed during wear. These jackets help decrease bacterial and skin shedding from bare arms. Closing the jackets helps prevent inadvertent contamination, which can occur if the loose fabric brushes against a sterile area. All jewelry should be confined within scrub attire or removed when personnel enter the semirestricted or restricted areas of the surgical suite. This includes any visible jewelry associated with body piercing. Confinement reduces the possibility of jewelry falling or shedding bacteria into a sterile field or wound. Before handwashing, rings, watches, and bracelets should be removed because organisms can be harbored beneath these pieces of jewelry (AORN, 2009b).

Before scrub attire is donned, the scrub personnel should put on a clean, lint-free surgical hat or hood that completely covers all head and facial hair. Hair acts as a filter when left uncovered and collects bacteria, which are released into the air during activity. Hair attracts, harbors, and sheds bacteria in proportion to its length, curliness, and oiliness. A head cover eliminates the possibility of hair or dandruff being shed on the scrub suit. The design and composition of the hat or hood should minimize dispersal of bacteria, be comfortable to wear, and confine and contain all hair. Head covers should always be worn in areas where equipment and supplies are processed and stored. Disposable bouffant and hood types of head covers are preferred. They are discarded in a designated receptacle immediately after use. Skullcaps that fail to cover the side hair above the ears and hair at the nape of the neck should not be worn in the OR. If reusable hats or hoods are worn, they should be laundered daily. If they become contaminated with blood or body fluids, they must be laundered according to OSHA (1991) regulations.

For personnel safety, shoes that provide protection should be worn. Cloth shoes provide little protection against spilled liquids or sharp items that may be accidentally dropped to the floor. Shoes with enclosed toes and heels help minimize injury. Shoe covers may be worn to help keep shoes clean and may decrease the amount of soil and bacterial tracking throughout the suite. It is easier to change a shoe cover than to stop to clean or change a shoe that has become soiled. If it is reasonably expected that the feet may become contaminated with blood or body fluids, shoe covers are required as part of personal protective attire. Shoe covers should be kept in an area adjacent to the semirestricted area entrance. They should be removed and discarded in the appropriate receptacle when leaving the restricted area (AORN, 2009b). A single surgical mask is worn to reduce the dispersal of microbial droplets expelled from the mouth and nasopharynx of personnel and to protect healthcare workers from aerosolized pathogenic organisms and particles from the surgical environment. Single, high-filtration surgical masks are worn in ORs and other designated areas where open

FIGURE 3-16 Proper handling of a mask. **A**, Edges of a properly worn mask conform to facial contours when the mask is applied and tied correctly. **B** and **C**, Personnel should avoid touching the filter portion of the mask when removing it. **D**, Masks should be discarded on removal.

sterile supplies or scrub persons may be located. A single mask provides a filter; double-masking creates a barrier, causing the exhaled air to be expelled through tents and gaps around the mask. Differences of opinion exist in the literature, with some researchers claiming that oral bacteria expelled by personnel in the OR are of no threat to the surgical patient and surgical masks for nonscrubbed personnel in the OR may not be necessary. OSHA (1991) regulations mandate the use of surgical masks as part of personal protection. Individual practice settings need to develop polices based on OSHA (1991) and state-mandated recommendations on the use of masks. Further research on the topic of surgical masks needs to be established.

Masks with a microbial filtration efficiency of 95% or greater should be selected. Aerosol particles generated by the surgical team, sometimes visible to the naked eye, are most likely 10 μm or larger. The plume of lasers or the electrosurgical unit has been found to contain particles with a mass of 0.31 μm, smaller than that expelled by the surgical staff. The filtration efficiency of masks should ensure protection against aerosol particles that are 0.1 μm or larger (AORN, 2009f). The most effective filter mask is relatively useless if worn incorrectly, however, and can be dangerous if handled improperly. Figure 3-16 illustrates the proper application and removal of a surgical mask.

The mask must cover the mouth and nose entirely and have facial compliance, fitting comfortably around the contours of the nose and cheeks. The mask is tied securely without crossing the strings. Crossing strings allows the sides of the mask to gap (tenting) and consequently permits nonfiltered air to

escape through venting. Air should pass only through the filtering system (the faceplate) of the mask. A pliable metal or adhesive strip in the top hem of some masks provides a firm, contoured fit over the bridge of the nose. This strip may help prevent fogging of protective eyewear. Masks should be either on (properly) or off. They should not be reused for different procedures (e.g., by allowing the mask to hang from the neck or by tucking it into a pocket). Bacteria that have been filtered by the mask become dry and airborne if the mask is worn necklace-fashion. Touching only the strings during removal of the mask reduces contamination of the hands. Masks should be changed between procedures and sometimes during a procedure, depending on the length of the operation and the amount of talking done by the team. The facepiece, which is contaminated with droplet nuclei, should not come into contact with the hands of personnel. Immediately after removal, masks should be discarded directly into a designated covered waste receptacle. After discarding the mask, the wearer must wash and dry the hands thoroughly (AORN, 2009b).

Gloves should be selected according to the task to be completed: sterile gloves for sterile procedures, and medical, unsterile gloves for nonsterile activities. Gloves should be changed between patient contacts and after contact with any infectious material. Hands should be washed thoroughly after gloves are removed. To reduce the risk of mouth, nose, and eye mucous membrane exposure, protective eyewear, masks, or face shields are worn whenever there is opportunity for contamination by splash or aerosols. When the protective devices become contaminated, they should be discarded or decontaminated as soon as possible to prevent contamination to the wearer. Other protective equipment such as liquid-resistant attire, including gowns and shoe covers, should be worn whenever there is a reasonable expectation of exposure to infectious materials (AORN, 2009b).

Surgical Hand Hygiene

Skin is a major source of microbial contamination in the surgical environment. Although members of the surgical team at the sterile field wear sterile gowns and gloves, the skin of their hands and forearms should be cleaned preoperatively to reduce the number of microorganisms in the event of glove failure. The purposes of surgical hand hygiene are as follows: to remove dirt, skin oil, and transient microorganisms from the nails, hands, and forearms; to reduce the resident microbial count to as near zero as possible; and to leave an antimicrobial residue on the skin to prevent regrowth of microbes for several hours (AORN, 2009n). Hand hygiene has been recognized as a primary method of decreasing healthcare-associated infections (Haas et al, 2008). The skin can never be rendered sterile, but it can be made surgically clean by reducing the number of microorganisms present.

The term hand hygiene is currently used to describe measures related to the physical hand condition and decontamination. Decontamination of the hands can be done by a variety of methods:

- Handwashing using soap and water, antiseptic and water, or antiseptic hand rub if visible soil is not present
- Surgical hand scrub using water-aided brushless surgical antiseptics; waterless, brushless surgical antiseptics; or traditional surgical hand scrub using a sponge (WHO, 2009; AORN, 2009n)

A standardized procedure for handwashing should be established and followed within the healthcare setting.

Scrub persons should be in good health and possess healthy, intact skin. Healthcare personnel with cuts, abrasions, weeping dermatitis, or fresh tattoos on exposed skin should not provide direct patient care because of the potential risk for infection (AORN, 2009n). The AORN's *Recommended Practices for Hand Hygiene in the Perioperative Setting* (2009a) provide guidance for healthcare personnel in relation to direct patient care.

Because microorganisms may be protected and harbored by rings, watches, body-piercing jewelry, and bracelets, these items should be removed before scrubbing (AORN, 2009n). Fingernails of scrub persons should be short, clean, and healthy. The subungual region of the nails harbors most microorganisms found on the hands. Soap, running water, and a nail-cleaning device are necessary to clean under the fingernails. Nails that extend beyond the tips of the fingers are more difficult to clean and increase the risk of glove tears. Longer nails also may scratch patients during the positioning or transfer process. Artificial nails or synthetic nails should not be worn by personnel in the perioperative environment. Higher numbers of gram-negative organisms have been cultured, both before and after handwashing, from the nails of individuals wearing artificial nails or nail additives than from individuals with natural nails. Fungal growth also occurs under artificial nails as a result of trapped moisture between the natural and artificial nail. The length of artificial nails may interfere with effective hand scrubs and handwashing. Studies have shown the positive correlation between the number of microorganisms present on healthcare personnel's hands to the number of patients who have surgical site infections (Anderson et al, 2008; AORN, 2009n).

Facility infection control procedures govern the selection of materials and the methods used for surgical hand hygiene. This may be accomplished by a surgical scrub or with the use of an approved hand rub agent.

Surgical Hand Rubs. Alcohol-based hand rubs are easy to use and fast-acting, and they provide activity against most bacteria, viruses, and fungi. All hand rub products that are alcohol-based are not indicated for use in place of the traditional hand scrub. Rubs come in many forms, combinations, and concentrations of alcohols, which may influence the antimicrobial strength and kill factor. Surgical hand hygiene products should be selected following a thorough analysis of each product's efficacy, effectiveness, application processes, cost-benefit ratio analysis, and acceptance by its users. When hand rubs are used for surgical hand antisepsis, the only acceptable products are alcohol-based antiseptic surgical hand rubs with documented persistent and cumulative activity that have met U.S. Food and Drug Administration (FDA) regulatory requirements for surgical hand antisepsis. The manufacturer's written instructions for product use, including time and amount, should be followed. The basic steps of a surgical rub are as follows:

1. Follow the manufacturer's written directions for use of the product.
2. Use the recommended amount of hand rub product.
3. Rub hands and cover all surfaces, including the backs of hands, fingertips, inner webs, and palms.
4. Rub hands until they are dry.

A sufficient amount of product is required to ensure the antimicrobial effect of the rub (AORN, 2009n).

Surgical Hand Scrub. A surgical hand scrub should be performed by healthcare personnel before donning sterile gloves for surgical or other invasive procedures (AORN, 2009n). For the traditional, standardized surgical scrub, individually packaged disposable brushes and sponges or synthetic sponges without a brush may be used. The use of synthetic sponges in place of brushes has gained wide acceptance, especially where long and repeated scrubbing may be traumatic to the skin. Disposable brushes or sponges are available with a variety of antimicrobial soap or antiseptic solutions impregnated into the sponge. A thorough handwash with an antimicrobial agent may be as effective as the traditional surgical scrub using a brush or sponge (TJC, 2009; AORN, 2009n).

Surgical hand scrub agent selection should be based on the efficacy and effectiveness of the product, application requirements, contact time, and user-friendliness. The antimicrobial soap or detergent used for the surgical hand scrub should have the following attributes:

- Reduce microorganisms on the skin
- Be fast-acting
- Have a broad range of activity
- Not depend on cumulative action
- Have a minimally harsh effect on skin
- Inhibit regrowth of microorganisms

Antimicrobial agents used for surgical hand scrubs include povidone-iodine complex and chlorhexidine gluconate (CHG). These agents are broad-spectrum, rapid-acting antimicrobials that are effective against many gram-positive and gram-negative microorganisms. Individuals who have skin sensitivity to CHG may use another broad-spectrum antimicrobial agent, *para*-chloro-*meta*-xylenol (chloroxylenol, PCMX), as an effective alternative agent for surgical scrubbing. Moisturizing agents are now being incorporated into various surgical scrub agents to reduce the potential of skin irritation resulting from multiple scrubs.

An anatomic scrub, using a prescribed amount of time or number of strokes plus friction, is employed for effective cleansing of the skin. The fingers, hands, and arms should be visualized as having four sides; each side must be scrubbed effectively. Individual attention to detail is essential. The prescribed number of strokes with a brush is usually 30 strokes to the nails and 20 strokes to each area of the skin. When using the timed approach, the institution's policies and procedures should be followed. Surgical hand scrub procedures should be documented and available within the perioperative practice setting.

SCRUB PROCEDURE. Before beginning the surgical hand scrub, members of the surgical team should inspect their hands to ensure that their nails are short, their cuticles are in good condition, and no cuts or skin problems exist. The procedure may include but not be limited to the following:

1. Remove all jewelry, including rings, watches, and bracelets, from the hands and forearms.
2. Cover all head and facial hair. Don a surgical mask. If other personnel are at the scrub sink, a surgical mask should be worn in the presence of hand scrub activity. Protective eyewear, such as goggles with side shields or a full-face shield, should be adjusted to ensure clear vision and to avoid lens fogging. Personnel confirm that the scrub shirt is tucked into the trousers to prevent potential contamination of the scrubbed hands and arms from brushing against loose garments.

The basic steps of the scrub procedure follow:

1. If visibly soiled, wash hands and forearms with soap and running water immediately before beginning the scrub procedure. Bring water to a comfortable temperature. Most scrub sinks have automatic or knee controls for the faucets.
2. Moisten hands and forearms. Using a foot control, dispense the manufacturer's recommended amount of the antimicrobial agent into the palms, adding small amounts of water to create lather if necessary.
3. Wash hands and forearms using the antimicrobial soap or detergent. Rinse before beginning the surgical hand scrub. The amount of time needed varies with the amount of soil and the effectiveness of the cleansing agent.
4. Open the scrub brush/sponge package, remove the brush and nail cleaner, and discard the package. Hold the brush in one hand; clean the subungual areas of both hands under running water and then complete the nails on the other hand (Figure 3-17).
5. Rinse the hands and arms thoroughly, exercising care to hold the hands higher than the elbows. Avoid splashing water onto the surgical attire because this moisture may cause subsequent contamination of the sterile gown.
6. Moisten the brush or sponge (if the brush or sponge is impregnated with antimicrobial soap) and begin scrubbing. If the brush or sponge is not impregnated with soap, apply antimicrobial soap or detergent solution to hands according to the manufacturer's written instructions. Starting at the fingertips, scrub the nails vigorously, holding the brush perpendicular to the nails. Scrub all sides of each digit, including the connecting webbed spaces. Next scrub the palm and back of the hand. Repeat on the other hand and arm.
7. Scrub each side of the forearm with a circular motion (see Figure 3-17) up to the elbows.
8. Hold the hands and arms away from the body, with the hands above the level of the elbows while scrubbing, allowing the water and detritus to flow away from the first-scrubbed and cleanest area. Add small amounts of water during the scrub to develop suds and remove any excess debris.
9. Rinse the hands and arms thoroughly.
10. Turn off the faucet by using the knee control or by using the edge of the brush on a hand control. Discard the brush or sponge.
11. Hold the hands and arms up in front of the body with elbows slightly flexed and enter the OR.

If the timed method is used, the policies and procedures of the facility should be followed.

Drying the Scrubbed Area. Moisture remaining on the cleansed skin after the scrub procedure should be dried with a sterile towel before donning sterile gown and gloves. The gown and gloves should be opened on a flat surface before the surgical scrub is completed. A small sterile field is created by the gown wrapper, which is opened over the flat surface. The gown and gloves should not be opened on the sterile back table because of the increased chance of contamination to the field. The towel must be used with care to avoid contaminating the clean skin. The folded towel is grasped firmly near the open corner and lifted straight up and away from the sterile field without dripping contaminated water from the skin onto the sterile field. The person steps away from the sterile field and bends forward slightly from the waist, holding the hands

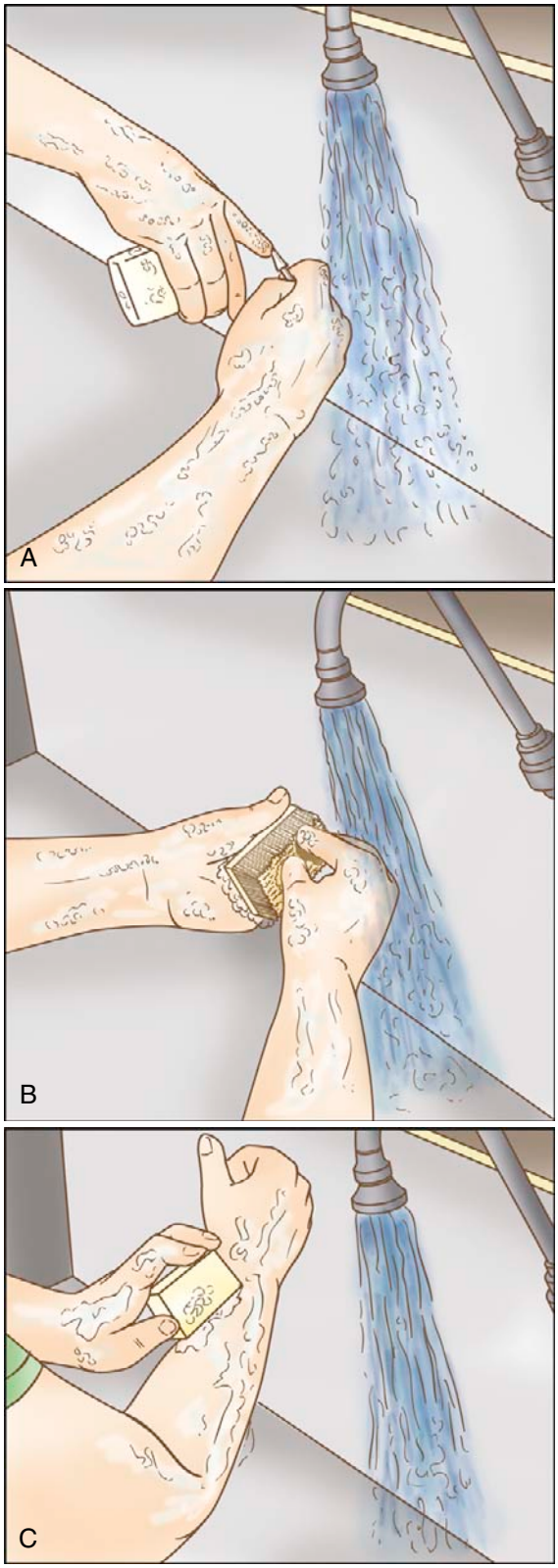


FIGURE 3-17 Traditional surgical scrub technique. **A**, Cleaning nails with plastic nail cleaner. **B**, Holding brush/sponge perpendicular to nails facilitates thorough scrubbing of underside of nails. **C**, Holding brush/sponge lengthwise along arm covers maximum area with each stroke.

FIGURE 3-18 Drying hands and forearms. Fingers and hand are dried thoroughly before forearm is dried. Extending arms reduces possibility of contaminating towel or hands.

and elbows above the waist and away from the body. The towel is allowed to unfold downward to its full length and width (Figure 3-18).

The top half of the towel is held securely with one hand and the opposite fingers and hand are blotted dry, ensuring that they are thoroughly dry before moving to the forearm. To avoid contamination, use a rotating motion while moving up the arm and do not retrace an area. The lower end of the towel is grasped with the dried hand, and the same procedure is used for drying the second hand and forearm. Care must be taken to prevent contamination of towel and hands. On completion, discard the towel without dropping the hands below waist level.

Gowning

Before scrub personnel touch sterile equipment or the sterile field, they must put on sterile gowns and surgical gloves to prevent microorganisms on their hands and clothing from being transferred to the patient's wound during surgery. The sterile gowns and gloves also protect the hands and clothing of personnel from microorganisms present in the patient or in the atmosphere.

The surgical gown should be made of a combustion-resistant material that establishes an effective barrier to minimize the passage of microorganisms, particulate matter, and fluids between unsterile and sterile areas. Reusable fabrics must allow complete penetration of steam during the sterilization process and should withstand multiple launderings and other processing. Tests indicate that 280-thread count, water repellent–treated materials lose their barrier quality when subjected to multiple laundering, and sterilizations, usually at about 75 to 100 cycles. The manufacturer must provide the facility with instructions for testing the material at periodic intervals during the life cycle of the product to ensure continued barrier quality. The particular item should be removed from circulation when the maximum number of

processing cycles have been reached. If possible, the item may be used in circumstances where surgical-barrier quality is not needed. With each processing, reusable materials also must be examined for worn areas, holes, or fraying. If these occur, the material should be removed from use. To reduce particle dissemination into the wound and the environment, materials used for surgical gowns and drapes should be resistant to penetration by blood and other body fluids as necessitated by their use (AORN, 2009o). Regardless of the gown material, the shape and size should fit personnel and allow freedom of movement. To provide extra protection, the gown's front from the waist upward and the forearms of the sleeves can be reinforced with additional or different water-repellent material. Each sleeve should be finished with a tight-fitting cuff that prevents the inner side of the sleeve from slipping down onto the outer side of the sterile glove. Cotton tapes, snaps, or Velcro fasteners are attached to the back of the gown to hold it closed. A wraparound gown may be used to achieve better coverage of the back. Once donned, however, the back of the gown is never considered sterile.

Because the outer side of the front and sleeves of the gown come into contact with the sterile field during surgery, the gown must be folded so that the scrub person can put it on without touching the outer side with bare hands. For in-house wrapping and sterilization, the gown is folded with the inner side out and the back edges together. The sleeves are not turned inside out; consequently, they remain within the folded gown. The side folds of the gown are folded lengthwise toward the center back opening, overlapping slightly at the center. With the open edges of the gown remaining on the inside, the bottom third of the gown is folded upward and the top third of the gown is folded over the bottom portion. The gown is then folded in half widthwise so that the inside front neckline of the gown is visible on top. Gowns with wraparound backs are prepared in the same manner, with care taken to tie the tape securely on the wraparound back flap to the external side tie of the gown before initial folding. A folded hand towel with its free corners facing up is usually placed on top of the folded gown before the gown is wrapped and sterilized. Surgical gowns should be selected for use according to the barrier quality of the item and the wearers' anticipated exposure to blood and body fluids in accordance with OSHA's guidelines for the use of PPE (OSHA, 2001).

Self-Gowning Procedure. The procedure for donning a wraparound sterile surgical gown is as follows (Figures 3-19 and 3-20). The scrub person should do the following:

1. Grasp the sterile gown at the neckline with both hands and lift from the wrapper. Step into an area where the gown may be opened without risk of contamination.
2. Hold the gown away from the body, and allow it to unfold with the inside toward the wearer.
3. Keep hands on the inside of the gown while it completely unfolds.
4. Slip both hands into the open armholes, keeping the hands at shoulder level and away from the body.
5. Push the hands and forearms into the sleeves of the gown, advancing the hands only to the proximal edge of the cuff.

The perioperative nurse should then do the following:

1. Pull the gown over the scrub person's shoulders, touching only the inner shoulder and side seams.

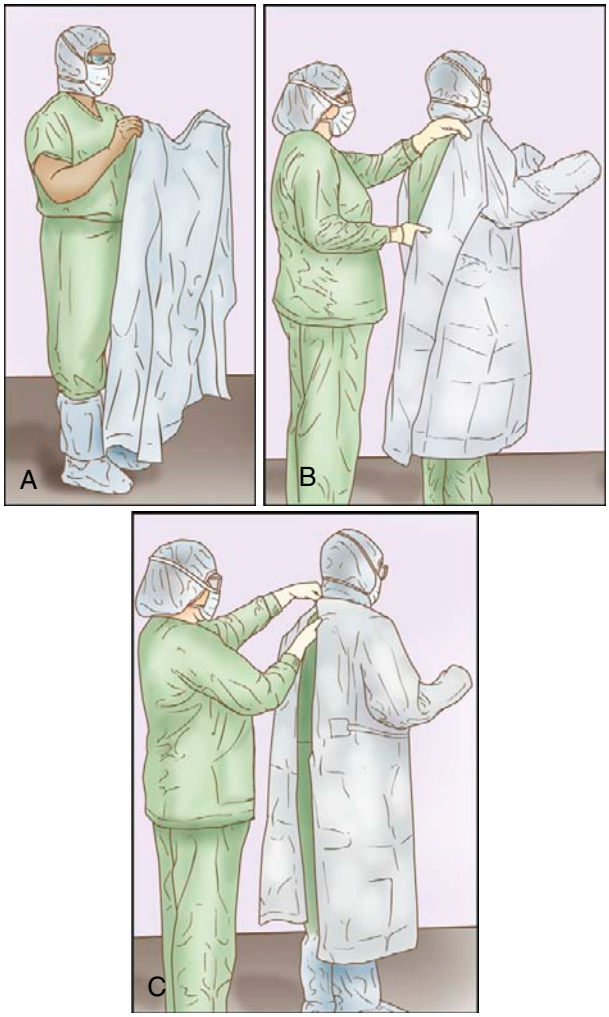


FIGURE 3-19 Gowning procedure. **A**, Scrub person keeps hands on inside of gown while unfolding it at arm's length. **B**, Circulating nurse reaches under flap of gown to pull sleeves on scrub person. **C**, Circulating nurse snaps neckline of gown, touching only snap section of neckline.

2. Tie or clasp the neckline and tie the inner waist ties of the gown, touching only the inner aspect of the gown. The gown should be completely fastened by the perioperative nurse before the scrub person dons gloves, to prevent contamination from flapping of the gown.

To secure the gown, the scrub person and the perioperative nurse do the following:

1. Take the tab (which is attached to the back tie of the gown) from the gloved scrub person. The scrub person then makes a three-fourths turn to the left while the perioperative nurse extends the back tie to its full length. This action effectively wraps the back panel of the gown around the scrub person and covers the previously tied inner waist ties. The scrub person retrieves the back tie by carefully pulling it out of the tab held by the nurse and ties it with the other tie, which had been secured to the front top of the gown.

When a reusable gown is used, the absence of a tab on the back tie necessitates use of an alternative procedure for securing the gown (see Figure 3-20, *C, D,* and *E*). If the closed-gloving technique and commercially prepared, double-wrapped gloves

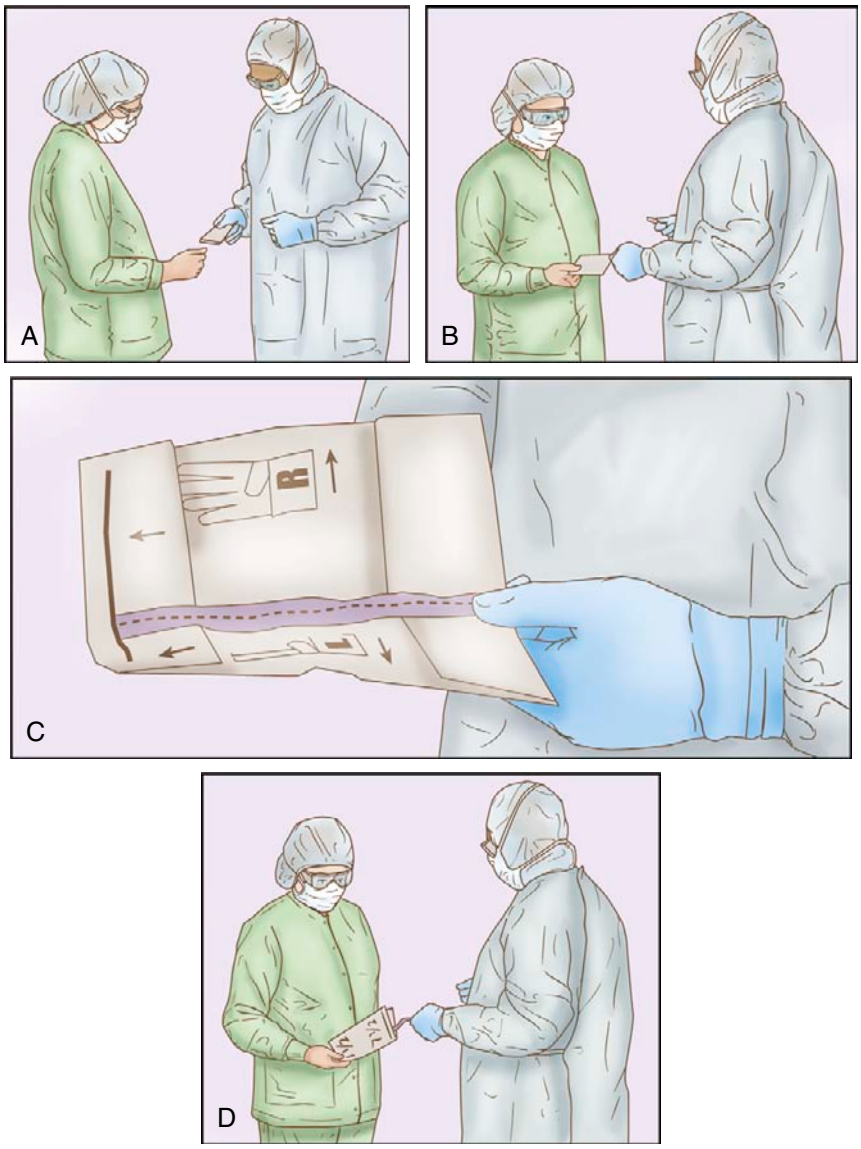


FIGURE 3-20 Methods of tying a wraparound gown. **A**, After handing tab on back tie of gown to perioperative nurse, scrub person makes a three-fourths turn toward the left. **B**, Sterile back panel now covers previously tied unsterile ties; scrub person retrieves back tie by carefully pulling it out of the tab held by the nurse and ties it securely with other tie. **C**, For gowns having no tab on back tie: using sterile inner glove wrapper, scrub person places the end of the back tie in the crease of the wrapper. **D**, After closing the wrapper, scrub person hands tie to the nurse, who grasps it carefully, touching neither the tie nor the gloved hand of the scrub person. The scrub person makes a three-fourths turn to the left, carefully pulls back tie from wrapper and ties it with other tie.

are employed, the inner wrap can be used as a protective extension for the gown tie when the perioperative nurse assists with tying a wraparound gown. After gloving, the scrub person unties the exterior gown ties (which were tied at the front of the gown before it was folded, wrapped, and sterilized) and holds both ties. The end of the back tie is placed in the center crease of the empty glove wrapper, approximately two thirds of the way up to the edge of the opened wrapper. The glove wrapper is then closed so that the tie is concealed. The closed wrapper is handed to the perioperative nurse, who firmly grasps the folded edge of the wrapper without touching the tie. The scrub person pivots in the opposite direction from the nurse, who extends the back tie to its full length. The scrub person grasps the exposed portion of the back tie, pulls it out of the glove wrapper while taking care to avoid touching the glove wrapper or the perioperative nurse, and ties both ties. If a sterile glove wrapper is unavailable, a sterile hemostat or ringed forceps may be clamped to the back tie and used in the same manner as a glove wrapper. After the gowning procedure has been completed, the perioperative nurse retains the instrument in the room to avoid problems with the subsequent instrument count.

If another scrub person is gowned and gloved, that individual, instead of the perioperative nurse, may assist with the wraparound procedure. The assisting individual must extend the back tie to its fullest length before the scrub person turns, to avoid any potential contamination.

FIGURE 3-21 Gowning another person. Gowned and gloved scrub person cuffs neck and shoulder area of gown over gloved hands to prevent contamination as scrub person puts hands and forearms into sleeves.

Assisted-Gowning Procedure. A gowned and gloved individual may assist another individual in donning a sterile gown (Figure 3-21). The gown is opened in the manner previously described. The inner side with the open armholes is turned toward the individual who is to be gowned. A cuff is made of the neck and shoulder area of the gown to protect the gloved hands. The gown is held until the person's hands and forearms are in the sleeves of the gown. The perioperative nurse assists in pulling the gown onto the shoulders, adjusting the back, and tying the tapes. The wraparound back on the gown is fixed into position by the scrub person after gloving is completed.

Gloving

Scrubbed personnel wear sterile surgical gloves to provide a protective barrier between the patient and healthcare personnel to decrease the probability of exposing the patient to exogenous organisms with a resulting surgical site infection. Gloves also decrease the chance of the healthcare provider being exposed to blood or other potentially infectious material. Nonetheless, many surgeons, first assistants, and perioperative scrub personnel have encountered blood on their hands at the conclusion of a surgical procedure without being aware of any breech in the glove barrier (glove puncture, tear, or rip). Increasing evidence supports and recommends the practice of double-gloving to offer a degree of protection from this and other common events (Research Highlight). The evidence for wearing two pairs of gloves during surgical procedures is compelling. According to Copeland (2009), *"Two layers of surgical gloves can reduce the number of breaks to the innermost glove that might allow cross-infection between the surgical team and patient…A second pair of gloves does protect the first set, without apparently lessening surgical skill."* Two gloves are better than one, and although this may be considered optional, all evidence points to double-gloving as being the best practice that can protect both the healthcare provider and the patient (Copeland, 2009). Although a breech may occur in the outer glove, the inner glove remains intact and continues to serve as a barrier. Some surgeons who work in areas where perforation risk is high, such as orthopedics or thoracic surgery, opt to wear double-layer gloves, with the inside glove being a colored glove, which allows the wearer to recognize perforations to the outer glove. In orthopedic surgery, surgeons may wear a glove liner between two layers of gloves to reduce perforations to the inner glove. On completion of the case, both pairs of gloves should be discarded, and hand antisepsis should be performed (Copeland, 2009).

The use of powder as a glove lubricant is not recommended because of three primary hazards: the potential for postoperative complication of powder granulomas; powder fallout from hands and gloves, which provides a convenient vehicle for dissemination of microorganisms throughout the OR; and the ability of powder to carry and disperse latex proteins, contributing to an increased latex sensitivity among healthcare workers and others. Powder-free gloves are widely available. If powdered gloves are chosen, any glove film or powder must be removed. The gloves must be wiped thoroughly after they are put on and before approaching the sterile field.

Latex Allergies and Sensitivities. The increased reporting of latex sensitivity continues to be a concern among perioperative personnel. Individuals can experience three types of reactions to latex. *Irritant contact dermatitis* is the most common type of reaction and is characterized by dry, reddened, itchy, or cracked hands. Irritant contact dermatitis is not a true allergic reaction. *Allergic contact dermatitis* is considered a type IV allergic reaction and is an allergic response caused by chemicals used in the manufacture of gloves. Allergic contact dermatitis is a delayed reaction, usually appearing 6 to 48 hours after exposure. Symptoms are similar to those of irritant contact dermatitis except that the reaction may extend beyond the actual point of contact. *True latex allergies* are classified as type I allergic responses. This is an allergy to water-soluble natural rubber latex (NRL) proteins. True latex allergies are usually seen within minutes of contact with the proteins. Symptoms range from skin redness and itching to hives, dyspnea, gastrointestinal upset, hypotension, tachycardia, and anaphylaxis. Reactions to latex rarely progress to anaphylaxis because the wearer is treated with appropriate drugs to interrupt the allergic response. Appropriate latex-free gloves should be provided for healthcare workers with known latex sensitivity or for procedures in which patients have known sensitivity or allergy. Some personnel claim allergy to the starch powder in latex gloves. Although this is possible, it is more likely that individuals are allergic to the latex proteins that bind with the starch powder and become aerosolized (AORN, 2009p).

RESEARCH HIGHLIGHT

Perioperative Practice of Double-Gloving

The ever-changing healthcare environment challenges perioperative practitioners to become more aware and challenged by their everyday practices. Preventing infections is critical to patient safety and protective barriers must be utilized to reduce the risk of skin exposure to potentially infectious materials. OSHA recommends that personal protective barriers be required when it can reasonably be anticipated that a healthcare worker will be exposed to blood, body fluids, or other infectious materials.

Surgery itself is considered invasive and increases the likelihood of healthcare personnel's exposure to blood and body fluids. Pathogens can be transferred through direct contact from the patient to the surgical team, resulting in infections. Both patients and healthcare providers need to be protected against the risks that exist today. In several studies, it was determined that the risk can be reduced by wearing two pairs of gloves, as opposed to wearing one pair. This provides an additional barrier and further reduces the risk of contamination and subsequent infection.

In reviewing the Cochrane Database, 14 trials of double-gloving (i.e., wearing 2 pairs of surgical gloves) were identified. In each of these trials, it was determined that more perforations were seen to a single glove than to an innermost glove during a double-gloving process. Along with the primary 14 trials, an additional 8 trials were performed using indicator gloves (colored latex gloves worn underneath latex gloves to more rapidly alert the team of perforations). These additional eight trials showed no direct evidence that glove protection worn by the surgical team reduces surgical site infections. The AORN's *Recommended Practices for Prevention of Transmissible Infections in the Perioperative Practice Setting* recommends the double-glove procedure during invasive procedures because of several issues based on a systematic review of the literature:

- Wearing two pairs of gloves significantly reduces the number of perforations to the inner glove.
- Wearing two pairs of gloves does not increase the risk of perforation to the outer glove.
- Wearing one pair of standard gloves on top of a pair of standard colored gloves facilitates rapid recognition of perforations to the outer glove.
- Wearing two layers of colored gloves does not assist in the recognition of a breach of the glove.
- Wearing a glove liner between both layers of gloves does not reduce the risk of perforation to the inner glove.
- Wearing steel-woven outer gloves during orthopedic surgery does not reduce the number of perforations to the inner glove, in comparison to the double-gloving technique.

In conclusion, the Centers for Disease Control and Prevention (CDC), the American College of Surgeons (ACS), and the American Academy of Orthopaedic Surgeons (AAOS) support the double gloving technique during invasive procedures. Although evidence points to double-gloving being a best practice, further research needs to be ongoing to ensure that this process is protecting the healthcare provider and patient and is fiscally responsible.

Modified from The Joint Commission (TJC): *Measuring hand hygiene adherence: overcoming the challenges,* OakBrook, Ill, 2009, available at www.jointcommission.org/PatientSafety/InfectionControl/hh_monograph.htm. Accessed April 30, 2009; Association of periOperative Registered Nurses (AORN): Recommended practices for prevention of transmissible infections in the perioperative practice setting. In *Perioperative standards and recommended practices,* Denver, 2009, The Association; Occupational Safety and Health Administration (OSHA): Occupational exposure to bloodborne pathogens: final rule, *Fed Register* 56(235), 1991, available at www.osha.gov. Accessed June 12, 2009; Tanner J, Parkinson H: Double gloving to reduce surgical cross-infection, *Cochrane Database Syst Rev* 2006, issue 2, article no. CD003087, DOI: 10.1002/14651858.CD003087.pub2; Copeland JT: Do surgical personnel really need to double-glove? *AORN J* 89(2):322-330, 2009.

Closed-Gloving Technique. The closed method of gloving (Figure 3-22) is the technique of choice when initially donning a sterile gown and gloves. Using this technique, the gloves are handled through the fabric of the gown sleeves. The hands are not extended from the sleeves and cuffs when the gown is put on. Instead, the hands are pushed through the cuff openings as the gloves are pulled into place. The woven cuff should remain in the natural wrist area. Because the cuffs of a sterile gown collect moisture, become damp during wearing, and are considered unsterile, the closed-gloving technique can be used only for initial gloving. Cuffs may not be pulled down over the wearer's hand for subsequent gloving. For subsequent gloving, an alternative technique must be used, such as assisted gloving or open gloving.

Open-Gloving Technique. With the open-gloving technique, the everted cuff of each glove permits a gowned individual to touch the glove's inner side with ungloved fingers and to touch the glove's outer side with gloved fingers (Figure 3-23). Keeping the hands in direct view, no lower than waist level, the gowned individual flexes the elbows. Exerting a light, even pull on the glove brings it over the hand, and using a rotating movement brings the cuff over the wristlet. Extreme caution is necessary when using the open method to prevent contamination by the exposed hands. This gloving technique can be used by individuals not wearing a gown.

Assisted-Gloving Technique. A gowned and gloved individual may assist another gowned individual with gloving. To assist another individual, grasp the glove under the everted cuff. Ensure the palm of the glove is turned toward the ungloved individual's hand with the thumb of the glove directly opposed to the thumb of the individual's hand. Using fingers stretch the cuff to open the glove. The ungloved individual can insert his or her hand into the glove. The procedure is repeated for the other hand (Figure 3-24).

Removing Soiled Gown, Gloves, and Mask

To protect the forearms, hands, and clothing from contacting bacteria on the outer side of the used gown and gloves, members of the scrub surgical team should use the following procedure to remove soiled gowns, gloves, and masks (Figure 3-25, p. 103):

- Wipe gloves clean with a wet, sterile towel.
- Untie surgical gown; the perioperative nurse must unfasten back closures.
- Grasp gown at one shoulder seam without touching scrub clothing.

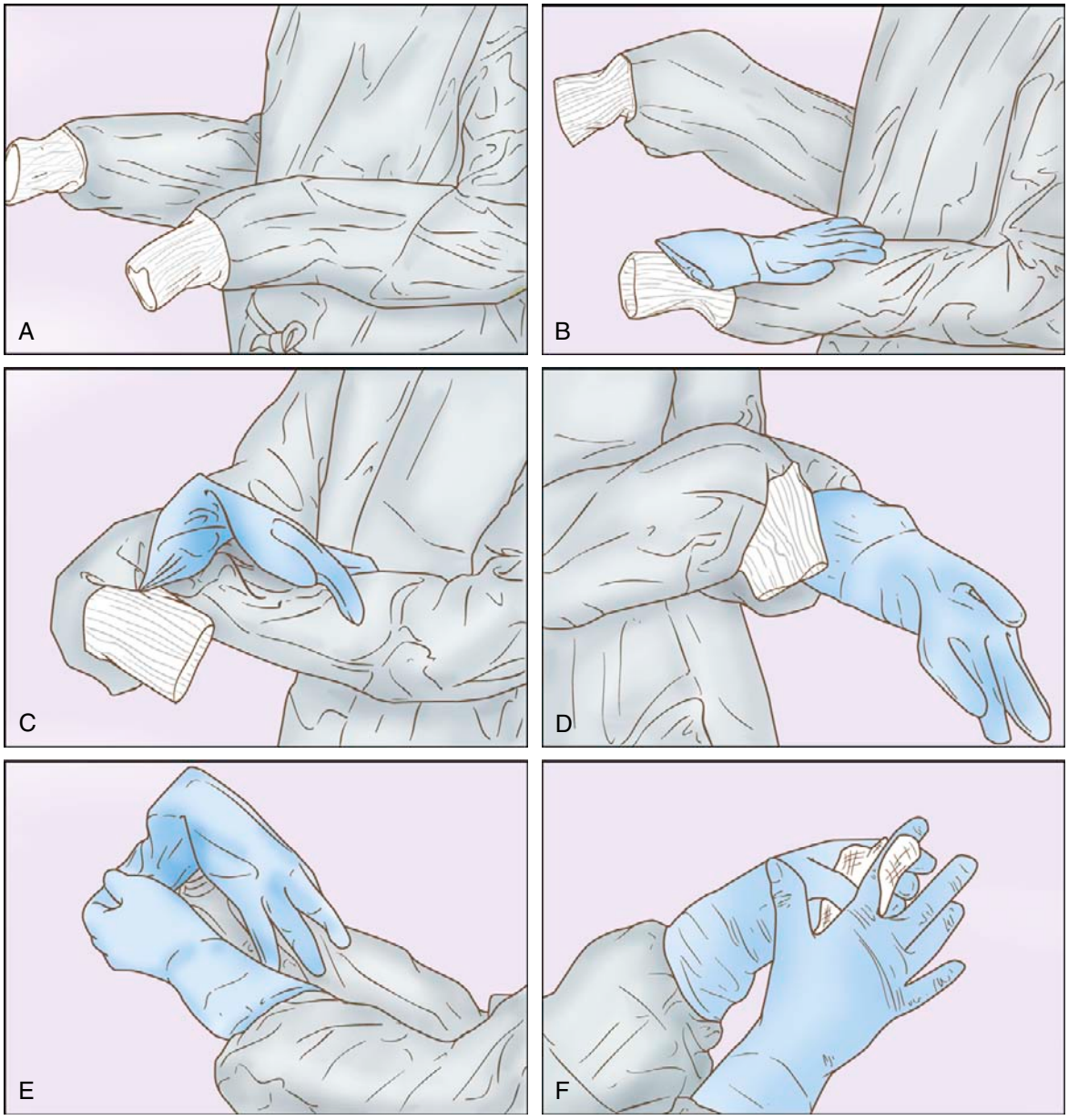


FIGURE 3-22 Closed-gloving procedure. **A**, When donning gown, scrub person does not slip hands through gown cuffs. Hands are not extended from sleeves. **B**, First the glove is lifted by grasping it through the fabric of the sleeve. The glove's cuff facilitates easier handling of the glove. The glove is placed palm down along the forearm of the matching hand, with thumb and fingers pointing toward elbow. Glove cuff lies over gown cuff. If the scrub person is double-gloving, the larger size gloves are donned first. **C**, The glove cuff is held securely by the hand on which it was placed, and with the other hand the cuff is stretched over the opening of the sleeve to cover the gown cuff entirely. **D**, As the cuff is drawn back onto the wrist, fingers are directed into their cots in the glove, and the glove is adjusted to the hand. **E**, Gloved hand is used to position remaining glove on opposite sleeve in the same fashion. Glove cuff is placed around gown cuff. The second glove is drawn onto the hand, and the cuff is pulled into place. **F**, Fingers of gloves are adjusted, and gloves are wiped with wet gauze sponge or commercially prepared sterile, disposable, glove wipe to remove any powder that may be on them.

- Bring the neck and sleeve of the gown forward, over, and off the gloved hand, turning the gown inside out and everting the cuff of the glove.
- Repeat the previous two steps for the other side.
- Keep arms and gown away from body while turning the gown inside out and discarding carefully in the designated receptacle.
- Using the gloved fingers of one hand to secure the everted cuff, remove the glove, turning it inside out. Discard appropriately.
- Using the ungloved hand, grasp the fold of the everted cuff of the other glove and remove the glove, inverting the glove as it is removed. Discard appropriately.
- After leaving the restricted area, remove the mask by touching the ties or elastic only.

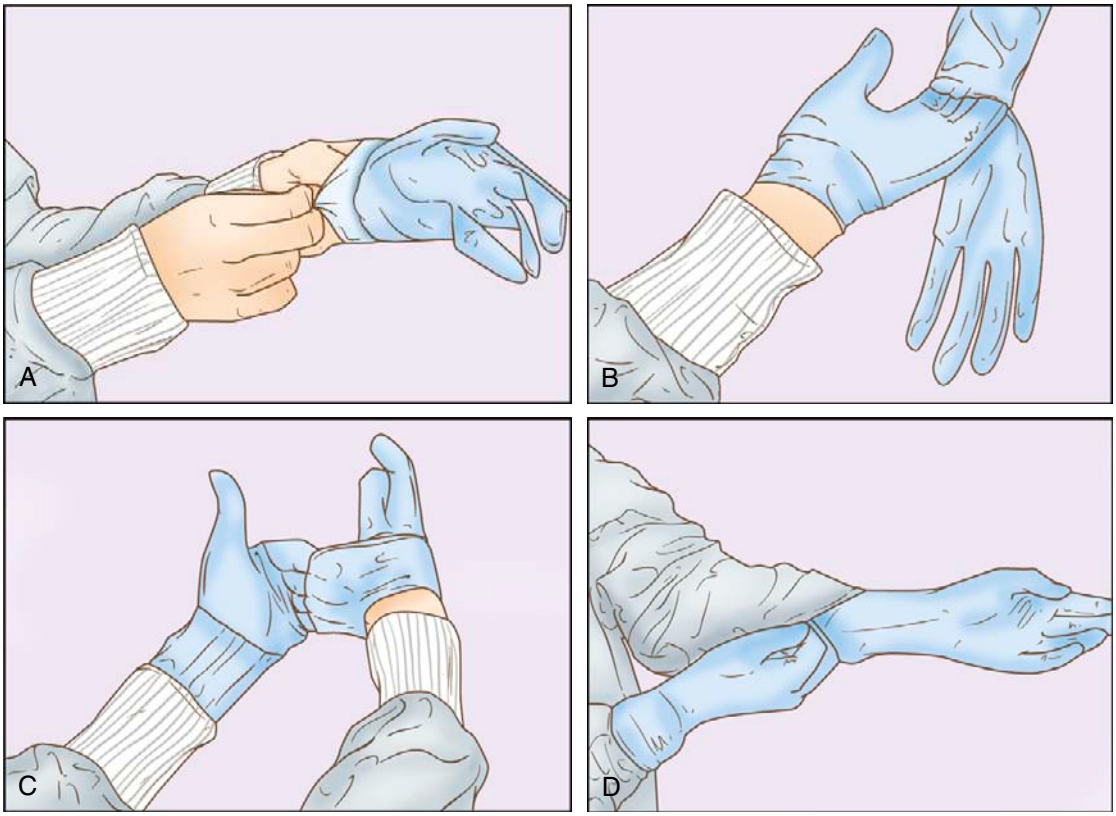


FIGURE 3-23 Open-gloving procedure. **A**, Scrub person takes one glove from the inner glove wrapper by placing the thumb and index finger of the opposite hand on the fold of the everted cuff at a point in line with the glove's palm and then pulls the glove over the hand, leaving the cuff turned back. If the scrub person is double-gloving, the larger size gloves are donned first. **B**, Scrub person takes the second glove from the inner glove wrapper by placing gloved fingers under the everted cuff. **C**, Scrub person, with arms extended and elbows slightly flexed, introduces free hand into glove and draws it over gown cuff by slightly rotating arm externally and internally. **D**, To bring turned-back cuff on other hand over cuff of gown, scrub person repeats step **C**.

FIGURE 3-24 Gloving another person. Gowned and gloved scrub person places fingers of each hand beneath everted cuff, keeping thumbs turned outward and stretching cuff as gowned person slips hand into sterile glove, using firm downward thrust. If other person is double-gloving, the larger size gloves are donned first.

- Discard in the designated receptacle.
- Wash hands and forearms.

Patient Skin Antisepsis

To prevent bacteria on the skin surfaces from entering the surgical wound, the skin area at and around the proposed incision site must be cleaned and disinfected. Skin preparation methods vary, but all are based on the same principles and share the same objectives: to remove dirt and transient microbes from the skin, to reduce the resident microbial count as much as possible in the shortest time and with the least amount of tissue irritation, and to prevent rapid rebound growth of microbes. Factors to be considered in skin disinfection are as follows:

1. Condition of the involved area
2. Number and kinds of contaminants
3. Characteristics of the skin to be disinfected
4. General physical condition of the patient

Many soaps and detergents are available for skin cleansing. Although most of them produce similar results for the immediate removal of soil and microorganisms, certain factors require further consideration in selecting a product for surgical use. Most soaps and detergents emulsify and peptize waste products and oils that are absorbed in surface soil and permit the debris to

RESEARCH HIGHLIGHT

Effects of Chlorhexidine Gluconate (CHG) Showers and Preoperative Shampoos

Patients that are Class 1 surgical interventions/procedures below the chin area should have two preoperative showers with chlorhexidine gluconate (CHG) when this is appropriate to the specific patient. As the epidemiology of infections with methicillin-resistant *S. aureus* (MRSA) changes, accurate information on the scope and magnitude of MRSA infections is needed to provide effective quality care. The incidence and estimated number of invasive MRSA infections and deaths are high. In one study of 8987 observed cases of invasive MRSA, it was noted that most MRSA infections were healthcare-associated: 58.4% (5250) were community-onset infections, 26.6% (2389) were hospital-onset infections, 13.7% (1234) were community-associated infections, and 1.3% (114) could not be classified. In 2005 the standardized incidence rate of invasive MRSA was 31.8 per 100,000. Incidence rates were highest among persons 65 years and older.

Invasive MRSA infection affects certain populations disproportionately. It is a major public health problem related to healthcare in general but no longer is confined to areas such as intensive care units, acute care facilities, or any specific health organization. *S. aureus* is the most common organism that causes surgical site infections (SSIs). The CDC's 1999 *Guideline for Prevention of Surgical Site Infection* recommended requiring patients to shower or bathe with an antiseptic agent at least the night before the operative procedure. Clinical trials have supported the use of preoperative antiseptic showers to reduce organisms on the skin and reduce the subsequent risk of surgical wound infection.

Researchers studied the effects of preoperative showering with a 4% concentration of CHG and povidone-iodine on patients whose skin was colonized with *S. sureus*. Two consecutive showers with 4% CHG the evening before surgery reduced the microbial counts in the incisional areas. Based on the study, povidone-iodine had little effect on colonization and inconsistent results ensued. The critical element is the reduction of the patients own flora with regard to Class 1 surgical wounds. For wounds that are partially or heavily contaminated, other ensuing factors are more likely to cause an SSI. Although there is sufficient evidence to support the effectiveness of two CHG showers in the reduction of microbial counts, additional research needs to be done to link the reduction of SSI rates to this decrease.

Modified from Mangram AJ et al: Guideline for prevention of surgical site infection, *Infect Control Hosp Epidemiol* 20, 1999; Centers for Disease Control and Prevention: *Guideline for prevention of surgical site infection,* 1999, available at www.cdc.gov/ncidod. Accessed April 25, 2009; Klevens RM et al: Invasive methicillin-resistant *Staphylococcus aureus* infections in the United States, *JAMA* 298(15):1763-1771, 2007; Association of periOperative Registered Nurses: Recommended practices for patient skin antisepsis. In *Perioperative standards and recommended practices,* Denver, 2009, The Association.

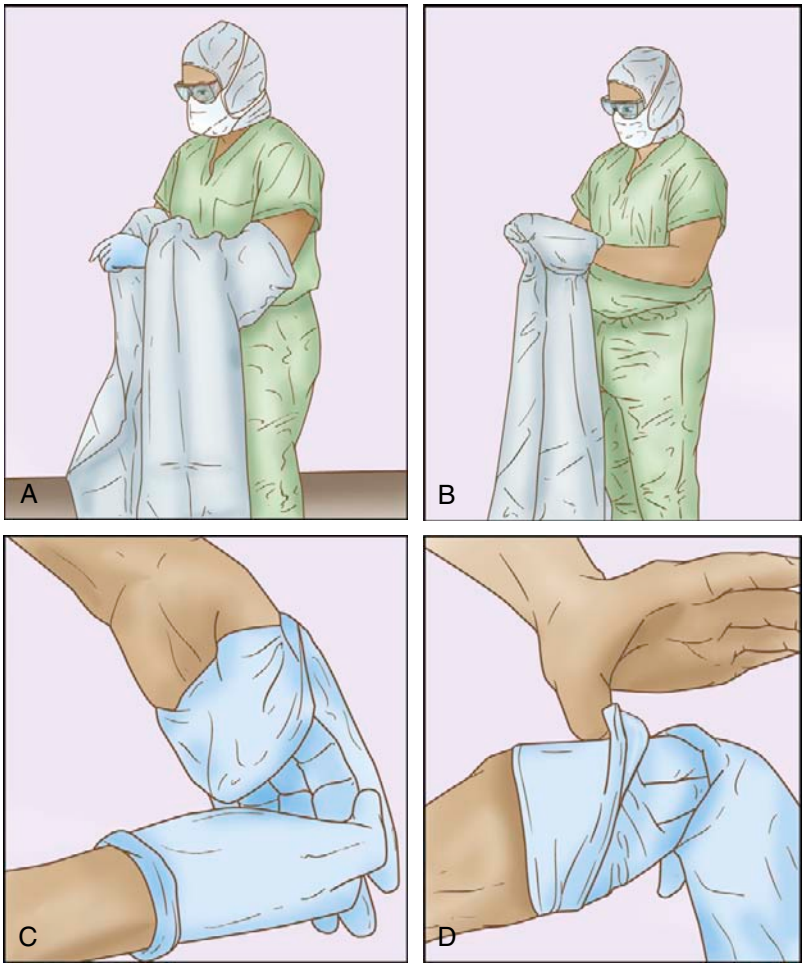


FIGURE 3-25 Removing soiled gown and gloves. **A**, To protect scrub suit and arms from bacteria that are present on outer side of soiled gown, the gown is grasped without touching the scrub clothes. **B**, Scrub person turns outer side of soiled gown away from body, keeping elbows flexed and arms away from body so that soiled gown will not touch arms or scrub suit. **C**, To prevent outer side of soiled gloves from touching skin surfaces of hands, the scrub person places gloved fingers of one hand under everted cuff of other glove and pulls glove off hand and fingers. **D**, To prevent ungloved hand from touching outer side of soiled glove, the scrub person hooks bare thumb on inner side of glove and pulls glove off.

be rinsed off the skin with running water. The product selected should become hydrolyzed in the presence of water and yield a pH that corresponds to that of average, normal skin. An odorless agent that produces a good lather for easy, comfortable use is usually preferred. It should not irritate the skin or in any way interfere with normal functioning. Equally important, an effective antimicrobial agent should be used to achieve appropriate disinfection of skin. The antimicrobial agent employed for disinfection of the skin should be selected according to its ability to decrease the microbial count of the skin rapidly, be applied quickly, and remain effective throughout the operation. The agent should not cause irritation or sensitization or be incompatible with or inactivated by alcohol, organic matter, soap, or detergent (Spry, 2005; AORN, 2009n).

Patients undergoing open Class I surgical interventions below the chin should have two preoperative showers with chlorhexidine gluconate (CHG) before surgery, when it is appropriate (Mangram, 1999). The process of washing and rinsing repeatedly removes microorganisms from the skin. Some organisms may be difficult or virtually impossible to kill with CHG alone. Unless contraindicated, patients should be instructed or assisted to perform two preoperative baths or showers with CHG before surgery to reduce the number of microorganisms on the skin and reduce the risk of subsequent contamination of the surgical wound (AORN, 2009n) (Research Highlight).

Hair should not be removed from the surgical site unless it is required. The necessity for hair removal depends on the amount of hair, the location of the incision, and the type of surgical procedure to be performed. Preoperative shaving of the surgical site increases the risk of surgical site infection (Anderson, 2008; AORN, 2009n). If hair is to be removed, clipping with an electric or battery-operated clipper, not shaving, is recommended. Clipping, immediately before surgery, is the simplest and least irritating method of hair removal. Wound infection rates are considerably higher for patients who are shaved preoperatively than for patients who have no preoperative shave preparation or a small amount of hair clipped or for patients on whom a depilatory is used. Use of a depilatory requires a pretest to ascertain that the patient is not sensitive to the depilatory product. The specific manufacturer's written instructions should be carefully followed. If a shave is desired by the surgeon, some institutions require a written order. The patient should be shaved as close to the time of surgery as is possible. The shave should be performed in an area within the surgical suite that affords privacy and is equipped with good lighting. The amount of time between the preoperative shave and the operation has a direct effect on the surgical site infection rate. Hair removal should be performed by skillful personnel, with great care taken to avoid scratching, nicking, or cutting the skin because cutaneous bacteria proliferate in these areas and increase the chances of infection. The method of hair removal and the condition of the skin before and after removal should be documented.

The surgical principle followed when preparing the patient's skin for surgery ("prepping") is to prepare ("prep") the cleanest area first and then move to the less clean areas (clean to dirty). The skin at the surgical site should be exposed and inspected before beginning the skin prep. Patients should have been instructed to remove any body jewelry before cleansing the site. Jewelry harbors microorganisms and traps these organisms in adjacent skin. Jewelry should also be removed to reduce the risk of injury when positioning the patient or from using electrical devices. Surgical departments often stock snap-ring pliers to remove jewelry from piercings for emergency situations or when a patient has neglected to remove body jewelry. The skin prep usually begins at the point of the incision and continues to the periphery of the area (Figure 3-26). When prepping the surgical site, the nurse dons sterile gloves and applies the antimicrobial agent using commercially prepared devices or applicators that have handles to provide distance between the nurse's hand and the area being prepared. A soiled applicator is never brought back over a previously prepped surface. On completion of the skin prep, the nurse blots the area with dry, sterile sponges or a sterile towel. Depending on the surgeon's preference, a topical antimicrobial solution or "paint" may be carefully applied to the prepped area, using care to avoid any pooling of solution beneath the patient. All wet drapes should be removed from the patient area after the skin preparation is complete (AORN, 2009n).

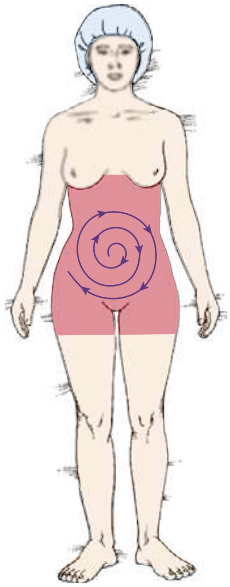


FIGURE 3-26 Principles of starting at the intended incision site and working towards the periphery are illustrated on this example of an abdominal prep. Shaded areas indicate the area to be cleaned with antiseptic; arrows show direction of motion for the prep.

When an intestinal or urinary stoma or other contaminated area is involved within the surgical field and during the prep procedure, a sponge soaked in the antimicrobial agent of choice is placed over the stoma when the prep is initiated. The area should be cleansed separately from the rest of the prepped area. At the completion of the prep, the sponge is discarded. Sponges used to cleanse or disinfect an open wound, sinus, ulcer, intestinal stoma, the vagina, or the anus are applied once to that area and discarded. In contrast to the principle of working from the proposed incision to the periphery, open wounds and body orifices are potentially contaminated areas and as such are prepared after the peripheral intact skin is cleansed. The surgical principle is to work from the cleanest to the least clean area (AORN, 2009n; Spry, 2005).

The nurse should document the area prepped and the antiseptic solution used in the perioperative record. Documentation

is an effective way to promote safe, continuous patient care. Although at times it may seem time-consuming, periodic audits of the documentation of skin preparation help the perioperative nurse assess the effectiveness of the process, while protecting patients from possible surgical site infections (AORN, 2009n; Spry, 2005).

Creating the Sterile Field with Surgical Drapes

To create a sterile field, sterile sheets and towels, known as surgical drapes, are strategically placed to provide a sterile surface on which sterile instruments, supplies, equipment, and gloved hands may rest. The patient and OR bed are covered with sterile drapes in a manner that exposes the prepared incision site and isolates it from surrounding areas. Objects normally draped and composing the sterile field include instrument tables, trays, basins, the Mayo stand, some surgical equipment, and the patient. Within this defined sterile area the actual operative procedure takes place.

Today, reusable and single-use (disposable) drapes are widely used. There are advantages and disadvantages for reusable (fabric) and single-use (disposable, nonwoven) drapes. Regardless of the type of material used, surgical drapes should have the following characteristics (AORN, 2009o):

- Appropriate barrier to microorganisms, particulate matter, and fluids
- Withstand methods of sterilization
- Maintain integrity
- Durable
- Withstand physical conditions
- Resist tears, punctures, fiber strains, and abrasions
- Free of toxic ingredients
- Low linting
- Free of holes or other defects
- Positive cost-to-benefit ratio

In addition to the characteristics just mentioned, draping materials should meet or exceed the current requirements of the National Fire Protection Association (Patient Safety).

Reusable Drapes. Chemically treated cotton or cotton-polyester fabrics provide a barrier to liquids and are abrasion-resistant. Quantitative data verifying the barrier quality of any textile drape must be provided by the manufacturer. Care should be taken with reusable drapes to eliminate pinholes caused by towel clamps, needles, or other sharp objects. Only nonpenetrating towel clamps should be used. Should breaks in the fabric occur, a heat-sealed patch may be used for repair after laundering. An abundance of heat-sealed patches on any surgical drape may interfere with the sterilization process and render the barrier ineffective. Manufacturer's written instructions on the use of patching should be followed. The exact percentage of any item that may be successfully patched is unknown. As with reusable gowns, laundering eventually impairs the barrier

PATIENT SAFETY

Preventing Surgical Fires

According to the ECRI Institute (2009) between 550 and 650 surgical fires occur each year in the United States. The consequences for both patients and the healthcare team are devastating. With appropriate awareness and good practice, all surgical fires can virtually be prevented.

The perioperative environment is a prime target for fires. The fire triad—fuel, ignition source, and oxidizers—is present in all ORs. The use of oxygen, nitrous oxide, medical air, or anesthetizing gases must always be considered as part of the oxygen-enriched environment in the OR. Ignition sources in the form of the electrosurgical units, lasers, fiberoptic lights, drills, or other surgical electrical equipment are also common. The third element—fuel—can be provided in the form of patient skin preparation agents and surgical drapes. Approximately 100 surgical fires occur annually. The Joint Commission (formerly JCAHO) issued a sentinel event alert to prevent surgical fires, and in 2005 it incorporated surgical fire prevention as a National Patient Safety Goal (NPSG). Surgical fires can be prevented if one of the elements of the fire triad is eliminated or reduced.

To reduce the risk of a surgical fire from an agent used to antiseptically prepare the surgical site, the following steps should be taken:

- Use only necessary preparation solutions and in appropriate quantities. Flammable preparation solutions should be packaged to provide for a controlled delivery, such as in unit-dose applicators or swabs.
- Avoid pooling of preparation solution. If linens on the OR bed or the patient become soaked with solution, remove them from the area.
- Allow preparation solution to dry completely (3 to 5 minutes) before surgical drapes are applied. This may be incorporated as a time-out or "all-clear" announcement before proceeding with the draping process.
- Activate an ignition source, such as an electrosurgical unit (ESU), cautery device, or laser, only when vapors from preparation solution have dissipated and areas are completely dry.
- Perform periodic safety hazard assessments for the OR environment.

If a surgical fire occurs, the *RACE* (*R*escue, *A*lert/*A*larm, *C*ontain, and *E*xtinguish) method should be used. Fire policies and fire drills should be readily available and reviewed on a continuous basis. Each member of the perioperative team is responsible for communicating with one another about the risk of surgical fires and for the steps in extinguishing a patient or airway surgical fire. Key concepts in establishing a culture of safety include evaluation, education, standard processes, and tools to foster interdisciplinary communication and collaboration. A culture of safety requires rapid identification of errors and root causes, successful implementation of improvement strategies, strong leadership, critical thinking, and commitment to excellence.

Modified from Cantrell S: Fanning the flames of surgical fire prevention, *Healthcare Purchasing News* 5, 2008; ECRI Institute: Surgical fire safety, *Health Devices* 35, 2006, available at www.hpnonline.com/inside/2008-05-OR-Fire.html. Accessed June 5, 2009; The Joint Commission: *Sentinel event alert: preventing surgical fires,* available at www.jointcommission.org/SentinelEvents/SentinelEventAlert/sea_29.htm. Accessed June 5, 2009; Ball MJ: Culture of safety, *Adv Nurses* 7(23):31-32, 2005; Giarrizzo-Wilson S: Clinical issues—fire protection standards, *AORN J* 82(4):673-674, 2005; Lypson ML et al: Preventing surgical fires: who needs to be educated? *Jt Comm J Qual Patient Saf* 31(9):522-527, 2005.

quality of the drape. Most manufacturers report a loss of barrier quality after 75 to 100 laundry or sterilization cycles. The process of laundering and steam-sterilization swells the fabric fibers, whereas drying and ironing shrink the fibers. Over time, these processes loosen fabric fibers, altering the fabric structure and decreasing the barrier properties and fluid impermeability of the fabric. As with surgical gowns, a system to monitor the number of times an item has been processed is essential for quality control of the barrier and fluid impermeability.

Single-Use (Disposable) Drapes. Many synthetic single-use (disposable) drapes prevent bacterial penetration and fluid breakthrough, also known as *strikethrough*. These versatile materials can be manufactured to meet different specifications in absorbent and nonabsorbent forms. Single-use products are packaged and sterilized by commercial sources. Single-use drapes reduce the hazards of contamination in the presence of known infectious microorganisms from body fluids and excretions and in situations where laundering of grossly contaminated textiles may be problematic. The danger inherent in the use of synthetic drapes is that solvents, volatile liquids, and sharp instruments tend to penetrate the barrier. Loss of effectiveness may be caused by cracking at the folds or by pinholes from the use of regular, perforating towel clamps. Manufacturers are continually improving single-use drapes to permit easy handling and adaptability to the body. When considering the purchase of single-use drapes, the perioperative team must determine whether the drapes will meet the needs of the surgical procedure, be acceptable to the perioperative team, and be cost-effective (versus laundering and processing of reusable drapes). A cost-benefit ratio analysis may warrant their use in the healthcare facility. Availability of items, storage facilities, and disposal methods must be analyzed (AORN, 2009q).

The environmental effect of disposable items can be only roughly estimated. Each facility must carefully evaluate its capabilities and restrictions for handling single-use and reusable supplies and equipment to make an informed decision about the products it will use in the practice setting.

Compactors provide a relatively inexpensive method of discarding disposable drapes. They accept any material and reduce its volume substantially. Storage, collection, and transportation of compacted waste materials can be a problem. Hospital engineers must establish methods of controlling odor and maintaining sanitation in the compactor area. Because a portion of the compacted material may be grossly contaminated, city or county codes may prohibit transporting this potentially infectious material through city streets or dumping it at landfills. Incineration is an alternative method for destroying waste disposables. If incinerators are used, they must be managed properly to prevent environmental contamination. Facilities choosing to incinerate must follow specific state and local guidelines established for medical waste incinerators. Many hospital incinerators do not meet federal pollution standards, and their use is prohibited.

Preassembled, sterile, disposable custom packs are used in many healthcare facilities. Advantages of these packs include reduced setup and room-turnover times, less risk of contaminated waste resulting from fewer individually wrapped items, improved inventory control, and fewer lost charges. Although custom packs may be more expensive than multiple separate items, indirect savings related to increased efficiency can offset those costs. Healthcare facilities choosing to use custom packs should determine and document ownership of liability for the function and integrity of individual items within the packs.

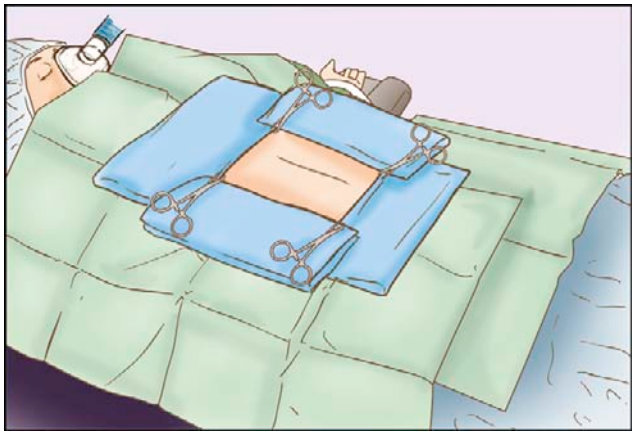


FIGURE 3-27 Abdomen may be draped with four sterile towels, which are secured with nonperforating towel clamps. Standard method of placement of disposable towels is used.

Drape Configurations. Careful planning by perioperative personnel helps determine the desired types and sizes of surgical drapes required for groups or individual surgical procedures. Standardized draping methods provide management control that ensures patient safety, simplifies staff education, and conserves human and material resources.

A whole, or plain, sheet is used to cover instrument tables, operating tables, and body regions. The sheet should be large enough to provide an adequate margin of safety between the surrounding physical environment and the prepared operative field. Surgical towels should be available in several sizes to drape the operative site. Four surgical towels of woven or nonwoven material are usually sufficient (Figure 3-27).

Fenestrated, or slit, sheets are used for draping patients. They leave the operative site exposed. A typical fenestrated (laparotomy) sheet is large enough to cover the patient and operating bed in any position, extend over the anesthesia screen at the head of the bed, and extend over the foot of the bed (Figures 3-28 to 3-30). The typical fenestrated laparotomy sheet can be used for most procedures on the abdomen, chest, flank, and back. Other types of fenestrated sheets with small or split fenestrations may be used for the limbs, head, and neck when the patient is in the supine or prone position. The size of the fenestration is determined by the use for which the sheet is intended. The fenestrated sheet is fan-folded and handled as a typical laparotomy sheet. A perineal drape is needed for procedures on the perineum and genitalia when the patient is in the lithotomy position. A lithotomy drape consists of a fenestrated sheet and two triangular leggings. Although a three-piece drape is less costly and is easier to handle and launder, a single drape with attached leggings may be used.

Several types of impermeable polyvinyl chloride (PVC) sheeting are available in the form of sterile, prepackaged surgical drapes. Plastic incisional drapes are available as a plain impermeable drape or impregnated with iodophor. These plastic drapes are useful adjuncts to the conventional draping procedure. They can be applied after the fabric drape, alleviating

FIGURE 3-28 Placement of laparotomy sheet. Identification of top portion of laparotomy sheet helps the scrub person readily determine correct placement of the drape. After placing the folded laparotomy sheet on the patient, with fenestration of sheet directly over site of incision outlined by sterile towels, the scrub person unfolds drape over sides of patient and bed.

FIGURE 3-29 Laparotomy draping continued. Scrub person protects gloved hands under cuff of fan-folded laparotomy sheet and draws the upper section above fenestration toward the head of the bed, draping it over the anesthesia screen. The bottom portion of the fan-folded sheet is extended over the foot of the bed in a similar manner.

the need for towel clamps. They obviate the need for skin towels and sponges to separate the surgeon's gloves from contact with the patient's skin. Skin color and anatomic landmarks are readily visible, and the incision is made directly through the adherent plastic drape. These materials facilitate draping of irregular body surfaces, such as neck and ear regions, extremities, and joints (Figure 3-31).

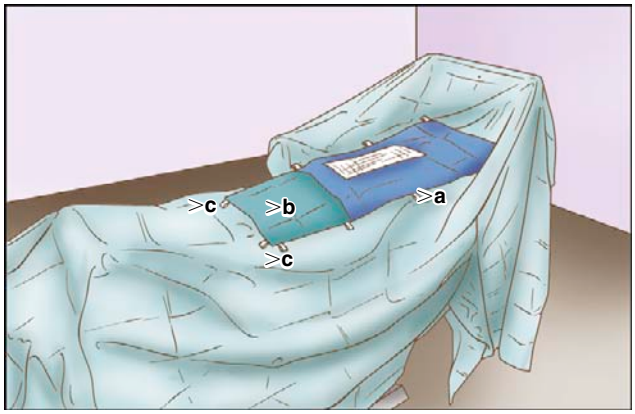


FIGURE 3-30 Laparotomy draping completed. Fenestration provides exposure of prepared operative site. *>a,* Reinforced area around drape fenestration provides greater protection and fluid control. *>b,* Built-in instrument pad prevents instrument slippage. *>c,* Perforated tabs provide means of controlling position of cords and suction tubes.

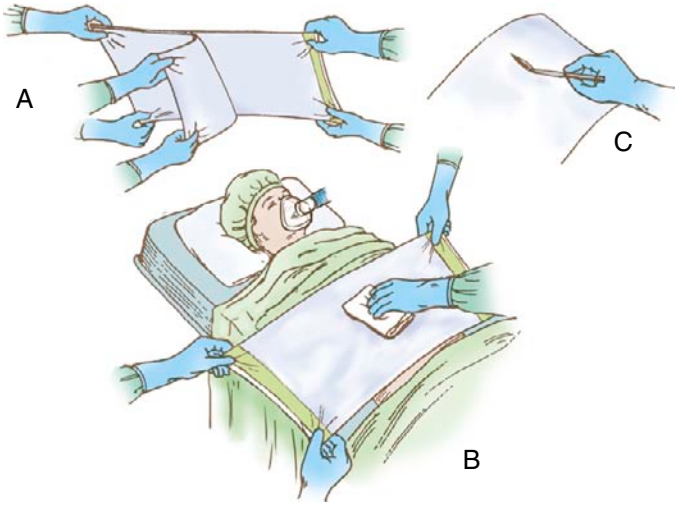


FIGURE 3-31 Sterile, impermeable adhesive drape. For maximum sealing to prevent wound contamination, prepared skin must be dry, and the drape must be applied carefully, preventing wrinkles and air bubbles. **A,** Surgeon and assistant hold plastic drape taut while another assistant peels off back paper. **B,** Surgeon and assistant apply plastic drape to operative site and, using folded towel, apply slight pressure to eliminate air bubbles and wrinkles. **C,** Surgeon makes incision through plastic drape.

Draping Procedure. Drapes should be folded so that the gowned and gloved members of the team can handle them with ease and safety. The larger, regular sheet is usually fan-folded from bottom to top. The bottom folds may be wider than the upper ones. The small sheet is folded in half and quartered, with the top corners of the sheet turned back or marked for easy identification and handling. To provide for safe, easy handling and a wide margin of safety between the unsterile item and the scrub person's gloved hands, the open end of the Mayo stand cover should be cuffed or folded back on itself (Figure 3-32). Most fenestrated sheets are fan-folded to the opening from the top and the bottom, and the folds are rolled or fanned toward the center of the

FIGURE 3-32 Draping Mayo stand. Folded cover is slipped over frame. Scrub person's gloved hands are protected by cuff of drape. Cover is unfolded to extend over upright support of stand.

opening. The edges of the top and bottom folds of the sheet are fanned to provide a cuff under which the perioperative scrub person may place his or her gloved hands. The top and lower sections should be identified by markings to facilitate easy handling.

When applying drapes to create the sterile field, these principles should be followed:

- Allow sufficient time and space to permit careful draping and proper aseptic technique.
- Handle sterile drapes as little as possible. Rapid movement of draping materials creates air currents on which dust, lint, and other particles can migrate (AORN, 2009l).
- Carry the folded drape to the operative site. Carefully unfold the drape, and place it in the proper position. Do not move the drape after it has been placed. Shifting or moving the drape may transport bacteria from an unprepared area of the patient's skin into the surgical field.
- Hold sterile drapes above waist level until properly placed on the patient or device being draped. If the end of a drape falls below waist level, it should not be retrieved because the area below the waist is considered unsterile.
- Immediately discard a drape that becomes contaminated during the draping procedure without contaminating the gloves or other sterile items.
- Protect the gown by distance. During draping, gloved hands should be protected by cuffing the draping material over the gloved hands to reduce potential contamination. Control all parts of the drape at all times during placement, using precise and direct motions.
- Do not flip, fan, or shake drapes. Shaking a drape results in uncontrolled motion ofthe drape, which may cause it to come into contact with an unsterile surface or object. A drape should be carefully unfolded and allowed to fall gently into position by gravity.
- Drape the incisional area first and then the periphery. Always drape from a sterile area to an unsterile area by draping the near side first. Never reach across an unsterile area to drape. When draping the opposite side of the OR bed, go around the bed to drape.
- Use nonperforating towel clamps or devices to secure tubing and other items on the sterile field. The low portion of a sheet that falls below the safe working level should never be raised or lifted back into the sterile area.
- Do not move the portion of the surgical drape that establishes the sterile field after it is positioned.
- Consider the drape contaminated any time the sterility is questionable.

After the patient is positioned, prepared, and draped, a time-out is conducted to verify patient identification, correct position, and correct surgical site (and side if applicable) and that required equipment is available.

Environmental Cleaning

Contamination in the OR can occur from various sources. The patient, healthcare workers, and inanimate objects are all capable of introducing potentially infectious material onto the surgical field. The patient should be provided a clean, safe, environment. Techniques have been established to prevent the transmission of microorganisms into the surgical area, such as wearing proper surgical attire and establishing controlled traffic patterns in the surgical suite. During the surgical procedure, traffic within and through the room should be kept to a minimum to reduce air turbulence and to minimize human shedding. All doors in and out of the OR should be kept closed to decrease air turbulence and the potential for contamination. HEPA filters placed between outside air processing and the OR vents are used in many facilities and are recommended for newly constructed systems/facilities. HEPA filters are capable of screening out particles larger than 0.3 μm (CDC, 2008a; AORN, 2009d). The perioperative registered nurse should assess the perioperative environment frequently for cleanliness and take action to implement cleaning and disinfection procedures if needed (AORN, 2009d; OSHA, 2001).

All surgical patients are potentially infected with bloodborne or other infectious material. For patient and personnel safety, cleaning procedures should be uniform throughout the OR and for all patients. Using a uniform procedure designed to protect persons from visible or invisible contamination eliminates the need for special cleaning procedures for so-called dirty cases. Cleaning procedures should be carried out in a manner that protects patients and personnel from exposure to potentially infectious microorganisms. Cleaning measures are needed before, during, and after surgical procedures and at the end of each day. A safe, clean environment should be reestablished after each surgical or invasive procedure. Overall housekeeping procedures, such as wall and ceiling washing, should be completed on a defined, regular basis and terminal cleaning and disinfection of operating and invasive procedure rooms should be performed when scheduled procedures are completed for the day or each regular 24-hour period (AORN, 2009d).

Transmission-based precautions are designed for patients who have a documented infection or who are suspected to be infected with a highly transmissible pathogen for which

additional precautions are necessary. There are three types of transmission-based precautions: airborne, droplet, and contact. The CDC (2008a) guidelines should be followed when all facility policies and guidelines are developed.

Before beginning the first procedure of the day, horizontal surfaces in the ORs should be dusted with a cloth dampened with a facility-approved disinfecting agent. Dust and lint deposited on horizontal surfaces during the night can become airborne vectors for organisms if not removed. During surgery, efforts should be made to confine contamination to as small an area as possible around the patient. Sponges should be discarded in plastic-lined containers. As they are counted, they should be contained in an impervious receptacle. The perioperative nurse must use protective eyewear and gloves, instruments, or both when collecting and counting sponges or handling contaminated items. Spills should be cleaned immediately, and the cleaned area should be disinfected with a broad-spectrum disinfectant or germicide. Specimens of blood or other potentially infectious tissues or materials should be placed in a container that prevents leakage. The container must be color-coded or labeled using the biohazard symbol (see Figure 3-2). If the outside of the container becomes contaminated, the primary container must be placed within a second container that prevents leakage and is labeled or color-coded. Some facilities use biohazard-labeled impervious bags to transport blood or other potentially infectious material (CDC, 2008a; AORN, 2009d).

On completion of the surgical procedure, soiled linens should be discarded in fluid-impervious bags to eliminate potential contamination from wet linen soaking through to the outside of the bag. Contaminated items should be placed in leak-proof, color-coded, or labeled containers. Sharps (e.g., needles, scalpels, electrosurgical tips) are considered infectious and should be placed in special puncture-resistant containers (OSHA, 2001). Bulk blood or suctioned fluid may be poured carefully down a drain connected to a sanitary sewer unless prohibited by environmental regulations. Local and state environmental regulations may exist and should be consulted before establishing guidelines for waste disposal. Wall suction units should be disconnected to eliminate contamination of the wall outlet. Suction contents should be disposed as soon as possible upon completion of the procedure. Depending on local and state regulations, powder treatments of a chlorine compound are available to solidify liquid material before transport. This chemical also may be tuberculocidal, virucidal, and bactericidal. Suction tubing should be discarded; reusable suction tubing should be avoided because of the difficulty of properly cleaning their lumens. Personnel should remove their gowns and gloves and place them in the proper receptacles before leaving the OR, and then perform handwashing. Instruments and supplies should be contained and taken to the decontamination area, where educated personnel wearing personal protective attire begin the instrument decontamination process. Care should be taken to arrange sharp instruments in such a manner that personnel need not reach into basins where sharp instruments are unexposed and could cause injury. Equipment and furniture in the OR should be cleaned with an EPA-approved hospital disinfectant, and the floor should be cleaned in a 3-foot to 4-foot perimeter around the operating bed and where visibly soiled. A standard practice of cleaning helps prevent surgical site infections and maintains a clean and safe environment (CDC, 2008a; AORN, 2009d).

At the end of each day's operative schedule, all rooms where procedures may be performed should be cleaned by qualified, trained, supervised personnel. Areas to be cleaned include the following:

- Surgical lights and external tracks
- Fixed and ceiling-mounted equipment
- All furniture and equipment including wheels and casters
- Equipment
- Handles of cabinets and push plates
- Ventilation faceplates
- Horizontal surfaces (e.g., countertops, fixed shelving, autoclaves)
- Floor
- Kick buckets
- Scrub sinks

If refillable liquid soap dispensers are used, they should be disassembled and cleaned before being refilled because they can serve as reservoirs for microorganisms. At the conclusion of the housekeeping protocol, cleaning equipment and supplies should be properly cleaned, disinfected, and stored. If a wet vacuum has been used, it should be disassembled and thoroughly washed with a disinfectant before being stored (AORN, 2009d).

REFERENCES

American Institute of Architects Academy of Architecture for Health (AIA); U.S. Department of Health and Human Services: Guidelines for design and construction of hospital and health care facilities, Washington, DC, 2006, available at www.aia.org. Accessed May 15, 2009.

Anderson DJ et al: Strategies to prevent surgical site infections in acute care hospitals, *Infect Control Hosp Epidemiol* 29(1):S51–S61, 2008.

Association for the Advancement of Medical Instrumentation (AAMI): Sterilization in healthcare facilities, Arlington, VA, 2009, The Association, available at www.aami.org. Accessed April 15, 2009.

Association for the Advancement of Medical Instrumentation (AAMI): Industrial process control, Arlington, VA 2009b, The Association, available at www.aami.org. Accessed April 15, 2009.

Association for the Advancement of Medical Instrumentation (AAMI): Sterilization equipment design & use, Arlington, VA, 2009c, The Association, available at www.aami.org. Accessed April 15, 2009.

Association of periOperative Registered Nurses (AORN): Recommended practices for hand hygiene in the perioperative setting. In *Perioperative standards and recommended practice,* Denver, 2009a, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for surgical attire. In *Perioperative standards and recommended practices,* Denver, 2009b, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for prevention of transmissible infections in the perioperative practice setting. In *Perioperative standards and recommended practices,* Denver, 2009c, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for environmental cleaning in the perioperative setting. In *Perioperative standards and recommended practices,* Denver, 2009d, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for the cleaning and care of surgical instruments and powered equipment. In *Perioperative standards and recommended practices,* Denver, 2009e, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for a safe environment of care. In *Perioperative standards and recommended practices,* Denver, 2009f, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for sterilization in the perioperative practice setting. In *Perioperative standards and recommended practices,* Denver, 2009g, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for selection and use of packing systems for sterilization. In *Perioperative standards and recommended practices,* Denver, 2009h, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for high level disinfection. In *Perioperative standards and recommended practices,* Denver, 2009i, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for cleaning and processing flexible endoscopes. In *Perioperative standards and recommended practices,* Denver, 2009j, The Association.

Association of periOperative Registered Nurses (AORN): AORN guidance statement: reuse of single-use devices. In *Perioperative standards and recommended practices,* Denver, 2009k, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for maintaining a sterile field. In *Perioperative standards and recommended practices,* Denver, 2009l, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for traffic patterns in the perioperative practice setting. In *Perioperative standards and recommended practices,* Denver, 2009m, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for Perioperative skin antisepsis. In *Perioperative Standards and recommended practices,* Denver, 2009n, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for selection and use of surgical gowns and drapes. In *Perioperative standards and recommended practices,* Denver, 2009o, The Association

Association of periOperative Registered Nurses (AORN): AORN latex guideline. In *Perioperative standards and recommended practices,* Denver, 2009p, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for product selection in the perioperative practice setting. In *Perioperative standards and recommended practices,* Denver, 2009q, The Association.

Banerjee S et al: Infection control during GI endoscopy, *Gastrointest Endosc* 67(6):781–790, 2008.

Centers for Disease Control and Prevention (CDC): Community-associated MRSA information for the public, 2005a, available at www.cdc.gov/ncidod/dhqp/ar_mrsa_ca_public.html. Accessed July 14, 2009.

Centers for Disease Control and Prevention (CDC): Guidelines for preventing the transmission of Mycobacterium tuberculosis in health-care settings, 2005b, available at www.cdc.gov/mmwr/preview/mmwrhtml/rr5417a1.htm. Accessed July 15, 2009.

Centers for Disease Control and Prevention (CDC): Management of multidrug resistant organisms in healthcare settings, 2006a, Atlanta, 2006, available at www.cdc.gov/ncidod/dhqp/pdf/ar/mdroguideline2006.pdf. Accessed April 15, 2009.

Centers for Disease Control and Prevention (CDC): HIV/AIDS Surveillance Supplemental Report-Vol. 14, No. 1, HIV/AIDS data through December 2006, Atlanta, 2006b, available at www.cdc.gov/hiv/topics/surveillance/resources/reports/2009. Accessed May 1, 2009

Centers for Disease Control and Prevention (CDC): Investigation and control of vancomycin intermediate and resistant *Staphylococcus aureus* (VISA/URSA): a guide for health departments and infection control personnel, 2006c, Atlanta, 2006c, available at www.cdc.gov/ncidod/dhqp/pdf/ar/visa_vrsa_guide.pdf. Accessed May 1, 2009.

Centers for Disease Control and Prevention (CDC): Overview of healthcare-associated MRSA in healthcare settings, 2007a, Atlanta, 2007, available at www.cdc.gov/ncidod/dhqp/ar_MRSA.html. Accessed April 15, 2009.

Centers for Disease Control and Prevention (CDC): 2007 Guideline for isolation precautions: preventing transmission of infectious agents in healthcare settings, 2007b, available at www.cdc.gov/ncidod/dhqp/pdf/guidelines/Isolation2007.pdf. Accessed July 15, 2009.

Centers for Disease Control and Prevention (CDC): Guideline for disinfection and sterilization in healthcare facilities, 2008, Atlanta, 2008a, available at www.cdc.gov/ncidod/dhqp/pdf/guidelines/Disinfection_Nov_2008.pdf. Accessed May 1, 2009.

Centers for Disease Control and Prevention (CDC): About CJD, 2008b, Atlanta, 2008, CDC, available at www.cdc.gov/ncidod/dvrd/cjd/. Accessed May 5, 2009.

Centers for Disease Control and Prevention (CDC): Bioterrorism overview, available at http://emergency.cdc.gov/bioterrorism/overview.asp. Accessed Nov 16, 2009.

Copeland JT: Do Surgical personnel really need to double-glove? *AORN J* 89(2):322–330, 2009.

Davenport A, Myers F: How to protect yourself after body fluid exposure, *Nursing* 39(5):23–28, 2009.

Droboni M et al: Vancomycin-resistant enterococci, Point Barrow, Alaska, USA, EID Journal, available at www.cdc.gov/eid/content/15/5/838.htm. Accessed May 20, 2009.

Haas JP et al: Compliance with hand hygiene guidelines: where are we in 2008? *AJN* 108(8):40–44, 2008.

Ignatavicius DD: Care of patients with infection, In Ignatavicius DD, Workman ML, editors: ed 6, *Medical-surgical nursing: patient-centered collaborative care* St. Louis, 2010, Saunders.

Mangram AJ et al: Guideline for prevention of surgical site infection 1999. Infection Control and Hospital Epidemiology 20 (250–278), available at www.cdc.gov/ncidod/dhqp/pdf/guidelines/SSI.pdf. October 26, 2007. Accessed June 1, 2009.

Matthews JB: *Clostridium difficile* infection in surgical patients, Access Medicine from McGraw-Hill, 2008. available at www.medscape.com. Accessed May 5, 2009.

Mitchum R: Unlocked mystery will help target insidious bacterial infection *Clostridium difficile* in hospitals. Chicago Tribune, 2009, available at www.chicagotribune.com/2009/mar/06/local/chi-fruitflies.sidebarmarch06. Accessed March 25, 2009.

Neil JA: Perioperative care of the patient with tuberculosis, *AORN J* 88(6):942–958, 2008.

Occupational Safety and Health Administration (OSHA): Occupational exposure to ethylene oxide, final standard, Federal Register 49(122):25737–25768, 1984, available at www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=FEDERAL_REGISTER&;p_id=12438. Accessed, June 12, 2009.

Occupational Safety and Health Administration (OSHA): Occupational exposure to ethylene oxide, final standard, Federal Register 53(66):11414–11438, 1988, available at www.osha.gov. Accessed June 12, 2009.

Occupational Safety and Health Administration (OSHA): Occupational exposure to bloodborne pathogens: final rule, Federal Register 56(235):64175–64182, 1991, available at www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&;p_id=10051. Accessed June 12, 2009.

Occupational Safety and Health Administration (OSHA): Occupational exposure to bloodborne pathogens: needlestick and other sharps injuries: final rule, Federal Register 66:5317–5325, 2001, available at www.osha.gov. Accessed June 12, 2009,

Patient Safety Authority (PSRS), produced by ECRI and ISMP under contract to the Patient Safety Authority: 2, June:1–8, 2005.

Rauscher M: Risk of *C. difficile* high with perioperative antibiotic prophylaxis, Reuters Health, 2008. available at www.medscape.com/viewarticle/576454. Accessed July 3, 2009.

Sampson JG, Workman ML: Care of patients with HIV disease and other immune deficiencies, In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care*, ed 6, St Louis, 2010, Saunders.

Sandlin D: Unlocking the mystery of MRSA, *J Perianesth Nurs* 23(2): 137–139, 2008.

Spry C: Brush up your skin prep protocol: manager's guide to infection prevention, Outpatient Surgery Magazine, 2005, available at www.outpatientsurgery.net. Accessed April 1, 2006.

Stanton C: AORN is working with partner organizations on safe flash sterilization, infection prevention, *AORN Connections* 6(1):8–10, 2008:1.

The Joint Commission: Measuring hand hygiene adherence: making the what, why and how decisions, Oakbrook, 2009, The Joint Commission, available at www.jointcommission.org/PatientSafety/InfectionControl/hh_monograph.htm. Accessed May 5, 2009.

WHO Guidelines on Hand Hygiene in Health Care. World Health Organization, 2009, available at www.who.int/patientsafety/information_centre/ghhad_download_link/en. Accessed June 10, 2009.

CHAPTER 4

Anesthesia

LINDA M. DeLAMAR

Without anesthesia, most modern surgical procedures would not be feasible. As integral members of the patient care team in operative and other invasive procedure settings, perioperative nurses need to be familiar with the principles and practices of anesthesia and the perioperative functions of the anesthesia provider. This chapter presents an overview of the modern practice of anesthesia, the factors involved, and the interrelationship with the perioperative nurse. It discusses major types of anesthesia, introduces the more commonly used drugs, reviews standards of anesthesia care, and summarizes problems that can occur during the perioperative period. The anesthesia machine and monitoring equipment are also described so that perioperative nurses can become familiar with their basic functions as the nurse may use them during local anesthesia or conscious sedation/analgesia procedures.

The sections of this chapter are organized so that they can be referred to independently without reading the entire chapter. Experienced perioperative nurses are familiar with the commonly used abbreviations employed in this chapter. To provide a single reference source for the student or novice perioperative nurse, most abbreviations are defined in Box 4-1.

HISTORY OF ANESTHESIA

The early history of modern anesthesia was fraught with controversy. Surgeons in the early nineteenth century frequently used alcohol or opium to intoxicate the patient for procedures involving intense pain or when muscle relaxation was needed. In some cases, hypnotism also was employed. Successful surgery was related directly to the speed of the surgeon (History box).

In March 1842 a physician in Danielsville, Georgia, named Crawford W. Long, used ether as an anesthetic to remove a cystic tumor from the neck of a patient named James Venable. As confirmed by other physicians in the area, Dr. Long subsequently used ether for other procedures, but did not publish reports of his experiences (Bankert, 2000; Gunn, 2005).

In 1844 Horace Wells, a dentist in Hartford, Connecticut, began to use nitrous oxide (N_2O) for anesthesia and communicated his results to his former partner, William T.G. Morton. After a death with N_2O, however, Wells quit the practice of dentistry and later committed suicide. Morton subsequently studied medicine and learned of the anesthetic effects of chloric ether from his preceptor, Charles T. Jackson, a chemist. In 1846, while employing this new drug, Morton was able to fill a tooth without the patient experiencing pain. He later learned from Jackson that sulfuric ether had similar properties and used it while extracting a deeply rooted bicuspid tooth from another patient (Bankert, 2000; Koch, 2010).

Morton contacted John C. Warren, a surgeon at the Massachusetts General Hospital, and persuaded him to give the new anesthetic a trial during a surgical procedure. With Morton as the anesthetist, this historic operation took place in the amphitheater (subsequently renamed "The Ether Dome") of Massachusetts General Hospital on October 16, 1846. In 5 minutes, Warren operated on an unconscious, quiet patient and dissected "a congenital but superficial vascular tumor just below the jaw on the left side of the neck." As the patient regained consciousness, Warren exclaimed, "Gentlemen, this is no humbug." The next day, Warren, with Morton as the anesthetist, removed a large fatty tumor from the shoulder of another patient (Koch, 2010).

Based on these events, the first medical report of anesthesia was announced to the world on November 18, 1846, by Henry J. Bigelow in the *Boston Medical and Surgical Journal*. An era had ended in which successful surgery was largely predicated on the lightning speed of the surgeon while working on a struggling, distressed patient. Anesthetic techniques gave the surgeon more time to operate and permitted new procedures to be undertaken that would have been impossible before. Many modern surgical techniques have become feasible because of the advances in the art and science of anesthesia.

The word *anesthesia* is derived from the Greek word *anaisthesia,* which literally means "no sensation." Anesthesia was listed in *Bailey's English Dictionary* in 1721. When the effects of ether were discovered, Oliver Wendell Holmes suggested *anesthesia* be used as a name for the new phenomenon. Some believed that he coined this term; others believed that he knew of the Greek word that Plato had employed. In any case, anesthesia was, in the memorable phrase of Werr Mitchell, the "death of pain." From these early beginnings, anesthesia has developed into a sophisticated science and "clinical art" that interfaces with many other medical specialties.

ANESTHESIA PROVIDERS

In the United States, anesthesia care usually is provided by an anesthesiologist, a certified registered nurse anesthetist (CRNA) working in collaboration with or under the direction of an anesthesiologist or a physician, or an anesthesiologist's assistant (AA) working under the direct supervision of an anesthesiologist.

An anesthesiologist is a physician with 4 or more years of specialty training in anesthesiology. Nurse anesthesia programs are a minimum of 2 years in length. They require a

BOX 4-1

Abbreviations Used in This Chapter

AANA—American Association of Nurse Anesthetists
ABG—Arterial blood gas; usually includes pH, Pao_2, $Paco_2$, HCO_3^-, K^+, and ionized Ca^{++}
ACLS—Advanced Cardiac Life Support, a protocol for resuscitation from the American Heart Association
APL—Adjustable pressure-limiting valve; a valve on anesthesia machines that limits the maximum pressure in the patient breathing circuit; frequently referred to as the "pop-off valve"
ASA—American Society of Anesthesiologists
cm—Centimeter; 1×10^{-3} m; 2.54 cm = 1 inch
CRNA—Certified registered nurse anesthetist
CSF—Cerebrospinal fluid; the fluid surrounding the brain and spinal cord; for spinal anesthesia, local anesthetics are injected into the CSF
EGTA—Esophageal (gastric tube) airway; a cuffed tube that is inserted blindly into the esophagus and connected to a mask; this permits ventilation through the mask and gastric suctioning through the cuffed tube
$ETco_2$—End-tidal carbon dioxide reported as a partial pressure; see Capnography section
ETT—Endotracheal tube
Fio_2—Fraction of inspired oxygen; this is a fraction (0.00 to 1.00) that corresponds to the percent (0% to 100%) of inspired oxygen
FO—Fiberoptic
mcg—Microgram
kg—Kilogram; 1 kg = 2.2 lb
LED—Light-emitting diode; an electronic device that emits light at a predetermined frequency
LMA—Laryngeal mask airway or laryngeal airway
MAC—Monitored anesthesia care; see Monitored Anesthesia Care section
mg—Milligram; 1×10^{-3} g
MH—Malignant hyperthermia; see Malignant Hyperthermia section
MHAUS—Malignant Hyperthermia Association of the United States
MMS—Master of medical science degree
MRI—Magnetic resonance imaging
NIOSH—National Institute for Occupational Safety and Health
nm—Nanometer; 1×10^{-9} m
NMS—Neuroleptic malignant syndrome; see Malignant Hyperthermia section
N_2O—Nitrous oxide
NSAID—Nonsteroidal antiinflammatory drug
PA—Pulmonary artery
$Paco_2$—Partial pressure of arterial carbon dioxide; lower case "a" denotes "arterial"; an uppercase "A" denotes "alveolar"
Pao_2—Partial pressure of arterial oxygen; lower case "a" denotes "arterial"; an uppercase "A" denotes "alveolar"
PCA—Patient-controlled analgesia; see Pain Management section
PNB—Peripheral nerve block
ppm—Parts per million; 1 ppm = 1×10^{-6}
psi—Pounds per square inch; a measurement of pressure
QA—Quality assurance; this function also may be identified as quality improvement (QI), continuous quality improvement (CQI), or similar names
RSI—Rapid-sequence induction
Spo_2—Saturation (pulse) of oxygen or in a pulsating vessel, expressed as a percentage; see Pulse Oximetry section
Svo_2—Saturation of mixed venous oxygen in percentage; this measurement is made from a special pulmonary artery catheter
torr—1 mm Hg

HISTORY

A Brief Look at Anesthesia

In *Nursing, The Finest Art,* Donahue notes that "The first nursing specialists have existed since the late nineteenth and early twentieth centuries: the nurse midwife and the nurse anesthetist…The role of the nurse anesthetist developed as part of the increasing sophistication of surgery in the early 1900s, when it was recognized that trained assistants were needed to administer anesthetics. No longer was it safe or satisfactory to have untrained medical students or attendants providing anesthesia. These early specialists were recruited from the available pool of trained nurses to meet very specific societal demands and needs."

Year	Breakthrough
1861-1865	Catherine S. Lawrence and other nurses provided anesthesia for surgeons during the Civil War.
1887	Sister Mary Bernard was the first nurse known to specialize in anesthesia.
1893	Alice Magaw began as a nurse anesthetist for Dr. Mayo, who would later give her the title "The Mother of Anesthesia" for her mastery of open drop ether.
1899	Magaw published the first paper by a nurse anesthetist in the Northwestern *Lancet.*
1909	St. Vincent's Hospital in Springfield, Illinois, began a nurse anesthetist program.
1911	Frances Hoeffer McMelhan began to advocate for physician anesthetists.
1914-1917	Agatha Hodgins and many other nurse anesthetists in volunteer American medical units provided anesthesia to casualties during World War I.
1931	Agatha Hodgins and 47 nurse anesthetists founded the National Association of Nurse Anesthetists (NANA).
1936	The American Society of Anesthesiologists (ASA) was founded.
1939	The NANA became the American Association of Nurse Anesthetists (AANA).
1941-1945	Second Lieutenant Mildred Clark became the first nurse anesthetist to serve as the Chief of the Army Nurse Corps. Nurse anesthetists provided anesthesia to World War II casualties.
1945	AANA administered its first certification examination (CRNA).
1998	A master's degree became mandatory to graduate from nurse anesthesia programs.
2007	AANA announces its support of doctoral education for entry into nurse anesthesia practice by 2025.

Modified from American Association of Nurse Anesthetists: *A brief look at nurse anesthesia history,* available at www.aana.com. Accessed July 1, 2009; American Association of Nurse Anesthetists: *AANA announces support of doctorate for entry into nurse anesthesia practice by 2025,* available at www.aana.com. Accessed July 1, 2009; Bankert M: *Watchful care: a history of America's nurse anesthetists,* New York, 2000, Continuum Publishing; Koch BE: Nurse anesthesia: a history of challenge. In Nagelhout JJ, Plaus KL, editors: *Nurse anesthesia,* ed 4, St Louis, 2010, Saunders.

bachelor of science (BS) degree in nursing or other appropriate field and a minimum of 1 year of critical care experience before acceptance. All nurse anesthesia programs are at the master's degree level. On program completion, graduates must successfully complete a National Certification Examination. As of 2025 CRNAs will graduate with a Doctorate of Nursing Practice (DNP).

In recent years, AAs also have been trained. These are assistants to anesthesiologists. Acceptance into an AA program requires a BS degree that includes college-level "premed" education. AAs are graduate students within a medical school and typically receive a master of medical science (MMS) degree from the medical school. They also take a national certification examination administered by the National Commission on Certification of Anesthesia Providers' Assistants under the supervision of the National Board of Medical Examiners.

In this chapter, the term *anesthesia provider* denotes the individual *providing* the continuous anesthesia care for the patient. Depending upon the practice in a given hospital, this may be an anesthesiologist, a CRNA, or an AA. In many hospitals, an *anesthesia care team* includes CRNAs, with or without AAs supervised by anesthesiologists. In small rural hospitals in some states, an anesthesiologist may not be present, and a CRNA may be the sole anesthesia provider.

The anesthesia provider is the patient's advocate in the perioperative period; as such, he or she must be concerned with many divergent factors when the patient's own sensory and cerebral functions are obtunded by anesthesia. The field of anesthesia has become so complex that in many large hospitals an anesthesia provider may specialize further in obstetric, neurosurgical, pediatric, cardiovascular, regional, or ambulatory anesthesia. Anesthesiologists also may subspecialize in acute and chronic pain management or in critical care medicine.

PATIENT SAFETY

Patient safety is always a concern during surgery and anesthesia. Approximately 26 million anesthetics are administered each year in the United States. Of these, data from several sources indicate a death rate ranging from 1 per 35,000 to about 1 per 40,000. These rates represent a significant decline during the past 30 years, despite surgical procedures being performed on increasingly higher risk patients than in the past.

The general public still considers anesthesia to be a major risk of surgery. This attitude may be attributable to sensationalized reports in the news media and in magazine articles. In addition, people may have a heightened awareness of anesthesia-related deaths because these often occur acutely in the perioperative period, whereas surgical or medical problems may not result in death until days after the procedure.

ENVIRONMENTAL NOISE

Many studies demonstrate the effects that noise has on humans. Multiple conversations, loud music, and other noises can create or worsen patient anxiety, as well as make communication difficult between team members and between the patient and team members. Noise can also cause distraction, increasing the potential for miscommunication and errors. Patients recovering during the immediate postoperative period have expressed dissatisfaction with high noise levels and overhearing staff member conversations. Improvement in patient satisfaction can be achieved when the noise level is decreased in the postanesthesia care unit (PACU) (Smykowski, 2008). While the patient is in the OR, *especially* during induction and emergence, every effort should be made to maintain a calm, quiet environment. This is especially true when caring for the pediatric patient. Hearing multiple voices can create patient anxiety and confusion. Interventions that may decrease noise are presented in the Risk Reduction Strategies box.

RISK REDUCTION STRATEGIES

Interventions to Reduce Noise

- Increase staff awareness via education and new employee orientation.
- Educate environmental service personnel about noise sources and reduction strategies during cleaning.
- Identify sources of noise to determine whether, how, and if these noises can be lessened.
- Modulate one's own voice tone and volume appropriately.
- Expect every team member to be personally responsible for managing how much noise he or she generates (e.g., minimize or eliminate irrelevant conversation during procedures).
- Limit telephone conversations to brief communications.
- Practice telephone etiquette protocol when answering a call or page.
- Use structured communication methods (e.g., standardized communication templates to disseminate pertinent patient care information).
- Minimize the number of people present during procedures and frequency of door openings.
- Establish times when noise levels routinely should be reduced (e.g., induction, emergence).
- Lower ring-tone volume on telephones and mobile communication devices (use silent mode whenever possible).
- Limit overhead pages with the use of text paging.
- Place pagers on silent mode whenever possible.
- Display "Quiet, Please" posters to remind staff to reduce noise.

Modified from AORN: *Position statement on noise in the perioperative practice setting,* Chicago, Ill, March 2009, AORN, Inc., available at www.aorn.org/PracticeResources/AORNPositionStatements/PositionStatementOnNoise/. Accessed April 11, 2009.

AWARENESS DURING ANESTHESIA

The possibility of being awake during anesthesia is a concern of patients and anesthesia providers (Research Highlight). Some patients are so anxious about being aware of anything during surgery that it may affect their reasoning when discussing the options for anesthesia. Many procedures, such as biopsies, inguinal hernias, or procedures on the lower extremities, can be done under regional anesthesia or monitored anesthesia care (MAC). These patients may want general anesthesia, however, because they do not want to be aware of anything during the procedure. In rare cases during general anesthesia, the patient may be paralyzed but be aware of what is occurring and unable to indicate this to anyone.

Intraoperative awareness (IOA) has been reported with many anesthetic techniques. Several factors may contribute to its occurrence. Overall, 20,000 to 40,000 patients each year experience awareness during general anesthesia (Bazzell et al, 2008). The incidence of awareness may increase to 1% to 1.5% in higher risk patient populations, such as patients requiring anesthesia for obstetrics, major trauma, and cardiac surgery (Lennmarken and Sandin, 2004; Sebel et al, 2004; Ghoneim et al, 2009).

For many years, the electroencephalogram (EEG) has been the standard for assessing a person's hypnotic and sleep state. However, using an EEG for all surgical procedures is unrealistic. In the late 1990s the bispectral index system (BIS) was developed, which analyzes the relationship and frequency of brain signals using an algorithm to generate a composite, numeric value that seems to correlate with the cerebral state. Five electrodes are positioned across the forehead, and the monitor gives an index (0 to 100) of the hypnotic state or sedation level; an index of 40 to 60 is considered optimal anesthesia. The BIS monitors effects of anesthetics and sedatives on the hypnotic status of the brain but is less informative about the level of analgesia. Motion artifacts and mental changes cause erratic changes under lighter levels of sedation commonly used with MAC. Use of the BIS monitor continues to increase. Often patients wake up more quickly and experience less nausea and vomiting because drugs can be titrated using BIS (Lennmarken and Sandin, 2004; Stanski and Shafer, 2005).

PREOPERATIVE PREPARATION

Patient Evaluation

Preoperative evaluation is done in advance of the scheduled surgical procedure, often one or more days before the procedure in a preadmission clinic (sometimes called *preadmission testing, preanesthesia clinic,* or *anesthesia-assessment unit*). Admission data and appropriate consent forms are completed, a preoperative history obtained, a physical examination done, a preanesthesia evaluation and examination completed, and appropriate diagnostic or laboratory tests processed. Numerous studies have shown limited benefits of extensive routine testing (Chung et al, 2009). More extensive testing is indicated for patients who have higher than average risk based on their history. The patient's physical status is assessed, and the most appropriate anesthetic technique selected. The patient's questions and concerns are resolved, and instructions given to expedite admission on the day of surgery.

Before elective surgery, the patient should be in optimal medical condition. Anesthesia, even in healthy patients, presents risks. Inhaled general anesthetics are myocardial depressants; they may lead to dose-dependent decreases in myocardial contractility and blood pressure. This response may be accentuated in patients who are volume depleted, who are overdiuresed, who have poor ventricular function, or who have autonomic neuropathy, such as found in patients with diabetes. If it is determined that the patient's physical status should be improved to reduce the risks involved, this is discussed with the patient's

RESEARCH HIGHLIGHT

Anesthesia Awareness

Intraoperative awareness (IOA) was recognized in 1846 when Morton demonstrated ether anesthesia and the patient later reported that he had been half-awake during the procedure. Although rare with modern anesthetic agents and techniques, IOA does occur. Multiple studies have found IOA to occur in 0.1% to 0.2% of patients undergoing general anesthesia. Of 21 million patients who receive general anesthesia, 20,000 to 40,000 experience awareness each year. Of patients who experienced awareness, 48% reported auditory recollections, 48% reported the sensation of not being able to breathe, and 28% reported feeling pain. Greater than 50% of these patients were reported to experience mental distress, including an indeterminate number with posttraumatic stress syndrome. More recent dramatized accounts in the lay press have caused an increasing number of patients to voice their concern during preoperative interviews. To evaluate this issue, investigators have used a variety of approaches, including the following:

- The effects of intraoperative therapeutic suggestions on the length of postoperative hospitalization or the level of pain
- Positive suggestions during anesthesia for changes in lifestyle (e.g., smoking cessation, weight loss)
- Assessment of inadequate amnesia or recall of intraoperative conversation or events, or both
- Intraoperative memory analyzed by recall of specific words or phrases spoken during anesthesia
- Intraoperative physiologic changes or postoperative recall evaluated under hypnosis when a mock crisis was staged during anesthesia
- Learning of new information during anesthesia

Many of these studies employed changes in the latency and amplitude of middle-latency, auditory-evoked potentials. They found that even under seemingly adequate general anesthesia, implicit memory may be retained along with the ability to process auditory stimuli subconsciously. Based on these studies, it seems prudent to avoid anesthetic techniques that rely solely on receptor-based drugs (i.e., benzodiazepines, opioids, nitrous oxide [N_2O]) and to include volatile anesthetics.

In an effort to reduce the risk of anesthesia awareness, the American Society of Anesthesiologists (ASA) and the American Association of Nurse Anesthetists (AANA) have provided guidelines for administering and monitoring anesthesia.

Studies in the area of patient memory are ongoing. Ghonheim's research suggests that the two most common risk factors are light anesthesia and a history of awareness. While a patient is anesthetized, it is important that all persons in the OR and procedure room conduct themselves in a professional manner. It remains possible that the patient may remember conversations conducted during the anesthesia experience.

Modified from American Society of Anesthesiologists (ASA): Practice advisory for intraoperative awareness and brain function monitoring: a report by the American Society of Anesthesiologists Task Force on Intraoperative Awareness, *Anesthesiology* 104:847-864, 2005; Ghoneim MM et al: Awareness during anesthesia: risk factors, causes and sequelae: a review of reported cases in the literature, *Anesthes Analges* 108:527-535, 2009; Lennmarken C, Sandin R: Neuromonitoring for awareness during surgery, *Lancet* 363:1747-1748, 2004; Sebel PS et al: The incidence of awareness during anesthesia: a multicenter United States study, *Anesth Analg* 99:833-839, 2004; Stanski DR, Shafer SL: Measuring depth of anesthesia. In Miller RD, editor: *Anesthesia,* ed 6, Philadelphia, 2005, Churchill Livingstone.

primary physician or surgeon and, if necessary, elective surgery is deferred until the patient's condition is optimized. In emergent surgery, however, any benefits gained from a delay must be weighed carefully with the hazards of waiting (DeLamar, 2005).

The assignment of a physical status classification is based on the patient's physiologic condition independent of the proposed surgical procedure. The physical status classification was developed by the American Society of Anesthesiologists (ASA) to provide uniform guidelines. It is an evaluation of the severity of systemic diseases, physiologic dysfunction, and anatomic abnormalities. The ASA classification system is widely used to estimate perioperative risk (Table 4-1).

While preadmission clinics are commonly used by many hospitals and ambulatory surgery centers, nurses may conduct preoperative telephone interviews with patients in reasonably good health. Questions are asked relating to pulmonary and cardiac disease; medication (prescription, over-the-counter, herbal, and homeopathic remedies) and alcohol use; medication, latex, or anesthetic allergies; pregnancy; and personal or family history of anesthetic reactions. The preadmission interview, whether by phone or in person, provides an opportunity for patient education as it relates to their procedure (Patient and Family Education). On the day of surgery, patients arrive 1 to 2 hours before the scheduled surgery time to complete other preoperative processes. In some facilities, certain ambulatory patients are evaluated just before surgery. These are usually healthy patients having minor procedures or patients with stable, chronic conditions having a procedure (e.g., cataract removal, skin lesion excision) under MAC. These preadmission processes have reduced costs of healthcare, decreased risk of nosocomial infections associated with longer hospital admissions, increased use and efficiency of healthcare resources, improved patient relations, and enhanced the chances of having a well-informed patient in optimal health status (DeLamar, 2005).

In larger hospitals and ambulatory surgery centers, the individual who evaluates the patient in the preanesthesia clinic is often not the anesthesia provider for the patient's surgical procedure. Immediately before surgery, the anesthesia provider (1) reviews the patient's chart, laboratory data, and diagnostic studies, such as electrocardiogram (ECG) and chest x-ray; (2) confirms that the appropriate consent forms (surgery, anesthesia, use of blood products) have been signed; (3) identifies the patient; (4) verifies the surgical procedure; (5) reviews the choice of anesthesia; (6) examines the patient; and (7) administers preoperative medications if appropriate (DeLamar, 2005; Stoelting and Miller, 2006a). As ambulatory surgery becomes increasingly common, other factors are taken into consideration (Ambulatory Surgery Considerations).

Choice of Anesthesia

The choice of anesthesia for a given surgical procedure is made by the patient, anesthesia provider, and surgeon. Many factors influence this choice, including the following:

1. Patient's wishes and understanding of the types of anesthesia that could be used
2. Patient's physiologic status

PATIENT AND FAMILY EDUCATION

Preanesthesia Preparation

During preoperative assessment, the patient is interviewed and it is important to discuss the following topics:

Preoperative fasting: Explain why it is important (see Research Highlight: Perioperative Nausea and Vomiting).

Medications: Patients should take necessary medications (such as antihypertensive, cardiac, seizure, and asthma medications) with sips of water, preferably before they leave their homes to come to the facility. Patients with diabetes should continue taking oral hypoglycemic agents until the evening before surgery. If the patient takes insulin, it is common to administer a fraction (one fourth to one half) of the usual morning dose. Aspirin and aspirin-containing products should be discontinued 1 week before surgery. Nonsteroidal antiinflammatory drugs should be discontinued 4 days before surgery. If the patient is taking warfarin, it is usually discontinued 3 days before surgery, if appropriate. The prescribing clinician may need to be consulted to ensure it is safe to discontinue these medications or switch to alternative medications, especially if the patient has recently undergone heart valve replacement surgery or other serious conditions that must be taken into consideration.

Herbal supplements: Many herbal supplements can potentially interact with anesthetics. It is important to ask about any supplements the patient is taking (see Chapter 29).

Recent upper respiratory tract infections: A patient with a reactive airway has an increased risk of respiratory complications (e.g., bronchospasm, laryngospasm).

Family-centered preanesthesia preparation for children and their families may include treatment options for anxiety, such as administering sedatives, having a parent present during induction, and providing hospital-based preparation programs (Kain et al, 2007). Preanesthesia patient and family education may also include postoperative care instructions and information about pain control, both nonpharmacologic (e.g., distraction, progressive muscle relaxation, diaphragmatic breathing [Roy-Byrne et al, 2009], ice, elevation) and pharmacologic (e.g., how pain will be assessed, when and how medication will be administered). A study by Kastanias and colleagues (2009) determined that information about pain management strategies and medication side effects was extremely important to patients ready to be discharged. Because patients place such high importance on information about the pain experience, anesthesia providers and perioperative nursing staff need to include discussion of after-discharge pain management plans as part of patient and family education.

An anesthesia provider will also discuss the anesthesia options that are appropriate for that patient/procedure after reviewing pertinent history and physical information that is provided, along with any pertinent diagnostic studies and consultations. The American Society of Anesthesiologists (ASA) has a number of patient education brochures available on their website. These brochures can be printed and offered to patients and their families, or the perioperative nurse can simply direct the patient and family to the appropriate website. One brochure specifically addresses ambulatory surgery anesthesia. These may be accessed at www.asahq.org/patientEducation.htm.

TABLE 4-1

ASA Physical (P) Status Classification

Status*,†	Definition	Description and Examples
P1	Normal healthy patient	No physiologic, psychologic, biochemical, or organic disturbance
P2	Patient with mild systemic disease	Cardiovascular disease with minimal restriction of activity; hypertension, asthma, chronic bronchitis, obesity, diabetes mellitus, or tobacco abuse
P3	Patient with a severe systemic disease that limits activity, but is not incapacitating	Cardiovascular or pulmonary disease that limits activity; severe diabetes with systemic complications; history of myocardial infarction, angina pectoris, poorly controlled hypertension, or morbid obesity
P4	Patient with a severe systemic disease that is a constant threat to life	Severe cardiac, pulmonary, renal, hepatic, or endocrine dysfunction
P5	Moribund patient who is not expected to survive 24 hr with or without operation	Surgery is done as last recourse or resuscitative effort; major multisystem or cerebral trauma, ruptured aneurysm, or large pulmonary embolus
P6	Patient declared brain dead whose organs are being removed for donor purposes	

*In statuses 2, 3, and 4, the systemic disease may or may not be related to the reason for surgery.
†For any patient (P1 through P5) requiring emergency surgery, an E is added to the physical status, such as P1E, P2E. ASA 1 through ASA 6 or I to VI is often used for physical status.
Modified from American Society of Anesthesia (ASA) Providers: *Manual for anesthesia departments,* Park Ridge, Ill, 1997, The Association, available at www.asahq.org/clinical/physicalstatus.htm. Accessed June 28, 2009.

3. Presence and severity of co-existing diseases
4. Patient's mental and psychologic status
5. Postoperative recovery from various kinds of anesthesia
6. Options for management of postoperative pain
7. Type and duration of surgical procedure
8. Patient's position during surgery
9. Particular requirements of the surgeon

Premedications

The primary purpose of premedication before anesthesia is to sedate the patient and reduce anxiety. Medications that may be given preoperatively include sedatives and hypnotics, anxiolytics, amnestics, tranquilizers, narcotics or other analgesics, antiemetics, and anticholinergics. A single drug may possess the properties of several classes. Midazolam (Versed) is administered frequently to relieve apprehension and to provide amnesia. An analgesic or narcotic may be ordered if preoperative discomfort is anticipated during invasive procedures or during the administration of a regional anesthetic. An anticholinergic, such as atropine or glycopyrrolate, may be used to prevent bradycardia in pediatric patients, to control secretions in patients

AMBULATORY SURGERY CONSIDERATIONS

Patient Selection

Ambulatory surgery is increasingly common. Approximately 65% of procedures performed in this country are done on an ambulatory basis. Ambulatory surgery may be done as a "same day" procedure in the hospital, in an office, or in an ambulatory surgery center (ASC). Patients usually enjoy an earlier return to their preoperative physiologic state and experience fewer complications with ambulatory surgery, when compared to surgery performed in the hospital setting. When procedures are performed on an ambulatory basis, there is also a reduced chance of hospital-associated infections (Zoremba et al, 2009).

The list of surgical procedures performed in ambulatory settings continues to grow. However, procedures requiring prolonged immobilization, involving parenteral pain management, and/or having increased incidence of complications are generally performed on an inpatient basis (Marley, 2010).

Patient selection is extremely important in ambulatory settings. The procedure should not have a significant incidence of perioperative or postoperative problems and should not require intensive postoperative management (Marley, 2010). The patient should be in general good health or have well-managed existing illnesses. Patients with a significant history should be interviewed before the day of surgery to determine how well co-existing diseases are controlled and what tests or consultations may be needed before the day of surgery.

The following are some patient conditions for which ambulatory surgery is unacceptable:

- Premature infants (gestational age 37 weeks or less at birth)
- Infants with a history of respiratory difficulties, apneic episodes, feeding difficulties
- Unstable physical status (ASA classification III or IV) (see Table 4-1)
- Active substance or alcohol abuse
- Poorly controlled seizures
- Previously unevaluated and unmanaged obstructive sleep apnea
- Uncontrolled diabetes
- Infectious process requiring isolation
- Anticipation of postoperative pain that will not be controllable with oral analgesics
- Inability to care for self and without access to assistance
- Noncompliance (Marley, 2010)

Anesthetic technique is based upon the surgical procedure, surgeon and patient preference, and skill of the practitioner. Some goals for anesthesia in an ambulatory setting include minimal physiologic changes secondary to the anesthetic, fast induction, rapid emergence while maintaining patient comfort, intraoperative amnesia and analgesia, suitable operating conditions, minimal perioperative side effects, and minimized postoperative side effects, such as nausea (Marley, 2010). Use of an LMA, awareness monitoring, and certain anesthetics (such as propofol, sevoflurane, and desflurane) have contributed to attaining these goals.

undergoing oropharyngeal procedures, or to control cardiac reflex that may cause bradycardia (e.g., during ophthalmic procedures) (Stoelting and Miller, 2006a, 2006b).

To decrease the risk of aspiration, metoclopramide (Reglan) may be given to empty the stomach and to reduce nausea and vomiting (Research Highlight) (see Chapter 9 for a thorough discussion of postoperative nausea and vomiting). In addition, an antacid or an H_2-receptor–blocking drug, such as cimetidine (Tagamet), ranitidine (Zantac), or famotidine (Pepcid), may be included to decrease gastric acid production or the acidity of the gastric contents, or both. Should aspiration occur, a gastric pH greater than 2.5 decreases resultant pulmonary damage (Stoelting and Miller, 2006b).

Before a premedication is given, any last-minute questions from the patient concerning surgery and anesthesia should be answered, and the preoperative verification process should be completed to ensure that all relevant documents (e.g., the history and physical examination, surgical consent) and imaging studies (properly labeled and displayed) are available before the start of the procedure. These must be reviewed and be consistent with the patient's stated expectations (when the patient is awake and aware, the patient should actively participate in the verification process). The surgical team must agree that this is the correct patient and the planned procedure on the specified side and site. Any additional special equipment, supplies, or implants also must be confirmed as being correct and available. Marking the surgical site also must be done before administering premedication (see Chapter 2 for a review of The Joint Commission's [TJC] Universal Protocol for preventing wrong site, wrong procedure, wrong person surgery).

Premedication may be administered intramuscularly (IM), intravenously (IV), intranasally, or orally (PO) with 15 to 30 ml of water. Patients usually prefer oral premedication, and the small amount of water is readily absorbed directly across the gastric mucosa. Premedication may be given 30 to 90 minutes before surgery, via IV in the preoperative holding area, or after the patient arrives in the surgical suite. Except for the small amount of water needed to swallow any medications, adult patients traditionally have been required to maintain nothing by mouth (NPO) status for a minimum of 4 to 6 hours before elective surgery. More recent data indicate, however, that clear liquids may be acceptable up to 2 hours before surgery (DeLamar, 2005) (Table 4-2).

Although premedications commonly are used, studies have shown that visits before surgery by the anesthesia provider and the perioperative nurse are far more important in relieving patient anxiety and concern. Major patient concerns include fear of the unknown, relinquishing control of one's life to someone else, being awake during surgery, and not awakening from anesthesia as well as concerns related to the surgery (e.g., diagnosis, prognosis). Premedication may be unnecessary for older patients because their anxiety levels are lower, their responses to medications are unpredictable, and sedation can be given IV in the OR if required.

RESEARCH HIGHLIGHT

Postoperative Nausea and Vomiting

Despite advances in anesthesia and surgery, postoperative nausea and vomiting (PONV) continues to be a problem for many patients. The estimated incidence is as high as 30% for low-risk patients and 80% for high-risk patients (Murphy et al, 2006). For some patients, this causes more anxiety than the surgery itself. With the increased utilization of ambulatory surgery, patients are discharged and are mobile sooner, before symptoms begin. While nausea is extremely uncomfortable, vomiting can be dangerous and has been associated with major complications such as pulmonary aspiration, dehydration, and electrolyte disturbances; it also can affect healing. Evidence has shown that PONV is more likely to occur after certain procedures such as ophthalmic, breast, ear, nose and throat, gynecologic, gastrointestinal (GI), and laparoscopic surgery. Patient risk factors for PONV include female gender, nonsmoker, history of PONV, history of motion sickness, history of migraines, anxiety, dehydration, and gastroparesis. Anesthetic risk factors include the use of nitrous oxide and/or opioids. The use of Diprivan has also shown to reduce PONV. Movement can also contribute to PONV, such as when patients are moved quickly from the OR bed to the stretcher, or moved quickly down hallways and around corners.

Prevention of PONV should be a high priority. Minimizing risk factors and administering antiemetics are important. Antiemetics have been designed to interact with the four main neurotransmitters that affect PONV: histamine, acetylcholine, serotonin, and dopamine. In higher risk patients, combination therapy of antiemetics has been shown to be more effective than using a single agent. Because of cost and potential side effects, multimodal therapy is generally used with patients at higher risk. Some common antiemetics currently being used are scopolamine (anticholinergic), Compazine and Reglan (antidopaminergics), Decadron (corticosteroid), and 5-HT (5-hydroxytryptamine [serotonin]) receptor antagonists (e.g., odansetron [Zofran], dolasetron [Anzamet], and granisetron [Kytril]). Antihistamines such as diphenhydramine (Benadryl) and dimenhydrinate (Dramamine) have also proven to be effective. As with any medication, one should be familiar with any potential side effects or interactions before administration.

Nonpharmacologic interventions include acupressure, acupuncture, ginger, and aromatherapy. Isopropyl alcohol (usually using an alcohol swab), placed under the nose, has proven effective. Another product, Quease Ease, combines essential oils of peppermint, spearmint, lavender, and ginger. Originally developed for use with sedated patients, it is used by placing under the nose and inhaling. This has also been found to be very effective for nausea, even outside the PACU, and is available on-line. Adequate fasting, IV hydration, antiemetic prophylaxis, selection of induction agents for anesthesia, and avoidance of nitrous oxide may all help to prevent PONV.

Modified from Fetzer S: Putting a stop to postop nausea and vomiting, *Am Nurse Today* 3(8):10-12, 2008; McCaffrey R: Make PONV prevention a priority, *OR Nurse* 1(2):39-45, 2007.

TYPES OF ANESTHESIA CARE

The Joint Commission's *Comprehensive Accreditation Manual for Hospitals* has Anesthesia Care Standards that apply when patients receive, in any setting, moderate or deep sedation or general, spinal, or other major regional anesthesia. Descriptions of frequently used classifications of anesthesia care follow.

General Anesthesia

General anesthesia is a reversible, unconscious state characterized by amnesia (sleep, hypnosis, or basal narcosis), analgesia (freedom from pain), depression of reflexes, muscle relaxation, and homeostasis or specific manipulation of physiologic systems and functions. Most patients think of general anesthesia when they

TABLE 4-2

NPO Fasting Guidelines*

Ingested Material	Minimal Fasting Period (hr)
Clear liquids†	2
Breast milk	4
Infant formula	6
Nonhuman milk	6
Light meal	6

*These guidelines are recommended for healthy patients undergoing elective procedures. They are not intended for women in labor. They do not guarantee complete gastric emptying.
†Clear liquids include water, juice without pulp, black coffee, clear tea, and carbonated beverages. Patients should also be instructed not to chew gum or eat any candies or mints.
Adapted from The American Society of Anesthesiologists: *Practice guidelines for preoperative fasting and the use of pharmacologic agents to reduce the risk of pulmonary aspiration: application to healthy patients undergoing elective procedures,* 1999, available at www.asahq.org/publicationsAndServices/NPO.pdf. Accessed May 24, 2009.

are scheduled to have a surgical procedure; that is, they expect to be "put to sleep." As such, they experience a drug-induced loss of consciousness during which they are not arousable. Their ability to maintain ventilatory function is often impaired, requiring assistance maintaining a patent airway. Positive-pressure ventilation may be required because of decreased spontaneous ventilation or drug-induced depression of neuromuscular function.

Regional Anesthesia

Regional anesthesia is defined broadly as a reversible loss of sensation in a specific area or region of the body when a local anesthetic is injected purposefully to block or anesthetize nerve fibers in and around the operative site. Common regional anesthesia techniques include spinals (subarachnoid block [SAB]), epidurals, caudals, and major peripheral nerve blocks. Although ultrasound guidance has been reviewed as a technique to enhance regional anesthesia and analgesia, it may not eliminate complications such as blood vessel puncture or inadvertent intraneural or intravascular injections. Nonetheless, in some healthcare facilities, ultrasound-guided regional anesthesia and analgesia is used to reduce time or number of attempts to perform blocks (Liu et al, 2009).

Monitored Anesthesia Care (MAC)

MAC ("*local standby*" and "*anesthesia standby*" are older, less accurate terms frequently used interchangeably with MAC) is infiltration of the surgical site with a local anesthetic and is performed by the surgeon. The anesthesia provider supplements the local anesthesia with IV drugs that provide sedation and systemic analgesia, monitors the patient's vital functions, and may use additional medication to optimize the patient's physiologic status. MAC is often used for healthy patients undergoing relatively minor surgical procedures. It may also be used for some procedures for critically ill patients who may tolerate a general anesthetic poorly.

Conscious Sedation/Analgesia

Conscious sedation/analgesia is administered for specific short-term surgical, diagnostic, and therapeutic procedures within a hospital or ambulatory center. In the ASA's *Practice Guidelines for Sedation and Analgesia by Non-Anesthesiologists* (Gross and Bailey, 1996), moderate sedation/analgesia (conscious sedation) is defined as "a drug-induced depression of consciousness during which patients respond purposefully to verbal commands, either alone or accompanied by light tactile stimulation." No interventions are required to maintain a patent airway, and spontaneous ventilation is adequate. Cardiovascular function is usually maintained. Patients whose only response is reflex withdrawal from a painful stimulus are sedated to a greater degree than encompassed by conscious sedation/analgesia.

The demand for appropriate providers to administer and monitor the patient receiving conscious sedation/analgesia has grown over the past few years, exceeding the supply of anesthesia providers. This demand has resulted in increased use of nonanesthesia providers (usually professional registered nurses with additional training in administering conscious sedation/analgesia medications and monitoring these patients) for these functions. Various medications and techniques may be used to achieve conscious sedation/analgesia, each with advantages and disadvantages. Competency-based education programs and assessment should be established for nurse-monitored conscious sedation. The Association of periOperative Registered Nurses (AORN) publishes recommendations for managing patients undergoing conscious sedation/analgesia that should be used by healthcare facilities to develop such programs (AORN, 2009b).

Local Anesthesia

Local anesthesia refers to the administration of an anesthetic agent to one part of the body by local infiltration or topical application, usually administered by the surgeon. Local anesthesia is used (1) for minor procedures, (2) if the patient's cooperation is necessary for the procedure, or (3) if the patient's physical condition warrants its use. An anesthesia provider is not involved in the patient's care. A perioperative nurse monitors the patient's vital signs and provides supportive care during the procedure. AORN publishes recommendations for managing patients undergoing local anesthesia and documenting care, which should be used to establish policies and procedures in operative and other invasive settings.

PERIOPERATIVE MONITORING

Significant advances continue in perioperative monitoring. Among medical specialties, anesthesiology has been a pioneer in review and analysis of perioperative mishaps and implementation of improved monitoring techniques and guidelines. These advances have resulted in significant decreases in morbidity and mortality. In several states, malpractice insurance carriers have recognized the significance of these improvements and have decreased premiums if certain monitors are used routinely. These monitors include pulse oximetry, which measures oxygen saturation in a pulsating vessel (Spo_2), and capnography, which measures end-tidal carbon dioxide ($ETco_2$) level (Kossick, 2010).

The ASA has adopted Standards for Basic Anesthetic Monitoring (Patient Safety) as guidelines for patient care. Perioperative nurses should be familiar with these standards and understand their significance in patient safety. If routine or frequent deviations from such standards occur, a performance assessment and improvement (also known as *quality assurance [QA]*) review along with a risk management analysis should be considered to ensure safe and high-quality patient care (ECRI Institute, 2009).

PATIENT SAFETY

Standards for Basic Anesthetic Monitoring

The following standards for basic anesthetic monitoring apply to all anesthesia care, although in emergency circumstances appropriate life-support measures take precedence. These standards may be exceeded at any time based on the judgment of the responsible anesthesia provider. They are intended to encourage quality patient care, but following them cannot guarantee any specific patient outcome. They are subject to revision from time to time, given constant advances in technology and practice. They apply to all general anesthesia, regional anesthesia, and monitored anesthesia care. This set of standards addresses only the issue of basic anesthetic monitoring, which is only one component of anesthesia care. In certain rare or unusual circumstances, some of these methods of monitoring may be clinically impractical and appropriate use of the described monitoring methods may fail to detect untoward clinical developments. Brief interruptions of continual monitoring may be unavoidable. Under extenuating circumstances, the responsible anesthesia provider may waive the requirements marked with an asterisk (*); it is recommended that when this is done, it should be so stated (including the reasons) in a note in the patient's medical record. These standards are not intended to apply to the care of an obstetric patient in labor or in the conduct of pain management.

STANDARD I
Qualified anesthesia personnel should be present in the patient's room throughout the entirety of all general anesthesia, regional anesthesia, and monitored anesthesia care.

Objective
Because of the rapid changes in patient status during anesthesia, qualified anesthesia personnel should be continuously present to monitor the patient and provide anesthesia care. In the event there is a direct known hazard (e.g., radiation) to the anesthesia personnel that might require intermittent remote observation of the patient, some provision for monitoring the patient must be made. In the event that an emergency requires the temporary absence of the person primarily responsible for the anesthetic, the best judgment of the anesthesia provider will be exercised in comparing the emergency with the anesthetized patient's condition and in the selection of the person responsible for the anesthetic during the temporary absence.

STANDARD II
During the administration of all anesthetics, the patient's oxygenation, ventilation, circulation, and temperature should be continually evaluated.

Oxygenation
Objective
To ensure adequate oxygen concentration in the inspired gas and the blood during all anesthesia

METHODS
1. *Inspired gas:* During every administration of a general anesthetic using an anesthesia machine, the concentration of oxygen in the patient breathing system should be measured by an oxygen analyzer with a low oxygen concentration limit alarm in use.*
2. *Blood oxygenation:* During all anesthesia, a quantitative method of assessing oxygenation, such as pulse oximetry, should be employed.* Adequate illumination and exposure of the patient are necessary to assess color.*

Ventilation
Objective
To ensure adequate ventilation of the patient during all anesthesia

METHODS
1. Every patient receiving a general anesthetic should have the adequacy of ventilation continually evaluated. Although qualitative clinical signs may be useful, such as chest excursion, observation of the reservoir breathing bag, and auscultation of breath sounds, quantitative monitoring of the carbon dioxide content or volume of expired gas (or both) is strongly encouraged.
2. When an endotracheal tube or laryngeal mask is inserted, its correct positioning must be verified by clinical assessment and by identification of carbon dioxide in the expired gas. Continual end-tidal carbon dioxide analysis, in use from the time of endotracheal tube/laryngeal mask placement until extubation/removal or initiating transfer to a postoperative care location, should be performed using a quantitative method, such as capnography, capnometry, or mass spectroscopy.*
3. When ventilation is controlled by a mechanical ventilator, a device that is capable of detecting disconnection of components of the breathing system should be in continuous use. The device must give an audible signal when its alarm threshold is exceeded.
4. During regional anesthesia and monitored anesthesia care, the adequacy of ventilation should be evaluated by continual observation of qualitative clinical signs or monitoring for the presence of exhaled carbon dioxide, or both.

Circulation
Objective
To ensure the adequacy of the patient's circulatory function during all anesthesia

METHODS
1. Every patient receiving anesthetics should have an electrocardiogram continuously displayed from the beginning of anesthesia until preparing to leave the anesthetizing location.*
2. Every patient receiving anesthetics should have arterial blood pressure and heart rate determined and evaluated at least every 5 minutes.*
3. Every patient receiving a general anesthetic should have, in addition to the aforementioned, circulatory function continually evaluated by at least one of the following: palpation of a pulse, auscultation of heart sounds, monitoring of a tracing of intraarterial pressure, ultrasound peripheral pulse monitoring, or pulse plethysmography or oximetry.

Body Temperature
Objective
To aid in the maintenance of appropriate body temperature during all anesthesia

METHODS
Every patient receiving anesthetics should have temperature monitored when clinically significant changes in body temperature are intended, anticipated, or suspected.

*Continual is defined as "repeated regularly and frequently in steady rapid succession," whereas continuous means "prolonged without any interruption at any time."

From the American Society of Anesthesiologists (ASA), Park Ridge, Ill. Approved by ASA House of Delegates on October 21, 1986, and last amended on October 25, 2005.

Monitors and basic anesthetic monitoring include the following:

- Inspired oxygen analyzer (F_{IO_2}), which is calibrated to room air on a daily basis
- Low-pressure disconnect alarm, which senses pressure in the expiratory limb of the patient circuit
- Inspiratory airway pressure
- Respirometer (these first four devices are an integral part of most modern anesthesia machines)
- Electrocardioscope
- Blood pressure (usually measured with a noninvasive automated unit)
- Heart rate
- Precordial or esophageal stethoscope
- Temperature
- Peripheral nerve stimulator if muscle relaxants are used
- Spo_2
- $ETco_2$

Newer models of anesthesia machines have basic monitors integrated into a computerized system. These generally include F_{IO_2}; inspired and expired CO_2; inspired and expired volatile agents; airway pressure and disconnect alarms; tidal volume, respiratory rate, and minute ventilation; noninvasive blood pressure (systolic, diastolic, and mean); Spo_2 and pulse rate; temperature; and an event marker. A sophisticated, prioritized system displays caution or alarm conditions in one location, making it unnecessary to scan numerous individual monitors with a variety of displays when an alarm sounds.

Based on the cardiovascular and pulmonary status of the patient, the surgical procedure, and the chance of significant physiologic changes, additional invasive monitors may be required. These include direct arterial and venous pressure measurements, a pulmonary arterial (PA) catheter, and continuous mixed venous O_2 saturation (Svo_2) measured with a special PA catheter. One type of PA catheter can provide a continuous measurement of cardiac output, employing pulsed thermodilution to provide intermittent heat along a distal segment of the catheter. Small changes in the temperature of the blood are proportional to blood flow (cardiac output). These changes are sensed by a thermistor on the tip of the catheter (Kossick, 2010).

For certain conditions equipment such as transcutaneous O_2 and CO_2 monitors, transesophageal echocardiography (TEE), evoked potentials, EEG, and cerebral or neurologic function monitors may be required. An indwelling urinary catheter is frequently inserted to provide a useful indication of renal function and hemodynamic status.

For procedures posing a risk of venous air embolism, a Doppler probe may be used. A central venous catheter is inserted, and the probe is placed over the right side of the heart, along the right sternal border between the third and sixth intercostal spaces. Positioning is confirmed if there is a change in Doppler signal after a 10-ml bolus of saline is rapidly injected through the catheter. The signal is monitored for the sound of a "millwheel" murmur. TEE is the most sensitive method of detection, but may also be the most expensive (Hamm and Maye, 2010).

Somatosensory evoked potential (SEP) monitoring may be used during some neurosurgery procedures. It is used widely to assess the integrity of the spinal cord during surgery in which the spinal cord is manipulated. Upper and/or lower extremities may be monitored. The electrodes are often placed preoperatively, but occasionally may be placed in the OR, before administration of anesthesia. Ischemia of ascending somatosensory pathways produces a drop in amplitude or loss of waveforms, thus warning the surgeon to take corrective action. Ischemic changes are usually widespread; rarely, however, is motor function lost when somatosensory pathways have not been affected (Chawla and Burneo, 2008).

Despite some controversy, most anesthesia providers believe that the monitoring employed depends on the physiologic status and stability of the patient, the surgical procedure planned and its potential for sudden changes in cardiopulmonary functions, the anticipated blood loss and major fluid shifts, and the anticipated monitoring needs for postoperative management. Although not yet a standard of care, many facilities use the BIS monitor (see Research Highlight: Anesthesia Awareness, p. 114). This monitoring modality is a processed EEG obtained noninvasively from scalp electrodes. It provides a measure of the sedative and hypnotic effects of anesthetic drugs on the central nervous system (CNS). Monitoring of some parameters may be negated by the anesthetic technique selected (Dosch, 2010; Kossick, 2010).

Pulse Oximetry

Pulse oximetry is based on principles of spectrometric oximetry, plethysmography, and the Lambert-Beer law, which relates the concentration of solute in suspension to the intensity of light transmitted through the solution. It gives a continuous noninvasive indication of arterial O_2 saturation of functional hemoglobin and pulse rate, providing an early warning of hypoxemia (Valdez-Lowe et al, 2009).

The O_2-dissociation curve indicates the percentage of totally saturated hemoglobin with O_2. The following values are approximations (the O_2 saturation [Spo_2] values are percentages and the Pao_2 levels are in torr): 98% to 100% (≥95 torr), 90% (60 torr), 75% (39 torr), 50% (26 torr), and 25% (16 torr). Most pulse oximeters are accurate to within ±2% greater than 70% and ±3% from 50% to 70% but correlate poorly at less than 50%. When breathing room air, the Spo_2 for a young, healthy individual should be 98% to 100%; the Spo_2 percentage for an elderly patient may be in the low 90s, whereas the percentage for a heavy smoker or a patient with severe lung disease may be in the 80s. It is wise to note the baseline Spo_2 value of a patient before any O_2, medications, or stimulation is introduced. Maintenance of Spo_2 levels greater than 90% corresponds to a Pao_2 value of 60 torr or greater (Moon and Camporesi, 2005).

The sensor combines two low-intensity, light-emitting diodes (LEDs) as light sources and a photodiode as a receiver or light detector. One LED emits red light (approximately 660 nm), and the other emits infrared light (approximately 940 nm). These light sources alternate about 480 times a second. When the two frequencies of light are transmitted through blood and tissue, they are absorbed differently by tissue components and by reduced hemoglobin and oxyhemoglobin. Because absorption by other tissue components is essentially constant, the major variable is saturation of hemoglobin with O_2. An internal microprocessor analyzes variations in absorption of light emitted from both LEDs and provides a readout of the percent saturation of hemoglobin with O_2. Pulse rate also is given. Many units also display a waveform that correlates with arterial pulsations (Kossick, 2010; Moon and Camporesi, 2005).

The pulse oximeter reading (often referred to as "pulse ox") can be adversely affected by any event that significantly

reduces vascular pulsations, such as hypoperfusion, hypotension, hypovolemia, vasoconstriction, or hypothermia. Electrosurgery, motion, or ambient light also may artifactually decrease the readout. Carboxyhemoglobin (carbon monoxide bound to hemoglobin) falsely elevates indicated Spo_2 saturation, while methemoglobin (hemoglobin that has an oxidized iron molecule and cannot reversibly combine with O_2) falsely lowers Spo_2 measurements. Intravenous dyes affect the pulse oximeter. Methylene blue may cause a drop to 65% for 1 to 2 minutes; indigo carmine, a very slight decrease; and indocyanine green, a slightly greater decrease. Nail polish also can decrease Spo_2 values. Blue, black, or green polish significantly decreases the Spo_2 value, whereas red polish has only a slight effect. Opaque, acrylic nail coverings may block the light beam. If nail polish or coverings seem to cause problems, the sensor can be turned sideways so that the fingernail is parallel to the light path.

The sensor usually is placed on a finger or a toe. Some manufacturers have sensors for the earlobe and the bridge of the nose, as well as smaller ones for soles and palms of infants and children. The pulse oximeter does not require user calibration. Care must be taken to prevent localized neurovascular or ischemic damage. For example, a hard-cased sensor placed on a finger may cause ischemia when the arms are tightly secured at the patient's side during a long procedure.

If trouble with the pulse oximeter is encountered when a local anesthetic is being used, the perioperative nurse should evaluate the patient's ventilatory status, verify proper placement of the sensor, and rule out the factors just listed that may adversely affect operation of the unit. Pulsatile blood flow in the extremity may be inadequate because of hypovolemia, decreased cardiac output, malpositioning, constriction by the blood pressure cuff, or hypothermia. As a final step, the nurse can place the sensor on his or her own finger to verify satisfactory function of the pulse oximetry unit, cable, and sensor.

Capnography

A capnometer measures CO_2 concentration, and a capnograph displays the CO_2 waveform. For patients with normal circulation and pulmonary function, capnography is an excellent method to evaluate alveolar ventilation because the gradient between arterial and alveolar CO_2 is small. With forced expiration, the $ETco_2$ level provides a close approximation of arterial CO_2 pressure ($Paco_2$). During general anesthesia, expiration is passive, and the point of measurement is near the connection between the patient's circuit and the endotracheal tube (ETT), laryngeal mask airway (LMA), or mask. The $ETco_2$ value is 5 to 10 torr lower than the $Paco_2$ value measured in arterial blood (Moon and Camporesi, 2005). During other types of anesthesia, in which oxygen may be administered via a nasal cannula, there is a small-bore tube connected to the cannula, which can be attached to the anesthesia machine so that $ETco_2$ levels can be measured.

$ETco_2$ can be measured by a mass spectrometer, a Raman spectrometer, or an infrared analyzer. Compact units that provide a continuous indication of the $ETco_2$ level are the most widely used. These units measure the amount of infrared light absorbed by CO_2 in the sample of gas. Two types of monitors are in use. In the *mainstream* unit, all respired gas passes through the detector, whereas with the *sidestream* unit, a portion of the gas is aspirated at a constant rate (50 to 250 ml/min) through small-bore tubing into the unit. Each design has advantages. Most units display a waveform of expiratory CO_2 partial pressure relative to time after a short sampling and processing delay. The waveform is important for correctly interpreting output data. Digital readouts usually give $ETco_2$ and respiratory rate. Daily user calibration is rarely required with newer units. Clinically, the units confirm proper endotracheal intubation and are useful to detect anesthesia circuit disconnection, alveolar ventilation, early return of respiratory function after muscle relaxants are used, and acute alterations in metabolic functions, such as malignant hyperthermia (MH) or thyrotoxicosis (Dosch, 2010; Moon and Camporesi, 2005).

ANESTHESIA MACHINES AND ANESTHETIC GASES

The first apparatus resembling an anesthesia machine was used in 1905. Since then, innumerable changes and improvements have been made. Anesthesia machines look complicated, but the basic functions are similar and simple to understand. Perioperative nurses should be familiar with the basic function of anesthesia machines (Figure 4-1) because they may need to

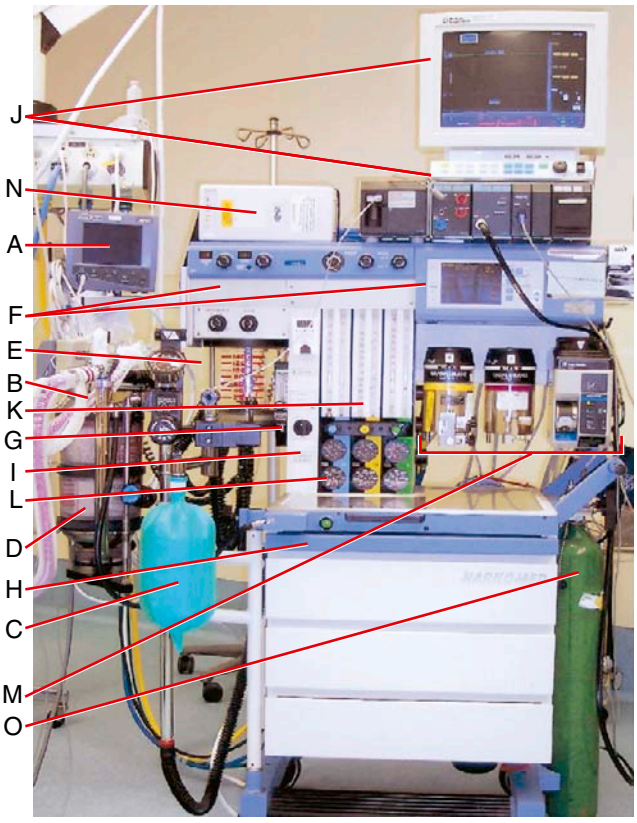


FIGURE 4-1 Modern anesthesia machine. **A**, BIS monitor display. **B**, Patient breathing circuit. **C**, Reservoir ("breathing") bag. **D**, CO_2 absorber. **E**, Ventilator. **F**, Integrated ventilator controls, monitor, and displays. **G**, O_2 flowmeter for nasal cannula. **H**, O_2 flush valve. **I**, On/off switch. **J**, Monitor display and controls for ECG, temperature, blood pressure, pulse oximetry, and end-tidal CO_2. Other modules can be inserted for additional pressures, cardiac output, and BIS. **K**, Flowmeters for air, N_2O, and O_2. **L**, Gauges for pipeline and E-tank pressures (air, N_2O, and O_2). **M**, Flow-through vaporizers (desflurane, isoflurane, and sevoflurane). **N**, Power surge protector for anesthesia machine. **O**, E-cylinder with O_2.

administer O_2 during procedures with local anesthesia or conscious sedation/analgesia.

Oxygen, N_2O, and air usually are supplied from facility pipelines to the anesthesia machine at pressures of 50 to 55 pounds per square inch (psi). Gas hoses connected to the machine are color-coded: green (O_2); blue (N_2O); and yellow (air). Connectors are specific for each gas so that they cannot be inadvertently cross-connected. If a central gas supply is not available or the hospital piping system fails, machines are equipped with E-size cylinders of O_2 and N_2O. One or two cylinders of each gas are connected to yokes on the machine. These yokes are pin-indexed so that only the correct gas can be connected in that position. In the pin-indexing safety system, two steel pins are in a unique location on the yoke assembly. The mating gas cylinder (e.g., the O_2 tank) has two matching holes in the same locations so that cylinders cannot be mounted in the wrong place (Dosch, 2010).

In cylinders, O_2 is stored as a compressed gas. A full E-size cylinder contains about 660 L of O_2 at approximately 2000 psi. As the O_2 is used, the pressure decreases in direct proportion to the remaining volume. Because the E-size cylinder is used to provide O_2 while patients are being transported, one should know how much O_2 is left in a partially used tank; 1000 psi indicates 330 L remaining, and 500 psi indicates 165 L remaining or sufficient O_2 at 5 L/min flow for approximately 30 minutes. When the pressure has decreased to about 250 psi, the cylinder should not be used because it no longer has an adequate reserve (Dosch, 2010).

N_2O is stored as a liquid in cylinders, and the pressure above the liquid is 745 psi. A full E-size cylinder contains about 1600 L of N_2O. As the N_2O is used, the pressure above the liquid remains constant. Only when the liquid has been completely vaporized does pressure begin to decrease. The N_2O cylinder can be nearly empty but still show the same pressure. In contrast to O_2, the amount remaining in the tank cannot be readily determined (Dosch, 2010).

Gases in the cylinders flow through regulators that reduce pressure to about 45 psi as gas enters the machine. Hoses from the hospital gas sources are connected to the machine at the outlet of these regulators. In machines sold after January 1, 1984, a safety interlock device either shuts off the N_2O flow if O_2 pressure is not present or proportionately lowers the O_2 and N_2O flow rates to maintain 30% O_2. The gases flow through individual flowmeters (or rotameters) on the front of the machine so that gas flows and the ratio of O_2 to N_2O or air can be selected by the anesthesia provider. From the top of the flowmeters, the gases are mixed and then flow through a vaporizer in which the inhalational anesthetic of choice is vaporized and added to the gas mixture. The total gas flow is delivered from the machine to the patient. With a flow-through vaporizer, all the fresh gas moving from the anesthesia machine to the patient flows through the vaporizer. The control dials usually are located on top of these vaporizers and are calibrated in percentages. The filling ports on the vaporizers are usually key-indexed so that only the appropriate volatile agent can be used. Newer vaporizers are flow and temperature compensated, meaning that they are reasonably accurate at all flow rates and temperatures (Dosch, 2010).

Desflurane (Suprane) is a unique inhalational anesthetic because it boils at 22.8° C, near room temperature, and its vapor pressure (669 mm Hg) approximates atmospheric pressure (760 mm Hg). The vaporizer for desflurane is pressurized and contains an electric heater. Desflurane also has several other unique characteristics: (1) its solubility in blood (blood-gas partition coefficient) is lower (0.42) than those of N_2O (0.47), sevoflurane (0.63 to 0.69), isoflurane (1.41), and halothane (2.30), which means that it has a faster "wash-in" (induction) and "wash-out" (emergence) than the other agents; (2) metabolism is far less (0.02%) than that of isoflurane (0.2%), sevoflurane (5%), and halothane (15 to 20%); (3) emergence and recovery from general anesthesia and discharge from PACU are significantly faster than when thiopental is used; (4) the cardiovascular effects are similar to those of isoflurane; and (5) muscle relaxation is similar to that which occurs with other inhalational agents. The pungency of desflurane precludes its use as an induction agent (Stoelting and Hillier, 2005b).

Sevoflurane (Ultane) is the newest volatile agent available in the United States. Its pleasant odor and low solubility in blood make it a popular volatile agent for inhalational induction in pediatric patients. In contrast to any of the other volatile agents, it also can provide a rapid, pleasant mask induction in adults.

Another important feature of the anesthesia machine is the O_2 flush valve. Pushing the O_2 flush valve allows 100% O_2 from the 50 psi line to flow directly to the *fresh gas outlet* on the machine and to the patient. This O_2 flow completely bypasses flowmeters and vaporizers. *Caution must be exercised because the pressure is 35 to 50 psi, and the flow rate is 35 to 75 L/min.*

In most hospitals and ambulatory surgery centers in the United States, a semiclosed-circle system (circle system) is used to deliver fresh gas flow (including anesthetic gases) to patients. The circle system is composed of a container filled with a CO_2-absorbing material (e.g., soda lime or Baralyme), two one-way (unidirectional) valves, an adjustable pressure-limiting (APL) valve, a reservoir bag, an inlet connection for fresh gas flow, and two connections to the patient through corrugated breathing (or anesthesia circuit) tubing. As the patient inspires, gases are drawn through the CO_2 absorber and from the fresh gas supply through the inspiratory limb of the corrugated tubing. As the patient exhales, the one-way valve on the inspiratory limb prevents backflow, and the exhaled gases flow into the expiratory limb and through the expiratory one-way valve. The expiratory limb and valve are easily identified by the condensation of water vapor along this portion of the circuit. The reservoir bag absorbs the peak flow of expired gases and allows the anesthesia provider to force gas through the CO_2 absorber, along the inspiratory limb of the circuit, and to ventilate the patient. The expired gases flow through the CO_2 absorber where CO_2 is removed. Substances used in the CO_2 absorbent include an indicator that changes color as the soda lime or Baralyme is exhausted. The soda lime may turn from white to blue, indicating that the absorbent material must be changed to prevent a buildup of CO_2 in the patient. Any excess gas vents through the APL valve into the gas-scavenging system. The APL valve usually is mounted just ahead of the CO_2 absorber (Dosch, 2010).

The F_{IO_2} sensor usually is mounted in the inspiratory limb just after the one-way valve. It measures the fraction of inspired O_2 (F_{IO_2}) and can be set to alarm if a low concentration is detected. A low-pressure sensor usually is mounted in the expiratory limb near the one-way valve to detect a ventilator malfunction or a circuit disconnection.

On newer machines, volumeters are mounted in the inspired and expired limbs where the patient breathing circuit is connected. When the ventilator is used, the electronic circuitry measures the inspiratory and expiratory volumes to ensure that they correspond with the tidal volume and respiratory rate selected. With a cuffed ETT, the ventilator compensates for changes in fresh gas flow or small leaks in the breathing circuit and alarms if a disconnect or inadequate flow occurs (Dosch, 2010).

The advantage of the circle system is that much lower flows of O_2, N_2O, and anesthetic gases can be used; this conserves the patient's body heat and respiratory moisture and reduces the cost of expensive, volatile agents. A *semiclosed-circle system* typically is used when fresh gas flows into the system (flow rate ranges from 0.5 to 6 L/min). During exhalation, some of the expired gases are recycled through the CO_2 absorber, and excess gas is scavenged or eliminated. With a *closed-circle system,* all of the CO_2 is absorbed. No gas is vented from the system, and only enough O_2 is added to meet the basal requirements of the patient (approximately 3.5 ml/kg/min). In a *semiopen circuit* (e.g., Ayres T-piece, Magill, Bain circuits), a relatively high flow of fresh gas is used and most exhaled gas is vented from the circuit. The fresh gas flow rate per minute varies from approximately two thirds of the patient's minute volume with the Magill circuit to at least 100 ml/kg with the Bain T-piece circuit. The semiopen circuit system is commonly used for neonates, infants, and small children (Dosch, 2010). With all these circuits, the final connection to the patient is by a mask, ETT, or LMA.

GENERAL ANESTHESIA

Mechanism of Action

Numerous proposed theories explain the action of general anesthetics. Recent investigations have involved inhalation anesthetics. (The terms *volatile anesthetic, potent agent,* and *inhaled* or *inhalational anesthetic* are synonymous with *inhalation anesthetic.*) Evidence suggests that synaptic transmission of nerve impulses is reversibly inhibited in several areas of the CNS. The extent of inhibition and consequent progressive depression of function are correlated with the partial pressure of the inhaled anesthetic at various sites. The inhibition is believed to occur at a lipophilic site on the biologic membrane of synapses and possibly on small, unmyelinated nerve fibers. Suppression of spinal reflex activity is believed to produce some relaxation of skeletal muscles. Although no single theory explains all phenomena, a few theories explain many of the actions (Stoelting and Hillier, 2005b). The following theories are some of those more widely accepted.

Protein Receptor Theory. This theory proposes that hydrophobic areas of specific proteins in the CNS act as receptor sites. The steep, dose-response curve of inhaled anesthetics seems to support this theory by suggesting that a critical number of receptor sites must be occupied before patient movement in response to noxious stimuli is obtunded (Stoelting and Hillier, 2005b).

Meyer-Overton Theory. This theory is also called the *critical volume hypothesis*. It explains the correlation between lipid solubility (oil-to-gas partition coefficient) and anesthetic potency. It proposes that when enough anesthetic molecules dissolve (i.e., a critical volume is reached) at a crucial hydrophobic site, such as the lipid cellular membrane, anesthesia is achieved. As the cell membrane expands in response to dissolved anesthetic molecules, changes in ionic channels occur and alter the sodium flux involved in cellular depolarization. Because some lipid-soluble compounds are not anesthetics, this theory does not completely explain anesthetic action (Stoelting and Hillier, 2005b).

Endogenous Endorphins. Endogenous endorphins, or opiate-like substances, suppress various pain pathways. Several classes of endorphins have been identified. The action of β-endorphins is antagonized by naloxone or nalmefene, specific narcotic antagonists, but the relative potency of inhaled anesthetics is not altered. Although some degree of analgesia may be explained by this mechanism, it does not correlate well with the level of anesthesia achieved by inhaled anesthetics.

Intravenous anesthetics also may function by some of the mechanisms proposed for inhaled anesthetics. Factors involved in the pharmacokinetics of IV anesthetics include the volume of distribution, biotransformation, and clearance of the drug by metabolism, excretion, or elimination of the drug and its metabolites (Stoelting and Hillier, 2005b).

No single theory for the mechanism of action explains all of the effects observed with anesthetic agents. The range of anesthetic activity varies with different anesthetics; the effects on the CNS and skeletal muscles are similar but not identical; structural and spatial differences exist among agents; changes at the membrane and cellular levels occur; and optical isomers produce different responses. Although similar in many respects, anesthetic agents are individually unique and probably work through numerous mechanisms and at multiple sites to produce their effects.

Levels of General Anesthesia

Guedel integrated the signs and stages of ether anesthesia into a system that was used clinically for more than 60 years. This system applied only to unpremedicated patients breathing spontaneously during ether anesthesia, a technique that is rarely used today except in developing countries. By evaluating physiologic changes and reflex responses, one can estimate the depth of anesthesia. Stage 1 is from the initial administration of anesthetic agents to loss of consciousness. Stage 2 is from loss of consciousness to the onset of regular breathing and loss of the eyelid reflex. Stage 2 also is called the *delirium* or *excitement* stage, and thrashing movements may occur. No auditory or physical stimulation should occur during this stage, especially in children. Stage 3, which begins with the onset of a regular breathing pattern and lasts until cessation of respiration, is divided into four planes and is the stage of surgical anesthesia. Stage 4 is from cessation of respiration to circulatory failure that leads to death (Nagelhout and Plaus, 2010).

Although Guedel's system gives us an appreciation for the interrelationships of numerous signs during anesthesia, the variety of drugs and anesthetic techniques used today do not provide uniform responses suitable to estimate the exact depth of anesthesia. Narcotics and anticholinergic drugs given as premedicants alter pupillary responses. Evaluation of respiratory responses and muscle tone is not valid when controlled ventilation and muscle relaxants are used. Today, general anesthesia usually is induced with IV injection of a rapid-acting drug, such

as thiopental or propofol (Diprivan), which takes the patient rapidly to stage 3 and eliminates the untoward responses often seen during stage 2.

For optimal anesthesia and good surgical conditions, several different but interrelated factors are evident. These include hypnosis (sleep), analgesia (freedom from pain), amnesia (lack of recall or awareness), appropriate surgical conditions including muscle relaxation and positioning of the patient, and continued homeostasis of the patient's vital functions. Different drugs and anesthetic agents possess various properties that facilitate these factors. Combinations of drugs are used to obtain the desired effects. Hypotensive or hypertensive drugs and cardioactive agents also may be used to achieve optimal depth of anesthesia while affecting physiologic homeostasis as little as possible. Drugs commonly used in anesthesia are briefly described in the Surgical Pharmacology box.

Phases of General Anesthesia

General anesthesia is divided into three phases: *induction*, *maintenance*, and *emergence*. *Induction* begins with administration of anesthetic agents and continues until the patient is ready for positioning or surgical prepping (surgical prep), surgical manipulation, or incision. The surgical prep is often started after the induction drugs are given. This end point of induction may vary with the surgical procedure. The *maintenance* phase continues from this point until near completion of the procedure and is accomplished with inhalation agents or with IV drugs given in titrated doses or by continuous infusions. *Emergence* varies in length and depends on the patient's state and the depth and duration of anesthesia. Emergence starts as the patient begins to "emerge" from anesthesia and usually ends when the patient is ready to leave the OR. Intubation occurs during the induction phase, and extubation usually

SURGICAL PHARMACOLOGY

Commonly Used Anesthetic Gases and Drugs

	Common Usage	Advantages	Disadvantages	Comments
INHALATION GASES				
Air	Maintenance with O_2; laser surgery near airway	Less support of combustion than N_2O	No anesthetic qualities	Possibly less nausea than N_2O (Stoelting, Hillier, 2005b)
Oxygen (O_2)	Essential for life	Can slightly ↑ O_2 available to tissues in low cardiac output states	Can cause retinopathy in premature infants	High concentrations hazardous with lasers in surgery of head, neck, and pulmonary areas (Stoelting, Hillier, 2005b)
Nitrous oxide (N_2O)	Maintenance; frequently for induction	Rapid induction and recovery; additive effects to other anesthetics	No relaxation; can depress myocardium	Hypoxia if overdose given; ↑ uptake of other volatile agents (Stoelting, Hillier, 2005b)
Enflurane (Ethrane)	Maintenance; occasionally for induction	Good relaxation; allows more epinephrine to be used than does halothane; 2.4% metabolized	Can cause ↑ HR and ↓ BP; lowers seizure threshold; slightly irritating odor	Abnormal EEG at high concentrations; used less often today (Stoelting, Hillier, 2005b)
Desflurane (Suprane)	Maintenance in short cases	Rapid emergence; good relaxation; 0.02% metabolized	May cause transient ↑ HR and ↓ BP; airway irritation; requires heated vaporizer	Rapid recovery phase; can use for emergence after maintenance with another volatile agent (Stoelting, Hillier, 2005b)
Halothane (Fluothane)	Maintenance; frequently for induction in pediatric patients	Rapid induction and recovery; pleasant, nonirritating odor; fair relaxation	May cause ↓ HR and ↓ BP; PVC and ventricular fibrillation may occur with epinephrine	Narrow margin of safety; sensitizes myocardium to epinephrine; rare cause of liver damage; 15-20% metabolized (Stoelting, Hillier, 2005b)
Isoflurane (Forane)	Maintenance	Good relaxation; allows more epinephrine to be used than does halothane; maintains cardiac output; 0.2% metabolized	↑ HR; slightly irritating odor	Isomer of enflurane; commonly used agent (Stoelting, Hillier, 2005b)
Sevoflurane (Ultane)	Induction and maintenance	Rapid induction and emergence; good relaxation; ≈5% metabolized	Metabolite (compound A) is nephrotoxic in rats; effect in humans unknown	Rapid and smooth mask induction in children and adults (Stoelting, Hillier, 2005b)

SURGICAL PHARMACOLOGY

Commonly Used Anesthetic Gases and Drugs—cont'd

	Common Usage	Advantages	Disadvantages	Comments
OPIOID ANALGESICS				
Morphine sulfate	Perioperative pain; premedication	Inexpensive; duration of action 4-5 hr; euphoria; good cardiovascular stability	Nausea and vomiting; histamine release; postural ↓ BP (↓ SVR); high first-pass effect with PO administration	Used intrathecally and epidurally for postoperative pain; elimination half-life 3 hr (Faut-Callahan, Hand, 2010)
Alfentanil (Alfenta)	Surgical analgesia in ambulatory patients	Duration of action 0.5 hr; used as bolus or infusion	—	Potency: 750 mcg = 10 mg morphine sulfate; elimination half-life 1.6 hr (Faut-Callahan, Hand, 2010)
Fentanyl (Sublimaze)	Surgical analgesia; epidural infusion for postoperative analgesia; add to SAB	Good cardiovascular stability; duration of action 0.5 hr	—	Most commonly used opioid; potency: 100 mcg = 10 mg morphine sulfate; elimination half-life 3.6 hr (Faut-Callahan, Hand, 2010)
Remifentanil (Ultiva)	0.25-1 mcg/kg/min infusion for surgical analgesia; small boluses for brief, intense pain	Easily titratable; metabolized by blood and tissue esterases; short duration; good cardiovascular stability	Expensive; requires mixing	Potency: 25 mcg = 10 mg morphine sulfate; 20-30× potency of alfentanil; elimination half-life 3-10 min (Faut-Callahan, Hand, 2010)
Sufentanil (Sufenta)	Surgical analgesia	Good cardiovascular stability; duration of action 0.5 hr; prolonged analgesia	Prolonged respiratory depression	Potency: 15 mcg = 10 mg morphine sulfate; elimination half-life 2.7 hr (Faut-Callahan, Hand, 2010)
DepoDur (morphine liposomal)	For epidural use only	Single dose provides analgesia for up to 48 hr Decreased requirements for supplemental opioids	Potential for respiratory depression Avoid other epidural drugs ≈48 hr	10-15 mg epidural, 1 dose (Hartrick et al, 2006)
DEPOLARIZING MUSCLE RELAXANTS				
Succinylcholine (Anectine, Quelicin)	Intubation; short cases	Rapid onset; short duration	Requires refrigeration; may cause fasciculations, postoperative myalgias, and dysrhythmias; ↑ serum K^+ with burns, tissue trauma, paralysis, and muscle diseases; slight histamine release	Prolonged muscle relaxation with serum cholinesterase deficiency and certain antibiotics; trigger agent for MH (Nagelhout, 2010)
NONDEPOLARIZING MUSCLE RELAXANTS—INTERMEDIATE ONSET AND DURATION				
Atracurium (Tracrium)	Intubation; maintenance of relaxation	No significant cardiovascular or cumulative effects; good with renal failure	Requires refrigeration; slight histamine release	Breakdown by Hofmann elimination and ester hydrolysis (Nagelhout, 2010)
Cisatracurium (Nimbex)	Intubation; maintenance of relaxation	Similar to atracurium	No histamine release	Similar to atracurium (Nagelhout, 2010)
Mivacurium (Mivacron)	Intubation; maintenance of relaxation	Short-acting; rapid metabolism by plasma cholinesterase; used as bolus or infusion	Expensive in long cases	Rarely need to reverse; prolonged effect with plasma cholinesterase deficiency (Nagelhout, 2010)

Continued

SURGICAL PHARMACOLOGY

Commonly Used Anesthetic Gases and Drugs—cont'd

	Common Usage	Advantages	Disadvantages	Comments
Rocuronium (Zemuron)	Intubation; maintenance of relaxation	Rapid onset (dose-dependent); elimination via kidney and liver	Vagolytic; may increase HR	Duration similar to atracurium and vecuronium (Nagelhout, 2010)
Vecuronium (Norcuron)	Intubation; maintenance of relaxation	No significant cardiovascular or cumulative effects; no histamine release	Requires mixing	Mostly eliminated in bile, some in urine (Nagelhout, 2010)
NONDEPOLARIZING MUSCLE RELAXANTS—LONGER ONSET AND DURATION				
Tubocurarine	Maintenance of relaxation	—	May cause histamine release and transient ganglionic blockade	Mostly used for pretreatment with succinylcholine
Pancuronium (Pavulon)	Maintenance of relaxation	—	May cause ↑ HR and ↑ BP	Mostly renal elimination (Nagelhout, 2010)
INTRAVENOUS ANESTHETICS				
Etomidate (Amidate)	Induction	Good cardiovascular stability; fast, smooth induction and recovery	May cause pain with injection and myotonic movements	—
Diazepam (Valium, Dizac)	Amnesia; hypnotic; preoperative medication	Good sedation	Prolonged duration	Residual effects for 20-90 hr; increased effect with alcohol (Stoelting, Hillier, 2005b)
Ketamine (Ketalar)	Induction, occasional maintenance (IV or IM)	Short-acting; patient maintains airway; good in small children and burn patients	Large doses may cause hallucinations and respiratory depression	Need darkened, quiet room for recovery; often used in trauma cases (Stoelting, Hillier, 2005b)
Midazolam (Versed)	Hypnotic; anxiolytic; sedation; often used as adjunct to induction	Excellent amnestic; water-soluble (no pain with IV injection); short-acting	Slower induction than thiopental	Often used for amnesia with insertion of invasive monitors or regional anesthesia (Stoelting, Hillier, 2005b)
Propofol (Diprivan)	Induction and maintenance; sedation with regional anesthesia or MAC	Rapid onset; awakening in 4-8 min	May cause pain when injected	Short elimination half-life (34-64 min) (Stoelting, Hillier, 2005b)
Sodium methohexital (Brevital sodium)	Induction	Ultrashort-acting barbiturate	May cause hiccups	Can be given rectally (Stoelting, Hillier, 2005b)
Thiopental sodium (Pentothal)	Induction	Induction	May cause laryngospasm; can be given rectally (Stoelting, Hillier, 2005b)	Large doses may cause apnea and cardiovascular depression
LOCAL ANESTHETICS				
Bupivacaine (Marcaine, Sensorcaine)	Epidural, spinal, or local infiltration	Good relaxation; long-acting	Overdose can cause cardiac collapse	Epidural or caudal: 2.5 mg/kg Duration: 120-240 min (Faut-Callahan, Hand, 2010)
Chloroprocaine (Nesacaine)	Epidural anesthesia	Ultrashort-acting; good relaxation	May cause neurotoxicity if injected into CSF	Maximum dose 600 mg; duration 30-45 min
Lidocaine (Xylocaine)	Epidural, spinal, peripheral, IV anesthesia, and local infiltration	Short-acting; good relaxation; low toxicity	Overdose can cause convulsions; possible transient neurologic changes with spinal anesthesia	Also used for ventricular dysrhythmias; maximum dose 7 mg/kg and 5 mg/kg with and without epinephrine; duration 60-120 min (Faut-Callahan, Hand, 2010)

SURGICAL PHARMACOLOGY

Commonly Used Anesthetic Gases and Drugs—cont'd

	Common Usage	Advantages	Disadvantages	Comments
Ropivacaine (Naropin)	Local infiltration, peripheral nerve block Epidural	Fast Slow Moderate	≈30-40% less cardiotoxic than bupivacaine (Salinas et al, 2004)	5-8 hr (max single dose 250 mg) 2-6 hr (max single dose 200 mg) (Salinas et al, 2004)
Tetracaine (Pontocaine)	Spinal anesthesia	Long-acting; good relaxation	—	Maximum dose 1–1.5 mg/kg (epinephrine rarely used); duration 60-180 min (Stoelting, Hillier, 2005a)
ANTICHOLINERGICS				
Atropine	Blocks effects of acetylcholine; ↓ vagal tone; reverse muscle relaxants; treat sinus bradycardia	↑ HR; suppresses salivation, bronchial and gastric secretions	Depresses sweating; may cause dry mouth, flushing, dizziness, CNS symptoms	Quite selective at muscarinic receptors in smooth and cardiac muscle and exocrine glands (Nagelhout, 2010)
Glycopyrrolate (Robinul)	Similar to atropine	Slightly ↑ HR; does not cross blood-brain barrier; can increase gastric pH more than atropine	Prolonged duration of effects	Lower incidence of dysrhythmias than atropine (Nagelhout, 2010)
CHOLINERGIC AGENT				
Neostigmine (Prostigmine)	Reverses effects of nondepolarizing neuromuscular blocking agents	Prevents breakdown of acetylcholine by inhibiting acetylcholinesterase	—	Given with either atropine or glycopyrrolate (Nagelhout, 2010)
OTHER				
Dexmedetomidine (Precedex)	Selective α_2-agonist	Produces centrally mediated sympatholytic, sedative, and analgesic effects	Provides hemodynamic stability, potentiates intraop anesthetics, reduces anesthetic requirements, less respiratory depression than opioids (Haselman, 2008)	Intraop 0.2–0.7 mcg/kg/hr (Haselman, 2008)

BP, Blood pressure; *CNS,* central nervous system; *CSF,* cerebrospinal fluid; *EEG,* electroencephalogram; *HR,* heart rate; *IM,* intramuscular; *IV,* intravenous; *MAC,* monitored anesthesia care; *MH,* malignant hyperthermia; *PO,* oral; *PVC,* premature ventricular contractions; *SAB,* subarachnoid block; *SVR,* systemic vascular resistance.

is performed during emergence. Recovery from anesthesia can be considered a fourth phase of general anesthesia.

Types of General Anesthesia

The type of general anesthesia employed often is described as IV technique, inhalation technique (with a volatile anesthetic agent), or a combination of IV and inhalation techniques. An IV technique traditionally includes (1) an induction agent such as thiopental, combined with 30% to 40% O_2 and N_2O; (2) an amnestic/anxiolytic, such as midazolam or diazepam; (3) an analgesic such as fentanyl or morphine sulfate; and (4) a muscle relaxant.

In contrast, an inhalation technique may use thiopental or propofol to facilitate a rapid induction, or patients may "breathe themselves down" with a potent agent, such as sevoflurane or halothane, plus N_2O and O_2. An inhalation induction is often used with children to avoid inserting an IV catheter while they are awake. Depending on the kind of surgical procedure, maintenance of anesthesia may be accomplished with only inhalation agents and spontaneous, assisted, or controlled ventilation. Effects of volatile agents are dose related and they provide differing levels of anesthesia, amnesia, analgesia, muscle relaxation, and hemodynamic responses. If supplemental muscle relaxation is needed, the relaxant dose required is significantly less than the dose necessary during IV anesthesia.

In the past, the term *balanced anesthesia* was used when various combinations of IV drugs were "balanced" to provide complete anesthesia. Today, the term is often used to describe a combination of IV drugs and inhalation agents employed to obtain specific effects for each patient and procedure.

Anesthesia providers also use *total IV anesthesia (TIVA)*. This technique may be used in the OR but is commonly employed for pediatric, uncooperative, or trauma patients in remote locations, such as in the magnetic resonance imaging (MRI), radiology, or surgical laser suite where a waste-gas evacuation system

is not available. TIVA also is used in the expanding area of office-based surgical procedures. With TIVA, short-acting drugs such as propofol with remifentanil or alfentanil are used for induction. These drugs may be administered by continuous infusion. Anesthesia is maintained by an infusion plus O_2 alone or with N_2O. An intermediate-acting muscle relaxant (mivacurium, cisatracurium, atracurium, rocuronium, or vecuronium) may also be given. As surgery nears completion, the maintenance drugs are titrated off, and emergence from anesthesia occurs.

Muscle Relaxants

Muscle relaxants (also referred to as neuromuscular blocking drugs [NMBDs]) are used to facilitate intubation and to provide good operating conditions at lighter planes of general anesthesia. These drugs may be used elsewhere for emergency intubation or, less frequently, when a patient is being mechanically ventilated. Muscle relaxants affect skeletal muscle and have little effect on cardiac or smooth muscle. Although not always dose dependent, many of these drugs have adverse side effects. The route of metabolism and elimination varies, and this may be important for patients with hepatic or renal disease. Muscle relaxants are classified as *depolarizing* or *nondepolarizing*.

Succinylcholine (Anectine) is the only *depolarizing* muscle relaxant used clinically. Its action is similar to that of acetylcholine, and at the neuromuscular junction it causes depolarization of the postjunctional membrane (Stoelting and Hillier, 2005b). Generalized skeletal muscle contractions known as *fasciculations* result from simultaneous depolarization of all the muscle fibers. To prevent these fasciculations and associated postoperative myalgias, a dose of a nondepolarizing relaxant (such as tubocurarine 0.04 mg/kg) is given 3 to 5 minutes before administration of the intubating dose of succinylcholine. Onset of paralysis (30 to 90 seconds) is faster and duration of action (5 to 10 minutes) is shorter than with other relaxants. The speed of onset makes it a preferred drug for rapid-sequence inductions. Adverse side effects associated with use of succinylcholine include cardiac dysrhythmias, hyperkalemia, myalgias (particularly in young and muscular patients), and increases in intraocular, intracranial, and intragastric pressures. It also can trigger malignant hyperthermia (MH) in susceptible patients. It can be infused for longer procedures, but an excessive dose may cause prolonged relaxation (known as *phase II blockade*). Succinylcholine is hydrolyzed by plasma cholinesterase, and the rare patient with an abnormal or absent enzyme (plasma cholinesterase) has prolonged muscle paralysis (Stoelting and Hillier, 2005b).

Nondepolarizing muscle relaxants competitively block the depolarizing action of acetylcholine at the neuromuscular junction, which results in skeletal muscle paralysis. Fasciculations do not occur. These drugs can be subdivided by duration of action into intermediate-acting (mivacurium, atracurium, cisatracurium, rocuronium, and vecuronium) and long-acting (tubocurarine, metocurine, pancuronium, pipecuronium, and doxacurium) (Lynn, 2009). The potency, duration (metabolism and elimination), and side effects of these drugs vary and may be individually altered in patients with hepatic or renal dysfunction, electrolyte imbalance, or hypothermia or when used in combination with other perioperative drugs (inhalation and local anesthetics, aminoglycoside antibiotics, calcium-entry blockers, magnesium, and cardiac antidysrhythmics). Generally, nondepolarizing relaxants can be used for patients with MH or plasma cholinesterase deficiencies (except for mivacurium). Side effects vary with individual drugs, are dose dependent, and include alterations in blood pressure (BP) and heart rate. The neuromuscular blockade of muscle relaxants can be monitored with a peripheral nerve stimulator. Paralysis caused by nondepolarizing relaxants may be antagonized (reversed) by IV anticholinesterases, such as edrophonium, neostigmine, or pyridostigmine. Antagonists allow acetylcholine to accumulate and compete for receptor sites at the neuromuscular junction and may be associated with bradycardia, for which atropine or glycopyrrolate is routinely given (Stoelting and Hillier, 2005b).

Typical Sequence of General Anesthesia

After arriving in the preoperative area or the OR suite, the anesthesia provider again identifies the patient; verifies consent or an operative permit is signed; reviews current laboratory tests, diagnostic studies, and pertinent medical history; and confirms there have been no interval changes in the patient's status. Depending on the practice of the anesthesia department and institutional policy, an IV infusion may be started in the preoperative area or after the patient is transferred to the OR, as nearly all anesthesia-related drugs are given IV except the inhalation agents. After the patient arrives in the OR and is transferred to the OR bed, monitors are connected.

Before induction, the patient usually is preoxygenated (i.e., denitrogenated) using a mask with 100% O_2 for 3 to 5 minutes. This practice permits washout of most gaseous nitrogen from the body and provides a large reserve supply of O_2 in the lungs. Opioids and benzodiazepines usually are administered at this time. A test dose of the induction agent (e.g., 50 mg of thiopental) often is given to check for any unusual or exaggerated response. If succinylcholine is to be used for intubation, a small pretreatment dose of a nondepolarizing muscle relaxant (e.g., 3 mg of tubocurarine, 0.5 to 1 mg of pancuronium or vecuronium, or 5 mg of rocuronium) usually is given. If the patient can be safely ventilated with a mask, many anesthesia providers avoid the adverse effects of succinylcholine and use one of the nondepolarizing muscle relaxants for intubation (Naguib and Lien, 2005).

To induce anesthesia, a short-acting barbiturate, such as thiopental (2 to 6 mg/kg) or propofol (1.5 to 2.5 mg/kg), is given. When the patient becomes apneic and the eyelash reflex is absent, the airway is checked for patency by ventilating the patient with a mask. Depending on several factors, such as the airway and the type and duration of surgery, O_2 and anesthetic gases may be delivered to a spontaneously breathing patient through a mask held in place with a head strap. Positioning of the head or insertion of an oral or nasal airway may be used to maintain a patent airway. If spontaneous or assisted ventilation is planned, an LMA may be inserted without a muscle relaxant. A mask or LMA may be used for a patient with a good airway who is at minimal risk of aspiration and is undergoing a relatively short procedure, and when the surgical site is not located in the head or neck area.

If mask anesthesia or an LMA is inappropriate, an ETT may be used to facilitate ventilation and to prevent aspiration. Typical equipment used for intubation and airway control and monitoring is shown in Figure 4-2. An intubating dose of a muscle relaxant is administered, resulting in temporary paralysis. When the patient is paralyzed, ventilation is controlled during the procedure.

To facilitate intubation, the patient's head is placed in a "sniffing" position. The laryngoscope is held in the left hand. The laryngoscope blade is inserted into the right side of the mouth and moved to the midline, "sweeping" the tongue to

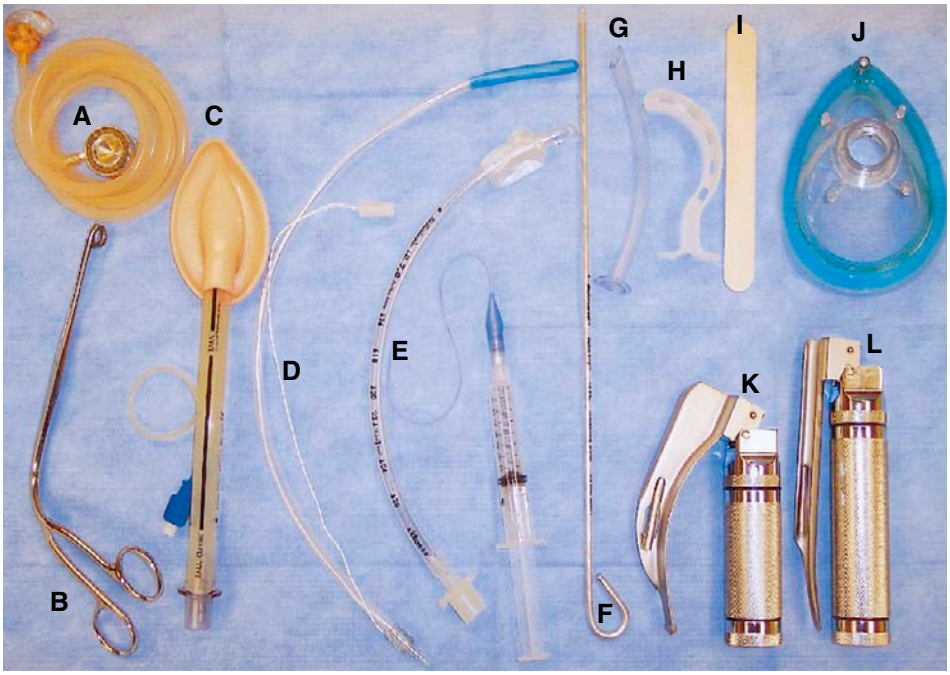


FIGURE 4-2 Commonly used anesthesia equipment. **A**, Precordial stethoscope. **B**, McGill forceps. **C**, Laryngeal mask airway (LMA). **D**, Esophageal stethoscope with esophageal temperature monitor. **E**, Endotracheal tube (ETT). **F**, Intubating stylet for endotracheal tube. **G**, Nasal airway. **H**, Oral airway. **I**, Tongue blade. **J**, Mask. **K**, "Stubby" laryngoscope handle with MacIntosh (curved) fiberoptic laryngoscope blade. **L**, Miller (straight) fiberoptic laryngoscope blade and handle.

the left. The ETT is introduced on the right side of the mouth and gently inserted into the trachea so that the cuff is approximately 1 cm below the vocal cords. The cuff is inflated just enough to occlude any air passage with the peak pressures used for ventilation. Location of the ETT in the trachea is verified by an appropriate level and waveform of $ETCO_2$, bilaterally equal breath sounds and absence of sounds over the stomach (determined using a stethoscope), symmetric movement of the thorax with positive-pressure ventilation, and condensation of moisture from expired air in the ETT and breathing circuit. Proper placement of the ETT is shown in Figure 4-3. While the vocal cords are the narrowest portion of an adult trachea, the smallest portion of a child's airway is below the vocal cords at the cricoid cartilage. Uncuffed ETTs usually are selected for children. After initial paralysis from the muscle relaxant has worn off, the patient may be allowed to breathe spontaneously with intermittent assistance, or additional muscle relaxant is given and ventilation controlled mechanically.

If the procedure is emergent or the patient is at risk for aspiration (as in cases of a full stomach, intestinal obstruction, hiatal hernia, or significant esophageal reflux) (Research Highlight), a rapid-sequence induction or an "awake" fiberoptic intubation may be planned. In these instances and in routine intubation, the perioperative nurse must be ready to assist by applying cricoid pressure (Figure 4-4). The nurse exerts downward pressure on the cricoid cartilage with the thumb and index finger of one hand (Sellick maneuver). The cricoid cartilage is the only complete ring in the trachea. Correctly applied downward pressure occludes the esophagus, which lies immediately posterior (or dorsal) to the trachea, enhancing the view required for intubation (Patten, 2007). The pressure

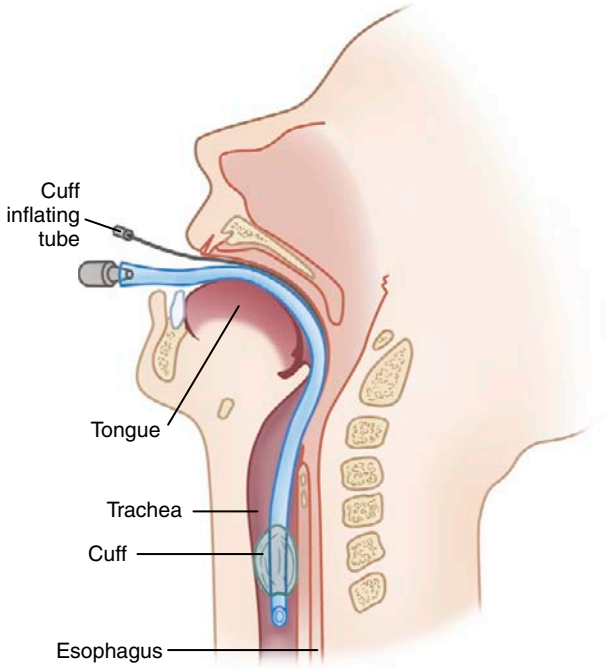


FIGURE 4-3 ETT in position.

should not be released until proper placement of the ETT has been confirmed and the cuff inflated. This procedure has been widely accepted among anesthesia providers. Research suggests that this maneuver is difficult to do correctly and effectively (Beavers et al, 2009).

RESEARCH HIGHLIGHT

Perioperative Pulmonary Aspiration

Pulmonary aspiration is an infrequent event, occurring in about 1 in 3000 patients undergoing general anesthesia. Sicker patients undergoing emergency procedures are at the greatest risk and have the highest incidence. Complications of aspiration have been reported to cause 10% to 30% of anesthesia-related deaths. Approximately 25% of patients who aspirate gastric contents develop significant complications. About 10% of patients who aspirate require mechanical ventilation support for more than 24 hours.

Induced unconsciousness interferes with multiple biologic mechanisms that normally guard the airway against aspiration. Aspiration may occur at any time, but it is most common during tracheal intubation and extubation. A common factor during intubation is inadequate muscle relaxation, which may cause gagging and vomiting. During extubation, aspiration may occur because the patient is weak or unresponsive. Consequences include aspiration pneumonia, acute respiratory distress syndrome, and pulmonary edema as well as long-term complications such as laryngotracheal damage and decreased lung compliance.

The perioperative nurse assists the anesthesia provider in emergent procedures and when a surgical patient is at risk for aspiration (as in cases of a full stomach, intestinal obstruction, hiatal hernia, or significant esophageal reflux). For these patients, a rapid-sequence induction (RSI) or an "awake" fiberoptic intubation may be planned. The perioperative nurse must be ready to assist by applying cricoid pressure—exerting downward pressure on the cricoid cartilage with the thumb and index finger of one hand (Sellick maneuver). When cricoid pressure is used to prevent aspiration, it should not be released until intubation is accomplished (or the anesthesia provider directs release, as in when and if a patient vomits), the cuff on the ETT inflated, the ETT secured, and proper placement of ETT verified by the anesthesia provider.

Modified from Patten SP: Apply cricoid pressure correctly, *OR Nurse* 1(3):72, 2007; Pisegna JR, Martindale RG: Acid suppression in the perioperative period, *J Clin Gastroenterol* 39(1):10-16, 2005; Pousman RM: *Rapid sequence induction for prehospital providers,* 2008, available at www.uam.es/departamentos/medicina/anesnet/journals/ijeicm/vol4n1/rapid.htm#V.%20Rapid%20Sequence%20Induction. Accessed June 3, 2009; Warner MA: Is pulmonary aspiration still an important problem in anesthesia? *Curr Opin Anesthesiol* 13:215-218, 2000.

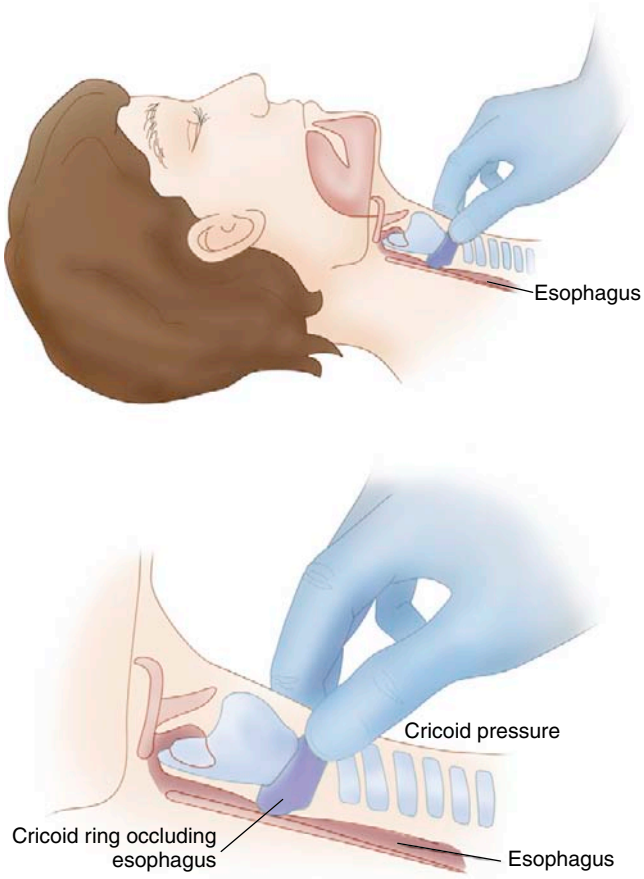


FIGURE 4-4 Applying cricoid pressure.

The perioperative nurse may provide additional assistance if an unexpected difficult intubation occurs or the patient cannot be ventilated adequately via mask. Emergency airway equipment should be brought into the room immediately. The perioperative nurse should be familiar with the location of the various pieces of equipment, know how to assemble the equipment for use, and should assist the anesthesia provider in securing the airway. Securing the airway in an emergency situation requires an intense team effort. The contents of a typical difficult-airway cart are listed in Box 4-2. If invasive monitors (e.g., an arterial line) are to be placed after induction, the perioperative nurse may assist by properly positioning the patient or extremity; prepping the area or areas; and assisting with placement, connection, and calibration of the monitors. If the procedure is emergent, the perioperative nurse also may assist by obtaining additional IV access, connecting fluid-warming or patient-warming units, double-checking blood products, and "pumping" IV fluids as needed. In situations in which the anesthesia provider is involved with a critical procedure, such as a difficult-airway/airway emergency, the perioperative nurse can perform a valuable service by ensuring 100% O_2, having suction available, observing the monitors, recording data (Spo_2 and $ETco_2$ values), and communicating significant changes to the anesthesia provider (Evidence for Practice).

The LMA is a major advancement in airway management. Placement is relatively simple and does not require laryngoscopy or muscle relaxation. When comparing ease of use, invasiveness, and airway protection, the LMA ranks between the facemask and an ETT. It is ideal for a supine patient under general anesthesia with spontaneous ventilation. The LMA also may be useful in a difficult-airway situation in which tracheal intubation cannot be achieved. It is available in six sizes, can be autoclaved, and is reusable. A disposable LMA also is available.

Before insertion, the LMA must be deflated carefully so that there are no wrinkles in the cuff. The recommended technique for insertion of the LMA is shown in Figure 4-5, and correct placement is shown in Figure 4-6. For adults, it is recommended that a 2.5- to 3-cm diameter roll of gauze sponges be used as a "bite block" and inserted beside the LMA tube (*LMA airway instruction manual,* 2004). The LMA and gauze roll can be secured with tape.

Maintenance of anesthesia can be accomplished with IV or inhalational anesthetic techniques or a combination of both,

EVIDENCE FOR PRACTICE

Difficult-Airway Management

Best practices, clinical guidelines, and evidence-based patient care are all forms of systematically developed recommendations that assist practitioners in making decisions about treatments and interventions. Although they are not standards or absolute requirements, they are utilitarian for the clinical situation they represent. In 1992 the ASA developed *Practice Guidelines for Management of the Difficult Airway.* Airway emergencies can occur at any time during the perioperative period. Serious airway problems can result in adverse outcomes, including death, brain injury, myocardial injury, and airway trauma. The ASA difficult-airway algorithm has recommended sequences of activity for recognized and unrecognized difficult airways as well as primary and alternative strategies for awake intubation and intubation attempts after induction of general anesthesia. Although patient management remains the responsibility of the anesthesia team, all perioperative nurses should know about necessary equipment, including location, setup, and function. Most institutions have a difficult-airway cart (see Box 4-2), centralizing items and supplies necessary to manage airway emergencies. The ASA *Practice Guidelines* suggest contents for this cart, but anesthesia providers may add or modify preference items.

The anesthesia provider assesses the likelihood and clinical impact of potential airway problems by evaluating the patient's airway. Questions related to congenital, acquired, and traumatic disease states are posed to detect factors that might indicate the presence of a difficult airway. The patient is examined to detect physical characteristics that may make intubation or mask ventilation difficult. The pharyngeal structures may be assessed, the distance from the mandible to the hyoid noted, and the ability to extend the neck determined. An obese patient is more likely to require a shoulder roll to align the three axes of the airway (oral, pharyngeal, and laryngeal). With a shoulder roll, the scapulae, shoulders, and nape of the neck are supported, resulting in an improved sniff position. Anticipatory action on the part of the perioperative nurse in assisting with shoulder roll placement is an example of the hallmark teamwork and collaboration that characterize good patient care. The perioperative nurse also should anticipate equipment and assistance required should an awake intubation be necessary or if the emergency pathway must be followed. Finally, patients who experience a difficult-airway may be recommended to wear a Medic-Alert bracelet. The National Medic Alert Registry for Difficult Airway/Intubation can be contacted. Information regarding why it was difficult to secure an airway and what technique finally worked is recorded in the Registry's data bank and can be accessed by future anesthesia providers.

Modified from American Society of Anesthesiologists: Practice guidelines for management of the difficult airway, *Anesthesiology* 98:1269-1277, 2003.

BOX 4-2

Typical Contents of a Difficult-Airway Cart

FIBEROPTIC (FO) EQUIPMENT
Flexible FO bronchoscopes (adult and pediatric); FO light source; Bullard scope (FO); and siliconized spray

LARYNGOSCOPE EQUIPMENT
Assorted pediatric and adult laryngoscope handles and blades; extra alkaline batteries; and video laryngoscope

ENDOTRACHEAL TUBES (ETT)
Regular ETT: uncuffed, 2.5-6 mm; regular ETT: cuffed, 5-9 mm; oral RAE ETT: uncuffed, 3-7 mm; oral RAE ETT: cuffed, 6-8 mm; nasal RAE ETT: uncuffed, 3-7 mm; nasal RAE ETT: cuffed, 6-8 mm; reinforced ETT: cuffed, 7-8 mm; controllable-tip ETT (Endotrol); Combitube

AIRWAYS
Regular oral: assorted pediatric and adult; regular nasal: assorted adult; intubating airways: assorted (e.g., Ovassapian, Williams); nasopharyngeal airway with inflatable introducer; assorted sizes of LMAs; tongue blades; and water-soluble lubricant (K-Y)

INTUBATING EQUIPMENT
Intubating stylets; McGill forceps: pediatric and adult; esophageal (gastric tube) airway (EGTA); hollow ETT changers with removable Luer-Lok connectors for O_2 insufflation

SUCTION EQUIPMENT
Assorted flexible suction catheters to fit ETT and LMA as well as stiff suction catheters (Yankauer)

TOPICAL ANESTHESIA EQUIPMENT
Atomizers and pressurized topical anesthetic spray; long Q-tips; lidocaine 4%; lidocaine 4% with phenylephrine; lidocaine 2%—viscous; lidocaine 5%—ointment; lidocaine 10%; tetracaine 1%

TRANSTRACHEAL AIRWAY EQUIPMENT
Transtracheal O_2 jet ventilator with pressure regulator, manual control valve, and Luer-Lok male connector; assorted large IV catheters; and assorted long guidewires, epidural needles, and epidural catheters (for retrograde intubation)

MISCELLANEOUS
Safety glasses; heat-moisture exchanger (Humidivent); assorted facemasks with port for FO scope; right-angled connector (for facemasks) with port for FO scope; $ETco_2$ chemical indicators (Easy Cap); twill tape (to secure ETT); skin adhesive (Mastisol)

with or without additional muscle relaxation. The anesthesia provider considers a variety of factors when selecting the anesthesia technique for each patient.

Whichever technique is selected for general anesthesia (or for any other anesthesia types discussed subsequently), the entire surgical team participates in a time-out just after the patient is positioned, prepped, and draped and before starting the surgical procedure. The patient's identity is rechecked. The procedure to be done, operative side and site, and correct surgical position are verified by the entire surgical team. The patient must be positioned such that the marking of the operative site (e.g., with the word "yes" or the surgeon's initials) is visible on the patient's skin. The availability of implants, special equipment, or other requirements (e.g., blood, if ordered) is verified. When this has been completed, the procedure can begin. The time-out should be documented according to institutional protocol.

Many factors influence emergence. The objective is to move the patient from the OR bed to the PACU bed as soon as the dressing is applied. During emergence, the anesthesia provider suctions the oropharynx before extubation to decrease the risk of aspiration and laryngospasm after extubation, reverses any residual neuromuscular blockade, and allows the washout of N_2O and volatile agents by giving 100% O_2 for several minutes before extubation. After extubation, the patient is transported to the PACU to awaken. In some situations, the patient may be

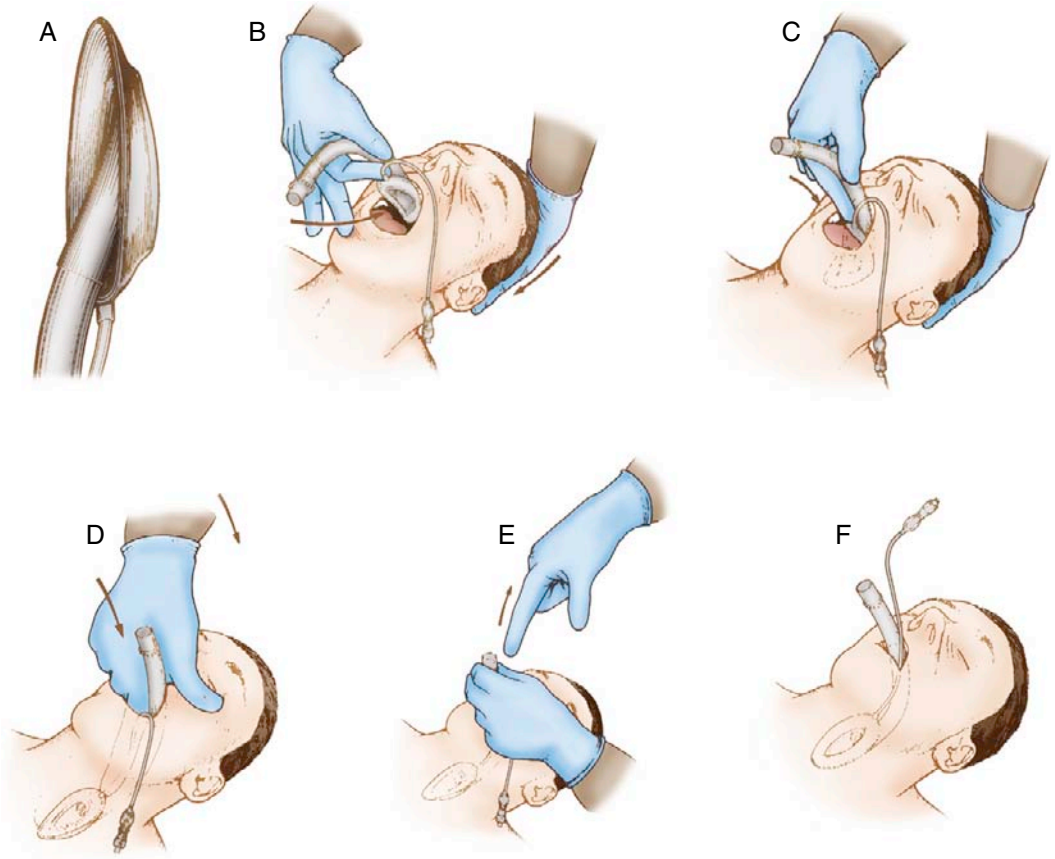


FIGURE 4-5 Insertion of the laryngeal mask airway (LMA). Select the appropriate-size LMA (1, neonates ≤5 kg; 1.5, infants 5 to 10 kg; 2, infants and children 10 to 20 kg; 2½, children 20 to 30 kg; 3, children and small adults >30 kg; 4, normal-size to large adults; 5, large adults). **A,** Carefully deflate the LMA as flat as possible so that the rim faces away from the mask aperture as shown. There should be no folds near the tip. **B,** Under direct vision, press the tip of the LMA cephalad against the hard palate to flatten it out. Using the index finger, continue pressing the LMA against the palate as the LMA is advanced into the pharynx to ensure that the tip remains flattened and avoids the tongue. **C,** Keeping the neck flexed and the head extended, use the index finger to press the LMA into the posterior wall. **D,** Continue pushing with the ball of the index finger, guiding the LMA posteriorly into position. By withdrawing the other fingers and slightly pronating the forearm, it is usually possible to push the LMA fully into position in one fluid movement. **E,** Firmly grasp the tube with the other hand; then withdraw the index finger from the pharynx. Gently press the LMA posteriorly to ensure that it is fully inserted. **F,** Carefully inflate the LMA with the recommended volume of air for size (1, 2 to 4 ml; 2, ≤10 ml; 2½, ≤14 ml; 3, ≤20 ml; 4, ≤30 ml; 5, ≤40 ml). Do not overinflate. Do not touch the LMA tube while inflating, unless it is obviously unstable (as with elderly edentulous patients with loose oropharyngeal tissues). Usually the LMA moves slightly forward out of the hypopharynx as it is inflated. Insert a bite-block (roll of gauze) alongside the LMA tube to minimize occlusion of the tube as the patient is awakening.

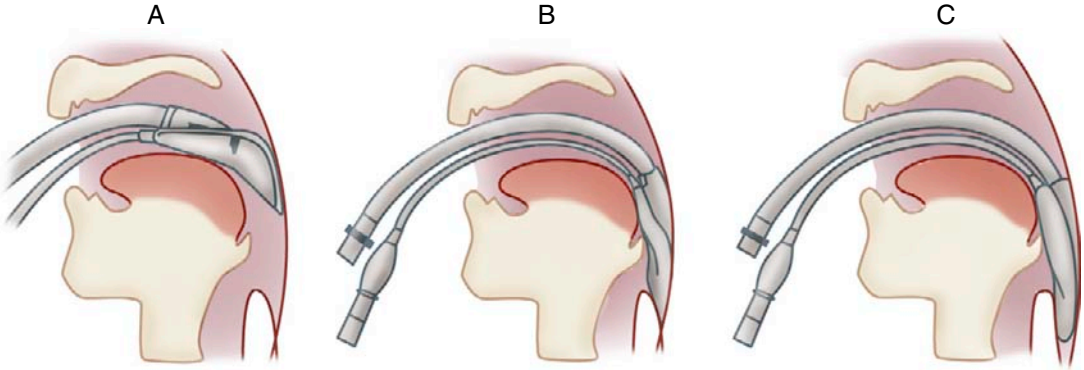


FIGURE 4-6 Sagittal views of insertion and proper placement of the laryngeal mask airway (LMA). **A,** Insertion of LMA. **B,** Proper location of LMA (deflated). **C,** Properly placed and inflated LMA.

transferred to the PACU before extubation and the ETT removed when the patient is fully awake.

Untoward events that can occur with general anesthesia include hypoxia; respiratory, cardiovascular, or renal dysfunction; hypotension; hypertension; fluid or electrolyte imbalance; residual muscle paralysis; dental damage; neurologic problems; hypothermia; and MH. The anesthesia provider usually directs the treatment and management of such events.

REGIONAL ANESTHESIA

Regional anesthesia (also called *conduction anesthesia*) can be accomplished by injecting a local anesthetic anywhere along the pathway of a nerve from the spinal cord. This injection provides anesthesia to a region of the body. Preoperative preparation for regional anesthesia is essentially the same as that for general anesthesia. Preoperative medication frequently is ordered before regional anesthesia to ease any discomfort that may be experienced during placement of the block. The criteria for monitoring during regional anesthesia are similar to those during general anesthesia. Whenever regional anesthesia is performed, resuscitative equipment and drugs must be immediately available. During preparation and placement of the regional anesthetic, the perioperative nurse can provide valuable assistance. This assistance may include placing appropriate monitors, such as pulse oximetry, ECG, and blood pressure; providing supplemental O_2 if indicated; reassuring the patient; administering sedation, such as midazolam, as directed; and properly positioning the patient, which is crucial for a successful block.

Peripheral blocks on the lower or upper extremities or on the head frequently are done in a preoperative holding area to allow adequate time for the local anesthetic to penetrate the peripheral nerve before the patient is transferred to the OR. For peripheral blocks, the perioperative nurse may need to perform aspiration during needle placement (to detect vascular puncture) and inject the local anesthetic while the anesthesia provider stabilizes the needle in the precise location. After an initial period of evaluation by the anesthesia provider, the nurse monitors the patient for any substantial change in vital signs or untoward reactions until the patient is transferred to the OR.

Spinal Anesthesia

A local anesthetic (usually lidocaine, tetracaine, or bupivacaine) injected into the cerebrospinal fluid (CSF) in the subarachnoid space is termed a *spinal anesthetic* or a *subarachnoid block (SAB)*. To provide additional analgesia, fentanyl or preservative-free morphine often is added to the local anesthetic. A spinal needle is inserted into a lower lumbar interspace with the patient either lying on one side or in a sitting position. The local anesthetic generally is mixed with a dextrose solution for a total of 1 to 4 ml to make a *hyperbaric* (heavier than the CSF) solution. These hyperbaric mixtures settle in a gravity-dependent manner after injection into the CSF. By changing the patient's position, the block can be directed up, down, or to one side of the spinal cord. With prostate surgery, the patient may remain in the sitting position for about 1 minute after the local anesthetic is injected to achieve a bilateral block of the S1-S5 dermatomes.

For surgery in the upper abdomen, the patient may be placed in a slight 5- to 10-degree head-down position to allow the anesthetic to move cephalad while the anesthesia provider carefully checks the level of sensory block. When an adequate level is obtained, the bed is leveled to minimize further extension of the sensory block. After 10 to 15 minutes, the block is usually "set" and does not extend farther. The sympathetic nervous system usually is blocked two dermatomes higher and the neuromuscular system two dermatomes lower than the sensory block. The patient is then positioned as necessary for surgery.

If the local anesthetic is mixed with a larger volume of sterile water, the solution is *hypobaric,* and the drug moves to the nondependent area. Hypobaric spinal anesthesia usually is done after the patient is positioned and the surgical site exposed (with the site of injection above the surgical site, as in perianal surgery in the prone position).

By mixing the local anesthetic with some CSF withdrawn from the subarachnoid space, the solution becomes *isobaric.* Distribution of this solution is minimally affected by gravity.

Spinal anesthesia may cause several physiologic responses that can result in major problems if not properly managed. A description of these follows.

Hypotension. Hypotension may occur rapidly after an SAB. It is caused by vasodilation because the sympathetic nerves that control vasomotor tone are blocked. Peripheral pooling of blood occurs, resulting in reduced venous return to the heart and decreased cardiac output. A hypotensive response usually can be avoided by infusing 750 to 1500 ml of balanced salt solution immediately before the block and placing the patient in a 5-degree head-down position to improve venous return to the heart. A vasopressor, such as ephedrine, also may be administered.

Total Spinal Anesthesia. Total spinal anesthesia (or an inadvertently high block) may cause paralysis of the respiratory muscles and necessitate immediate intubation and ventilation. Any sign or symptom of respiratory distress occurring shortly after instituting spinal anesthesia should alert the anesthesia provider to the possibility of a high spinal block.

Positioning Problems. Positioning problems can occur because pain and sensory inputs to a portion of the patient's body are blocked. Care must be taken in positioning the patient intraoperatively to avoid neurologic damage, burns, loss of skin integrity, or other trauma. Positioning the surgical patient is a collaborative effort among the anesthesia provider, the surgeon, the assistant, and the perioperative nurse (see Chapter 5 for a comprehensive discussion of surgical positioning).

Postdural Puncture Headache. Postdural puncture headache (PDPH) (also called *postspinal cephalgia* or *spinal headache*) is a frequent postoperative complaint after spinal anesthesia. It occurs more commonly in young parturients or other patients younger than 40 years. The incidence is about 1% when a 25- or 27-gauge blunt-bevel needle is used. It is unrelated to how soon the patient ambulates postoperatively. The headache is believed to result from leakage of CSF through the hole in the dura and typically occurs when the patient assumes an upright position. The incidence, severity, and duration of the headache appear to correlate with the size of the hole left in the dura. The headache usually occurs in the occipital area and generally resolves over 1 to 3 days but may last 2 weeks. Several treatments

have been used to relieve the headache: strict bed rest for 24 to 48 hours, vigorous hydration, abdominal binders, epidural infusion of saline, oral (PO) or IV caffeine, and injection of 5 to 20 ml of autologous blood into the epidural space at the puncture site ("blood patch") (Burkard and Vacchiano, 2010).

Many anesthesia providers use different spinal needles that have a tip shaped like a sharpened wood pencil with the hole on the side of the needle. These 24- to 26-gauge spinal needles (e.g., Whitacre, Sprotte, Gertie Marx) presumably separate or go between the dural fibers as opposed to cutting the fibers, which may occur when a blunt-bevel spinal needle is used. With these "pencil-point" needles, the incidence and severity of PDPH are substantially lower (Burkard and Vacchiano, 2010).

Epidural and Caudal Anesthesia

The epidural space is located between the ligamentum flavum and the dura and extends from the foramen magnum to the sacrococcygeal membrane. It is filled with epidural veins, fat, and loose areolar tissue. For *epidural* anesthesia, the local anesthetic usually is injected through the intervertebral spaces in the lumbar region (lumbar epidural), although it also can be injected into the cervical or thoracic regions. The anesthetic spreads cephalad and caudad from the site of injection. A comparative location of the needle points and injected anesthetic is shown in Figure 4-7.

For *caudal* anesthesia, the local anesthetic also is injected into the epidural space, but the approach is through the caudal canal in the sacrum. Compared with a lumbar epidural, this approach requires a greater volume of anesthetic to fill the epidural space. Caudal anesthesia has a 5% to 10% technical failure rate. Given its ease of administration, however, it is often employed for perineal procedures or pediatric surgery on the lower extremities (Tobias and Litman, 2004).

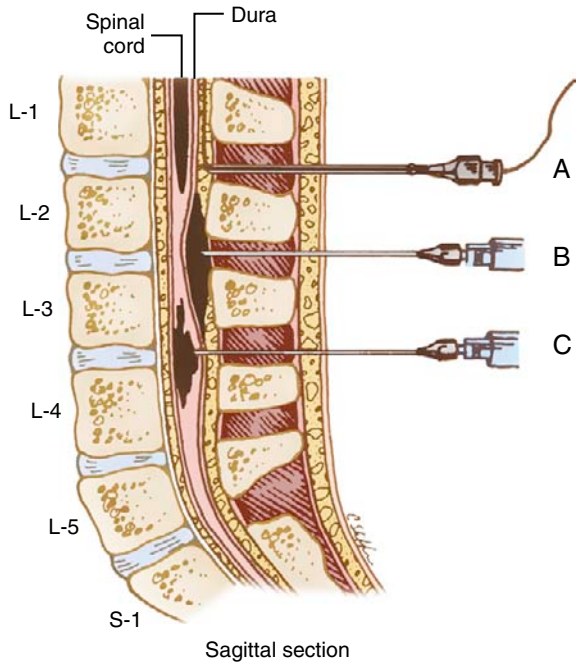


FIGURE 4-7 Location of needle point and injected anesthetic relative to dura. **A**, Epidural catheter. **B**, Single injection epidural. **C**, Spinal anesthesia. (Interspaces most commonly used are L4-L5, L3-L4, and L2-L3.)

Several techniques may be used for epidural or caudal anesthesia. A "single-shot epidural" involves administration of a local anesthetic through the needle before its removal. For intermittent injections or continuous infusions, a small catheter is inserted into the epidural space for administration of local anesthetic.

For combined spinal and epidural anesthesia, the epidural needle is inserted into the epidural space, and a special, long 26-gauge spinal needle is inserted through the epidural needle into the CSF. A small amount of fentanyl or preservative-free morphine may be injected and provides good analgesia for several hours. The spinal needle is removed, and an epidural catheter is inserted. This technique is especially useful for obstetric anesthesia (Burkard and Vacchiano, 2010).

Techniques used to identify the epidural space include the "hanging drop" and the "loss of resistance" to injection of either air or liquid (saline or local anesthetic) as the needle is advanced slowly through the ligamentum flavum. With the hanging-drop technique, the needle is filled with liquid to form a meniscus at the needle hub. As the needle is slowly advanced into the epidural space, negative (less than atmospheric) pressure draws the liquid inward toward the epidural space. Location of the needle tip within the epidural space is verified by injection of an additional 1 to 2 ml of air or saline.

When local anesthetics are injected into the epidural space, the major sites of action are the nerve roots as they leave the spinal cord and proceed out the intervertebral foramina beyond the meningeal sheath. Some of the anesthetic diffuses into the subarachnoid space, however, to the spinal cord. As local anesthetics diffuse away from the site of injection, segmental anesthesia may be possible in specific areas. In contrast to spinal anesthesia, much larger volumes of local anesthetic are needed with epidural anesthesia; the head-up, head-down, or lateral position of the patient does not affect the level of the epidural anesthetic as much, and the onset of anesthesia is much slower with epidural anesthesia. As with spinal anesthesia, hypotension can occur with epidural anesthesia, but the onset is much slower and usually can be managed with rapid IV infusion of balanced salt solution or repositioning of the patient (Burkard and Vacchiano, 2010; Stoelting and Hillier, 2005a).

The local anesthetics most frequently used for epidural anesthesia are lidocaine, bupivacaine, and chloroprocaine. Ropivacaine and levobupivacaine are newer local anesthetics that may prove to be less cardiotoxic than bupivacaine and possess a larger therapeutic ratio. Although much of their pharmacologic profile is similar to that of bupivacaine, levobupivacaine and ropivacaine seem to possess more selective action for neural blockade (Burkard and Vacchiano, 2010; Stoelting and Hillier, 2005a). Depending on the concentration of anesthetic agent, effects can range from loss of sensory input to complete motor blockade. To verify that the anesthetic is not being injected into the subarachnoid space or into an epidural vein, a test dose of 3 to 5 ml of lidocaine with a 1:200,000 concentration of epinephrine is frequently used. Injected intravascularly, this test dose causes a transient tachycardia. If injected into the subarachnoid space, it produces a low level of spinal anesthesia. Complications associated with the use of local anesthetics in the epidural and subarachnoid spaces are unique to the agent used. Permanent neurologic sequelae have been reported when chloroprocaine

with a preservative was injected into the subarachnoid space. Bupivacaine is associated with pronounced cardiac toxicity if injected intravascularly (Burkard and Vacchiano, 2010; Stoelting and Hillier, 2005a). With epidural anesthesia, several complications can occur, including inadvertent dural puncture, subarachnoid injection, and vascular injection.

Inadvertent Dural Puncture. Inadvertent dural puncture with the epidural needle (a wet tap) can cause a PDPH. This headache is significant in about 50% of patients, and the intensity can be incapacitating. Treatment is essentially the same as that discussed under Spinal Anesthesia earlier in this chapter.

Subarachnoid Injection. Subarachnoid injection occurs if the needle or catheter is unintentionally inserted into the subarachnoid space. If a large volume of local anesthetic is injected as a bolus, it causes "total spinal" anesthesia. This condition is associated with a rapid onset of hypotension caused by vasodilation and profound bradycardia as the sympathetic nerves to the heart are blocked, causing a totally paralyzed patient. Treatment includes intubation, control of ventilation, support of blood pressure and the cardiovascular system, and administration of amnestic drugs until the block resolves. If properly managed, this problem is not life-threatening, but use of the test dose described previously and injection of only 3 to 5 ml at a time usually avert this problem. With patient movement over time, the epidural catheter may migrate through the dura. Therefore a small test dose should be given each time additional local anesthetic is injected through the catheter. In addition, each subsequent dose should be injected in increments of 3 to 5 ml each.

Vascular Injection. Injection of local anesthetic into an epidural vein may occur inadvertently with the initial dose or with subsequent injections. Intravenously injected bupivacaine is associated with cardiac arrest. Toxicity from other local anesthetics can cause sudden and profound hypotension, convulsions from effects on the CNS, and tachycardia if the solution contains epinephrine. Convulsions usually dissipate rapidly as local anesthetic redistributes throughout the body. Intravenous thiopental or a benzodiazepine may be given to reduce these effects. A vasopressor (e.g., ephedrine or phenylephrine) can be used to restore blood pressure. If the patient becomes paralyzed, intubation and ventilation may be required until the toxic effects are gone. Use of a test dose with each injection usually prevents these problems.

Peripheral Nerve Blocks

Peripheral nerves can be blocked effectively by injecting local anesthetic around them to provide adequate surgical anesthesia. Onset and duration of the block depend on the drug used and its concentration and volume, addition of epinephrine, and site of injection. Complications usually are caused by an inadvertent intravascular injection or an overdose of the local anesthetic. Rarely, nerve damage occurs from trauma caused by the needle or compression from the volume of local anesthetic injected.

Peripheral nerve blocks (PNBs) are an effective method to deliver analgesia and anesthesia, and have been used by surgeons and anesthesia providers since the late 1800s. However, in the twentieth century, PNBs were replaced with general anesthetics for their desired effect of total body anesthesia and analgesia. Ironically, the advent of ambulatory surgery created renewed interest in the use of PNBs.

With the exponential growth of ambulatory surgery and the demand for time and cost consciousness, the benefits of PNBs are many. Local anesthetics have quick onset of action, provide prolonged analgesia, and often do not require administration of powerful anesthetics that have undesired side effects. Patients are often discharged with less pain and less nausea and vomiting, report greater satisfaction with the quality of care received, and are spared the undesirable side effects of excessive opioids. PNBs are considered an essential aspect of contemporary multi-modal anesthesia.

Peripheral Nerve Anatomy and Physiology. The peripheral nervous system consists of 31 pairs of spinal nerves that exit between the vertebrae on each side of the body. These spinal nerves traverse the torso and innervate specific regions in order to coordinate within the CNS our ability to perceive cutaneous sensation and respond with synchronized motor reflexes. Peripheral sensory nerve impulses are initiated by noxious stimuli, such as a surgical incision. This stimulus creates an "action potential" that changes the electrical voltage traveling across the axonal membrane of the nerve by allowing influx of sodium ions (referred to as cellular depolarization). This creates a propagating electrical wave that conducts the sensory nerve impulse to the brain where it is then interpreted as pain. Local anesthetics work by blocking the opening of these sodium ion channels so that the nerve impulse does not travel back to the CNS and the patient does not perceive pain (Cousins and Bridenbaigh, 2009).

Common Peripheral Nerve Blocks

UPPER EXTREMITY—THE BRACHIAL PLEXUS. Spinal nerves leaving the cervical vertebrae, C5-T1, converge to form a bundle of nerves known as the brachial plexus. Each bundle of nerves innervates the right and left side of the neck and axilla. The brachial plexus divides further into branches that eventually terminate in the radial, ulnar, and median nerves. For example, the median nerve is released from impingement when a carpal tunnel procedure is performed.

PNBs of the brachial plexus are therefore performed for surgery of the shoulder, forearm, or hand. The different anatomic landmarks anesthesia practitioners use to perform a brachial plexus nerve block are the interscalene, supraclavicular, infraclavicular, or axillary sites. The choice of anatomic site for PNB depends on (1) the area of the arm undergoing surgery and (2) the surgical procedure being performed. As an example, for shoulder arthroscopy, an interscalene brachial plexus block is appropriate, whereas for carpal tunnel surgery an infraclavicular or axillary block suffices.

LOWER EXTREMITY. Lumbar and sacral spinal nerves, also exiting through each side of the vertebrae, eventually separate into the sciatic, femoral, popliteal, and tibial nerve roots that innervate the lower extremities. PNBs for the lower extremity are often performed for knee and foot procedures. For example, a femoral nerve block can be used for a knee arthroscopy while an ankle block (essentially a block of the deep and superficial peroneal, tibial, and sural nerves branches of the sciatic nerve) can be used for podiatric procedures (Hadzic and Vlodka, 2004).

PNB Equipment. To identify the correct injection site for the PNB, the anesthesia provider typically uses a nerve stimulator, sometimes with ultrasound guidance. The nerve stimulator creates an electrical current. The goal is to elicit a motor response from the nerve while applying the correct amount of voltage. Once the anesthesia provider isolates the desired nerves to be "blocked," the appropriate local anesthetic is carefully injected into tissue close to the nerve. The local anesthetic then inhibits the propagation of the nerve impulses to the CNS by blocking sodium ion channels. Depending on the desired site of action, PNBs can take from a few minutes to as long as 1 hour to achieve complete effect. The duration of the nerve block depends on the local anesthetic used.

Important Nursing Considerations

EXPECTED SIDE EFFECTS AND SPECIAL CARE CONCERNS. PNBs often have side effects. For example, with an interscalene block, patients may experience Horner syndrome (miosis, ptosis, and increased salivation) and may also have a unilateral phrenic nerve paralysis that causes breathing difficulty. These side effects may need special anesthesia attention depending upon their severity. All perioperative staff must be mindful of the fact that the patient with a PNB has lost the protective reflex of pain sensation. Therefore special care is required with patient positioning and padding pressure points, as is postoperative patient education regarding the risk of burns or falls, for example.

PREPARATION FOR ADVERSE EVENTS. PNBs are a safe method of anesthesia and analgesia delivery. There are, however, serious potential complications that all perioperative staff should understand and anticipate in the event of an emergency.

Local anesthetic toxicity results when an unsafe amount of a local anesthetic has been absorbed into the patient's bloodstream. This can occur either slowly from systemic absorption of a local anesthetic that is correctly injected into the tissue or immediately and catastrophically if the anesthetic is accidentally injected directly into a blood vessel. Signs of systemic local anesthetic toxicity often progress in a stepwise manner. Patients may initially report perioral numbness, a metallic taste in the mouth, ringing in the ears, visual disturbances, and/or dizziness. If toxicity progresses, or is immediate, the patient will likely have seizures, respiratory arrest, and/or cardiac arrest.

PNBs should only be performed in areas that are well equipped to handle emergencies—that is, areas having access to an external oxygen source, vacuum suction, ventilation bag and mask, laryngoscope, ETT tubes, monitoring equipment, and resuscitation drugs to treat hypotension, bradycardia, and seizures. Along with increased use of PNBs have come increased reports of cardiac arrest from accidental intravascular injection. There are new potentially lifesaving treatments that all perioperative staff must know (Research Highlight).

RESEARCH HIGHLIGHT

Lipid Infusion for Local Anesthetic Toxicity and Cardiac Resuscitation

IV local anesthetics work by blocking voltage-gated sodium ion channels that are essential for normal nerve impulse conduction. The result impedes transmission of painful stimuli. There are, however, voltage-gated sodium ion channels found in cardiac nerve cells. Bupivacaine, a commonly used local anesthetic agent, has been implicated as the causative agent for patients experiencing cardiac arrest following an accidental intravascular injection during a PNB. Recent research findings and more than 25 case reports between 2006 and 2008 suggest an effective adjunct to standard cardiac resuscitation procedures for bupivacaine toxicity. An infusion or bolus of a 20% lipid emulsion, such as 20% Intralipid (Baxter Pharmaceuticals), has been shown to help with successful cardiac resuscitation and returning patients to a normal cardiac rhythm. While the exact mechanism of action remains unknown, experts have suggested that lipids simply bind-up and provide a reservoir for bupivacaine, thus allowing the cardiac sodium ion channels to become "unblocked" (Sirianni et al, 2008). Warren and colleagues (2008) discuss a case report of a 60-year-old patient who was successfully resuscitated with IV lipid infusion following cardiovascular collapse after a supraclavicular brachial plexus block with bupivacaine and mepivacaine. After analysis and a literature review, they recommend "lipid rescue for presumed local anesthetic toxicity should be considered during resuscitative efforts in prolonged CPR refractory to standard ACLS protocols." They further recommend availability of 20% lipid emulsion in any site where local anesthetics are administered.

Modified from Sirianni et al: Use of lipid emulsion in the resuscitation of a patient with prolonged cardiovascular collapse after overdose of bupropion and lamotrigine, *Ann Emerg Med* 51(4):412-415, 2008; Warren JA et al: Intravenous lipid infusion in the successful resuscitation of local anesthetic-induced cardiovascular collapse after supraclavicular brachial plexus block, *Anesth Analg* 106(5):1578-1580, 2008.

Intravenous Regional Anesthesia

IV regional anesthesia was first described by Bier in 1908 and is frequently called a *Bier block*. Although it can be used on a lower extremity, it is used more often on the upper extremities. It is highly reliable and easy to accomplish.

A small IV catheter is inserted as distal as feasible, and a single-cuffed or double-cuffed pneumatic tourniquet is placed around the limb proximal to the surgical site. The limb is raised and exsanguinated by wrapping it with an Esmarch bandage. The tourniquet is inflated to approximately 100 mm Hg above the patient's systolic blood pressure, and the Esmarch bandage removed. Approximately 50 ml of 0.5% lidocaine is injected through the catheter. Onset of anesthesia is rapid and lasts until the tourniquet is deflated.

When a double-cuffed pneumatic tourniquet is used, the proximal cuff is initially inflated. When the patient experiences discomfort from the cuff pressure (usually about 35 to 40 minutes after cuff inflation), the distal cuff, which is located over an anesthetized area, is inflated and the proximal cuff deflated. The proximal cuff remains inflated until the distal cuff has been inflated to prevent loss of the IV anesthetic from the limb. Two single-cuffed tourniquets can be used instead of a double-cuffed tourniquet. If the patient experiences pain from the tourniquet, an IV analgesic or sedative can be used to supplement the block (Stoelting and Hillier, 2005a).

Although problems can occur from an overdose or toxic reaction to lidocaine, these are rare if the tourniquet has been inflated more than 20 minutes. The risk is minimized by intermittently deflating the cuff for a few seconds at a time for several cycles when the surgical procedure concludes. This

reduces the transient peak blood level of local anesthetic in the CNS and heart. Loss of pneumatic pressure in the tourniquet can cause a toxic reaction and loss of anesthesia.

MONITORED ANESTHESIA CARE (MAC)

Surgeons can safely accomplish minor and even some major procedures with a peripheral nerve block or when the surgical site is infiltrated with a local anesthetic. These techniques can be employed for normal, healthy individuals as well as for sicker, unstable patients who otherwise would require extensive invasive monitoring and pharmacologic management if general anesthesia were employed. For sicker, unstable patients, relative risks and benefits of MAC versus general anesthesia must be weighed.

During MAC, the anesthesia provider may supplement the local anesthetic with an IV analgesic (e.g., fentanyl) and with sedative and amnestic drugs (e.g., midazolam or propofol). In addition, the anesthesia provider carefully monitors vital signs, respiratory and cardiovascular status, and positioning, and may give supplemental low-flow O_2. Depending on the clinical situation, the anesthesia provider may have to induce general anesthesia or use one of the regional techniques described previously if a greater degree of anesthesia becomes necessary.

CONSCIOUS SEDATION/ANALGESIA

Conscious sedation/analgesia refers to IV administration of certain sedatives and analgesics that produces a condition in which the patient exhibits a depressed level of consciousness but retains the ability to independently maintain a patent airway and respond appropriately to verbal commands or physical stimulation. The anesthesia provider is not involved in the patient's care. Perioperative nurses who have additional training and demonstrated competencies in (1) administering medications to achieve conscious sedation/analgesia and (2) patient monitoring (AORN, 2009b) perform these functions. Objectives for a patient receiving conscious sedation/analgesia include alteration of mood, maintenance of consciousness, enhanced cooperation, elevation of pain threshold, minimal variation of vital signs, some degree of amnesia, and rapid and safe return to activities of daily living.

Selection of patients for conscious sedation/analgesia should be based on established criteria developed by an interdisciplinary team. Patients must be thoroughly assessed physiologically and psychologically before the procedure. Assessment should include a review of physical exam findings; current medications; existing allergies; current medical problems; history of smoking, hazardous alcohol intake, or substance abuse (Tonnesen et al, 2009); current chief complaint; baseline vital signs, height, and weight; age; emotional state; any communication deficits; and the patient's perceptions of conscious sedation/analgesia. Monitoring methods for patients receiving conscious sedation, medications administered, and interventions initiated must be within the scope of nursing practice as defined by the respective state board of nursing. If the nurse does not feel comfortable managing the care and monitoring of a particular patient, the attending physician and an anesthesia provider should be consulted. During the past few years administration of propofol by nurses has been advocated. The FDA continues to include a "black box" warning that it should only be administered by trained anesthesia providers. The AANA and the ASA continue to support the FDA view for patient safety reasons. Even in the hands of a trained anesthesia provider, propofol can affect respirations, possibly requiring advanced airway management.

When monitoring a patient receiving conscious sedation/analgesia, the nurse should have no other responsibilities that would leave the patient unattended or compromise continuous patient monitoring. The nurse must be clinically competent in the use of monitoring equipment and oxygen-delivery devices, medications used for conscious sedation/analgesia and resuscitation, and airway management. Advanced cardiac life support (ACLS) certification of nurses responsible for monitoring patients receiving conscious sedation/analgesia may be required by some healthcare institutions. If not, healthcare professionals with ACLS skills should be readily available to render support if needed in an emergency situation (AORN, 2009b).

The nurse who administers conscious sedation/analgesia medications should know usual dosages, contraindications, interactions with other medications, onset and duration of action and desired effects, adverse reactions, and emergency management techniques. Benzodiazepines (e.g., diazepam, midazolam) and opioids (e.g., fentanyl, meperidine hydrochloride) are used for conscious sedation/analgesia (AORN, 2009b). Equipment that should be ready for use in the room where conscious sedation/analgesia is administered includes a noninvasive blood pressure device, an ECG, a pulse oximeter, oxygen-delivery devices, and suction. An emergency cart with appropriate resuscitative medications and equipment (e.g., a defibrillator) should be immediately available.

An IV access line is established to administer conscious sedation/analgesia medications and emergency medications and fluids if needed. Parameters monitored during conscious sedation/analgesia are respiratory rate, cardiac rate and rhythm, blood pressure, oxygen saturation, level of consciousness, and skin condition.

Nursing documentation should include preprocedure assessment; dosage, route, time, and effects of all medications administered; type and amount of fluids administered; physiologic data from continuous monitoring at 5- to 15-minute intervals and on significant events; level of consciousness; nursing interventions initiated and the patient's responses; and any untoward significant patient reactions and their resolution (AORN, 2009b).

Postprocedure monitoring should be provided until the patient has returned to preprocedure baseline parameters. Patients and family members or significant others should receive appropriate oral and written discharge instructions and be able to verbalize understanding (teach back in their own words). It is helpful if discharge instructions are given after the procedure because conscious sedation/analgesia medications may cause amnesia.

Discharge criteria should be established by an interdisciplinary team and should include adequate respiratory function, stable vital signs, return to preprocedure level of consciousness, intact motor reflexes, return of motor and sensory control, absence of protracted nausea, acceptable skin color and condition, absence of significant pain, and satisfactory surgical

site and dressing condition (when present). A responsible adult must accompany and drive the patient home.

LOCAL ANESTHESIA

The terms *local anesthesia, local,* and *straight local* are used interchangeably to describe the administration of an anesthetic agent to a specific area of the body by topical application, local infiltration, regional nerve block, or "field" block. Local anesthetics are administered by the surgeon. In addition, other physicians, such as cardiologists, pulmonologists, proctologists, and gastroenterologists, may perform local procedures in the OR suite. No anesthesia provider is involved.

Hospitals and ambulatory surgery centers establish interdisciplinary guidelines for selecting patients who are appropriate for local anesthesia procedures and for patient monitoring criteria. Decisions to monitor the patient receiving local anesthesia, parameters that need to be monitored, and the frequency of observation and monitoring are tailored to the patient, the surgical procedure, and medications used. Patients receiving local anesthetics are assessed preoperatively and monitored continually by the perioperative nurse during the procedure.

Local anesthesia usually is employed for minor, short-term surgical, diagnostic, or therapeutic procedures. As the patient does not lose consciousness, local anesthesia is frequently preferred when the patient's cooperation is necessary for the procedure. Local anesthesia is economical and eliminates the undesirable effects of general anesthesia. Adverse reactions, however, may occur from large doses of local agents. If the agent enters the bloodstream directly, convulsions, circulatory and respiratory distress, cardiovascular collapse, or even death can result.

The surgeon chooses local anesthetics based on desired duration of action, surgery site, potency potential, and the patient's physical status. Topical agents, such as cocaine hydrochloride, tetracaine, or lidocaine, may be applied to mucous membranes of the nose, throat, trachea, and urethra. Lidocaine 0.5% to 2%, with or without epinephrine, is the drug most commonly used for local anesthesia, although bupivacaine (Marcaine) may also be selected. Epinephrine may be added to the local anesthetic agent for vasoconstricting properties in the area injected, slower rate of absorption of the local anesthetic agent, and lower incidence of toxicity. Adding epinephrine allows longer duration of action for the local agent by reducing blood flow to the area injected. Epinephrine is used with caution in patients with hypertension, diabetes, or heart disease. A general recommendation for a local anesthetic such as lidocaine is that no more than 50 ml of a 1% solution, or 100 ml of a 0.5% solution, be injected per hour. For maximum adult dosages, see the Surgical Pharmacology box, pp. 124-127. All local anesthetic containers or syringes should be clearly labeled when on and off the sterile field.

Preoperatively, the perioperative nurse reviews the patient's history, physical examination findings, and results of any ordered laboratory or other diagnostic tests. Patients are assessed carefully to determine their physiologic baseline, any allergies (to medications, latex, adhesive tape, or other substances), and emotional status. An IV infusion is started before the procedure because adequate venous access can be crucial in life-threatening situations when resuscitative drugs must be given immediately.

The perioperative nurse must be clinically competent in using monitoring equipment, placing equipment connections, and interpreting data. Most often, intraoperative monitoring minimally includes heart rate and regularity, respiratory rate, and mental status. Additional monitoring parameters are based on the patient's condition and include blood pressure, skin condition, and oxygen saturation status (AORN, 2009b). Any changes in the patient's condition should be communicated immediately to the surgeon.

The perioperative nurse must also be familiar with the drugs administered during the procedure, usual dosages, limits on rate of injection and maximum dosage (usually stated on a per-kilogram basis), duration of action, physiologic and psychologic changes expected, normal and abnormal reactions, and appropriate action to take if untoward reactions occur. The nurse should document dosage, route, and time of administration of all local anesthetics administered. The patient is observed for side effects, such as CNS disturbances, cardiovascular problems, hypersensitivity to medication, and toxic reaction resulting from high levels of the local anesthetic. Emergency drugs, suction apparatus, and resuscitation equipment should be readily available. Symptoms of adverse drug reactions include restlessness, unexplained anxiety or fearfulness, diaphoresis, nausea, palpitations, disturbed respiration, pallor or flushing, syncope, and convulsive movements. Signs and symptoms of allergic reaction include urticaria, tachycardia, laryngeal edema resulting in breathing difficulties, nausea, vomiting, and elevated temperature. In some instances, anaphylactoid symptoms, including severe hypotension, can occur. If any significant change occurs in the patient's physiologic or psychologic status, the nurse should notify the physician immediately. Good communication is essential for optimal patient care (National Quality Forum, 2009). As the patient is awake during the procedure, extraneous or irrelevant conversation and noise are kept to a minimum.

Documentation of care provided to a patient receiving a local anesthetic should be consistent with the AORN's *Recommended Practices for Documentation of Perioperative Nursing Care* (AORN, 2009a). This includes all medications administered, including their dosages, routes, and times of administration; patient monitoring performed; and results of patient care procedures.

After the procedure, the patient's postoperative status is assessed carefully. This evaluation and any special patient needs are documented on the chart, and a report is conveyed to the receiving unit before the patient's transfer (if the patient is going to a recovery area). The hand-off report should include type and amount of drugs given and any adverse reaction noted, site and condition of the IV infusion (if applicable), type and amount of solution infused in the OR, range of intraoperative vital signs, surgical procedure performed, and condition of the dressing. Any special postoperative orders, allergies, and a general statement of the patient's tolerance of the procedure are included. The patient may be transferred to the day-surgery and discharge area or returned directly to a hospital room. Local anesthesia patients are rarely transferred to the PACU for recovery or observation.

PAIN MANAGEMENT

Many anesthesia providers have applied their expertise in analgesia and regional anesthesia to the management of acute and chronic pain. Chronic pain is often multifactorial and may occur after a discrete injury (or trauma), amputation, laminectomy, or

other surgical procedure. It also may result from prolonged repetitive stress, such as "low back pain." Chronic pain frequently has complex psychologic components unrecognized by patients or by individuals closely associated with patients. Diagnosis and treatment of such chronic pain problems usually involve multiple medical disciplines and prolonged management.

Acute perioperative pain is a different problem. Traditionally, postoperative pain has been treated with intramuscular (IM) narcotics every 3 to 6 hours as needed. This treatment is often associated with undesirable side effects, including oversedation, respiratory depression, deep vein thrombosis (DVT) secondary to decreased mobility, and variable degrees of pain relief. Other pain-management modalities are now used successfully. Patient-controlled analgesia (PCA) uses a programmable electronic pump that can continuously infuse a small amount of IV narcotic (at a basal rate); in addition, the patient can administer a predetermined bolus "on demand." Safety interlocks limit the frequency of boluses and total dose per hour (Faut-Callahan and Hand, 2010).

When spinal or epidural anesthesia is employed for a surgical procedure, a small amount of preservative-free narcotic, such as fentanyl, sufentanil, or morphine, may be added to the local anesthetic mixture. The narcotic acts via central opiate receptors and provides analgesia for 24 to 36 hours.

Continuous epidural analgesia also may be used for prolonged postoperative pain management. This technique is employed for extensive procedures, including total hip or knee replacements; knee reconstruction; and major abdominal, thoracic, or gynecologic operations. In addition, it can be used for acute trauma, such as multiple rib fractures.

Typically, a lumbar or thoracic epidural catheter is inserted before surgery, covered with a transparent occlusive dressing, and injected with local anesthetic. Given the duration, manipulation, or positioning required for the operative procedure, general anesthesia is often used for patient comfort. The epidural greatly reduces the analgesic requirements of general anesthesia. For postoperative pain control, the epidural infusion of local anesthetic is usually one eighth to one sixteenth of the concentration used for surgical anesthesia (Faut-Callahan and Hand, 2010). A small dose of preservative-free narcotic, such as fentanyl, sufentanil, or morphine, is usually added to enhance analgesia. After surgery, the infusion rate is adjusted to provide analgesia during early recovery. As the level of pain decreases over time, the infusion rate is reduced. The catheter is removed after 2 to 5 days to minimize the risk of infection. Benefits of epidural analgesia for acute postoperative pain include good analgesia with minimal sedation, early ambulation and physical therapy, and excellent patient satisfaction. Possible side effects include nausea, pruritus, and areas of slight numbness. These are controlled by using drugs such as diphenhydramine (Benadryl) or naloxone (Narcan) and by adjusting the infusion rate. A nonsteroidal antiinflammatory drug (NSAID), such as ketorolac (Toradol), is given for any "breakthrough pain" instead of increasing the epidural infusion.

A single caudal injection is often used in pediatric patients having surgery of the lower abdomen, pelvis, or lower extremities. It usually is administered after induction of general anesthesia, and a long-acting local anesthetic, such as bupivacaine with epinephrine, typically is used. This injection provides good analgesia for 8 to 24 hours postoperatively and greatly decreases intraoperative requirements for general anesthesia. If the procedure requires prolonged recovery, a lumbar epidural catheter can be placed intraoperatively. Postoperatively, management is similar to that for adult patients, although for younger patients the level of analgesia and the presence of side effects must be assessed by someone other than the patient (Faut-Callahan and Hand, 2010; Tobias and Litman, 2004).

Epidural infusions also have been used for patients experiencing the intense pain of terminal malignancies. These patients may experience pain that is so severe that parenteral analgesics provide inadequate pain relief and produce deep respiratory depression. Epidural infusions for prolonged periods have been used in these patients. Transdermal fentanyl patches also may be used for these patients and for patients experiencing chronic pain.

TEMPERATURE CONTROL

Monitoring temperature is an important part of anesthesia monitoring. Temperature monitoring was not routinely practiced until malignant hyperthermia (MH) was described in the 1960s. This complication eventually led to routine monitoring of body temperature in the OR (Kossick, 2010). Increased attention has been directed toward intraoperative maintenance of normal temperature ranges (normothermia) for pediatric and adult patients. Hypothermia is the most common disorder of temperature homeostasis. It may be intentional or unintentional. Unintentional hypothermia can cause patient discomfort, untoward cardiac events, adrenergic stimulation, impaired platelet function, altered drug metabolism, delayed emergence from anesthesia, and impaired wound healing (Burns et al, 2009).

Risk factors for developing inadvertent hypothermia include age extremes (elderly and pediatric patients), co-morbidity, length of surgical procedure, cachexia, fluid shifts, cold irrigating fluids, and general and regional anesthesia. Agents such as skeletal muscle relaxants interfere with shivering mechanisms. Agents that depress the CNS decrease autonomic reflexes that ordinarily autoregulate body temperature. Vasodilation, which accompanies various anesthetic agents, including inhalation agents, enhances heat transfer from the core to the periphery, where it is lost to the atmosphere. Cold, unhumidified inhalation gases further promote hypothermia through convection and evaporation.

Room temperature can be increased and infrared warming lamps used for pediatric patients. Fresh-gas flow rates of cool, dry anesthetic gases can be lowered. A heat and moisture exchanger (e.g., Humidivent) helps to maintain the heat and moisture of inspired gases. A variety of IV fluid warmers are available to warm crystalloid solutions or refrigerated blood products. Some of these units, originally designed for major trauma procedures, warm fluids at flow rates of 500 ml/min. Units that blow heated air onto the upper or lower body surface also are available. These units are effective in maintaining body temperature even during a long abdominal procedure and can be used subsequently in the PACU. Forced-air warming units must be used according to manufacturers' instructions. They must be used with the appropriate disposable patient warming blankets and should *not* have the hose inserted under surgical drapes to warm the patient (this directs the heat on the patient, with the risk of a burn, rather than filtering it through the blanket). The blanket air temperature is typically a couple of degrees lower than that coming directly from the hose because heat is dissipated as it moves through the blanket (Research Highlight).

RESEARCH HIGHLIGHT

Preventing Perioperative Hypothermia

Current evidence-based clinical practice guidelines detail numerous benefits of maintaining a patient's normal body temperature (normothermia) during delivery and recovery from anesthesia. Benefits identified include increased patient satisfaction, decreased surgical site infections, decreased coagulopathies, improved circulation, and normalization of drug metabolism and clearance. As a result of these benefits, the American Society of PeriAnesthesia Nurses (ASPAN), the Association of periOperative Registered Nurses (AORN), and the American College of Cardiology (ACC) have recommendations for maintaining normothermia.

Researchers today focus on new questions that seek to optimize thermal management of perioperative patients. Sessler (2008) reviewed different modalities for temperature monitoring and suggested methods to improve accurate and consistent measurements of a patient's core temperature. Wadhwa and colleagues (2007) reviewed the efficacy of traditional forced-air warming devices compared to circulating water devices on patient rewarming after general anesthesia. A novel research question posed by Andrzejowski and colleagues (2008) asked: "Will pre-warming a patient prior to surgery in the preoperative holding area actually help in preventing the occurrence of inadvertent perioperative hypothermia?" They implemented a prospective randomized trial that assigned patients to one of two cohorts: patients prewarmed using a forced-air warming blanket designed to be worn as a gown by the patient, or patients who received the current standard of care (i.e., no prewarming in the preoperative area).

The study by Andrzejowski and colleagues (2008) suggested that prewarming a patient before surgery with a forced-air warming device was statistically significant in reducing the incidence of inadvertent perioperative hypothermia after induction of general anesthesia at the 60- and 80-minute postinduction marks (p-value <0.05). The authors suggest that prewarming surgical patients may improve vascular circulation and tissue oxygenation, which may reduce rates of postoperative infections. The benefits of prewarming, however, remain to be validated in multiple studies and are considerations for future research.

Modified from American Society of Perianesthesia Nurses: Clinical guideline for the prevention of unplanned perioperative hypothermia. In *2006-2008 Standards for perianesthesia nursing practice,* Cherry Hill, NJ, ASPAN, 2006; Andrzejowski J et al: Effect of prewarming on post-induction core temperature and the incidence of inadvertent perioperative hypothermia in patients undergoing general anaesthesia, *Brit J Anesthes* 101(5):621-631, 2008; AORN: Recommended practices for the prevention of unplanned perioperative hypothermia. In *Perioperative standards and recommended practices,* Denver, 2009, The Association; Burns SM et al: Unintentional hypothermia: implications for perianesthesia nurses, *JOPAN* 24(3):167-176, 2009; Fleisher LA: ACC/AHA 2007 guidelines for perioperative care for noncardiac surgery, *J Am Coll Cardiol* 50:1707-1732, 2007; Sessler DI: Temperature monitoring and perioperative thermoregulation, *Anesthesiology* 109(2):318-338, 2008; Wadhwa A et al: New circulating water devices warm more quickly than forced-air in volunteers, *Anesth Analg* 105(6):1681-1687, 2007.

MALIGNANT HYPERTHERMIA (MH)

First identified in the late 1960s, MH is a rare, life-threatening complication that may be triggered by drugs commonly used in anesthesia. Inhalational anesthetics and succinylcholine are the most frequently implicated triggering agents. Trauma, strenuous exercise, or emotional stress also may induce MH. It is multifactorial and genetically transmitted as an autosomal dominant trait with variable expression in affected individuals (Hernandez et al, 2009). The incidence of MH is increased in patients with central core disease (a congenital myopathy) and some muscular dystrophies (Karlet, 2010; Malignant Hyperthermia Association of the United States [MHAUS], 2005; Theroux, 2004).

The syndrome begins with a hypermetabolic condition in skeletal muscle cells that involves altered mechanisms of calcium function at the cellular level. Characteristics include cellular hypermetabolism resulting in hypercarbia, tachypnea, tachycardia, hypoxia, metabolic and respiratory acidosis, cardiac dysrhythmias, and elevation of body temperature at a rate of 1° to 2° C every 5 minutes. Increase in body temperature is a late manifestation of MH. These signs may occur during induction or maintenance of anesthesia, although MH can occur postoperatively or even after repeated exposures to anesthesia. It is seen most frequently in children and adolescents (Karlet, 2010; MHAUS, 2005; Theroux, 2004). The signs and symptoms associated with MH are listed in Box 4-3.

It is important to remember that MH is a rare, multifaceted syndrome and can have variable clinical presentations. Many of the signs and symptoms associated with MH can have other causes. Other disorders, such as neuroleptic malignant syndrome (NMS), may have similar presentations. NMS occurs after use of neuroleptic drugs, such as haloperidol, and is characterized by muscular rigidity, akinesia, hyperthermia, and autonomic dysfunction. As MH is such a life-threatening disorder, many anesthesia providers initiate a treatment protocol when some of these early signs and symptoms occur that cannot otherwise be readily explained.

Time is crucial when MH is diagnosed. All OR and anesthesia personnel should be familiar with the protocol for its management. In the past, mortality ranged up to 80%, but the immediate infusion of dantrolene (Dantrium) and

BOX 4-3

Signs and Symptoms Often Seen with Malignant Hyperthermia

- Hypercarbia
- Tachycardia
- Tachypnea (may not be seen in a paralyzed patient)
- Muscle stiffness or rigidity
- Hypoxia and dark (desaturated) blood in operative field
- Unstable or elevated blood pressure
- Cardiac dysrhythmias
- Changes in CO_2 absorbent (temperature, color)
- Metabolic and respiratory acidosis
- Peripheral mottling, cyanosis, or sweating
- Rising body temperature (1° to 2° C every 5 minutes)
- Myoglobinuria
- Hyperkalemia, hypercalcemia, lactic acidemia
- Pronounced elevation in creatine kinase level

proper treatment have reduced the mortality to about 7%. Dantrolene is a hydantoin skeletal muscle relaxant that also has effects on vascular and heart muscle. In addition to dantrolene, the major modalities of treatment include cooling the patient with ice packs and cold IV solutions, administering diuretics, treating cardiac dysrhythmias, correcting acid-base and electrolyte imbalances, and monitoring fluid intake and output and the body temperature. Many hospitals maintain an emergency MH kit or cart that contains the drugs, laboratory tubes, other supplies, and instructions to treat MH in the OR area. The location of the iced or cold saline and other equipment also should be listed with the emergency kit. Chilled saline is often kept in the refrigeration unit for blood products (Karlet, 2010; MHAUS, 2005). The Rapid Response Team box presents an outline for emergency treatment of MH. The Malignant Hyperthermia Association of the United States (MHAUS) has names of on-call physicians available for consultation in MH emergencies at 1-800-MH-HYPER (1-800-644-9737). For patient-referral or nonemergency calls, 1-607-674-7910 should be used.

Patients known or suspected to have MH can be anesthetized with minimal risk if appropriate precautions are taken. If the syndrome is suspected, a muscle biopsy specimen should be obtained to make a diagnosis before the patient is electively anesthetized (Dixon and O'Donnell, 2006). For their own safety, relatives of persons with MH should be evaluated for the presence of the syndrome (MHAUS, 2005). A molecular genetic diagnostic test determines risk by means of a DNA analysis obtained from a blood sample (Litman and Rosenberg, 2005). It does not, however, replace muscle biopsy.

PERIOPERATIVE NURSING CONSIDERATIONS

Care of the surgical patient is a cooperative effort, and perioperative personnel should function as a smooth, well-coordinated team. As part of conducting the preoperative patient assessment and developing the plan of care, the perioperative nurse participates with the anesthesia provider in the preoperative verification process. As part of this process, the nurse checks the chart to verify the patient's identity, the surgeon,

RAPID RESPONSE TEAM

Rapid response teams (RRTs) are ordinarily called by the bedside nurse or other clinician when the patient's condition begins to deteriorate or there is an emergent crisis. In OR settings, there are occasions when the perioperative nurse or anesthesia provider triggers the RRT call to summon assistance in stabilizing an at-risk patient, such as the one in MH crisis. The RRT and surgical team members will follow the lead of the anesthesia provider in facilitating the following:

1. Immediately discontinue all triggering agents (inhalational anesthetics and succinylcholine).
2. Terminate surgery if possible, or continue with safe anesthetic drugs.
3. Hyperventilate with 100% O_2 at highest flow rate. It is not necessary to change any anesthesia equipment.
4. Immediately give dantrolene sodium (Dantrium) 2.5 mg/kg rapidly through large-bore IV, if possible. Repeat until the signs of malignant hyperthermia (MH) are controlled. Sometimes more than 10 mg/kg (up to 30 mg/kg) is necessary.
5. Give sodium bicarbonate IV to correct the metabolic acidosis. Refer to arterial blood gas (ABG) values to determine dosage. If ABG results are not available, consider administering 1 to 2 mEq/kg IV.
6. If the patient is hyperthermic (>39° C), begin active cooling.
   a. Infuse cold saline IV.
   b. Lavage the stomach, bladder, rectum, and open body cavities as feasible.
   c. Cool the body surface with a hypothermia blanket. Rub with cold, wet towels or ice.
   d. Monitor the temperature to avoid hypothermia. Stop cooling when temperature is 38° C.
7. Cardiac dysrhythmias usually resolve with correction of acidosis and hyperkalemia. If not, antidysrhythmic agents, such as procainamide 3 mg/kg (maximum 15 mg/kg), may be used. Avoid calcium-entry blockers because they may cause hyperkalemia and cardiovascular collapse.
8. Closely monitor temperature, $ETCO_2$, arterial or central venous blood gases, urine output, K^+, Ca^{++}, and coagulation studies. Insert a urinary catheter. Consider inserting an arterial line and a central venous or pulmonary arterial (PA) catheter.
9. Hyperkalemia is common. Treat with hyperventilation, sodium bicarbonate, or 10 units of regular insulin in 50 ml of 50% dextrose (D_{50}) IV titrated to K^+ level, or regular insulin 0.15 unit/kg in D_{50} 1 ml/kg. Life-threatening hyperkalemia also may be treated with calcium (e.g., 2.5 mg/kg $CaCl_2$).
10. Maintain urine output >2 mg/kg/hr. Consider volume of urine output to determine need for mannitol or furosemide administration.
11. Children <10 to 12 years old who have sudden cardiac arrest without hypoxia after succinylcholine is given may have subclinical muscular dystrophy. Treat for acute hyperkalemia first. Give $CaCl_2$ concomitant with other treatments listed in step 9.
12. Transfer patient to intensive care unit (ICU) when stable. Monitor at least 24 hours for recurrence of MH and for late complications.
13. Administer dantrolene 1 mg/kg IV every 6 hours for 24 to 48 hours; then dantrolene 1 mg/kg every 6 hours for 24 hours may be given orally as necessary.
14. Monitor core body temperature (continuously), ABG, K^+, Ca^{++}, creatine kinase (CK), serum and urine myoglobin, and coagulation studies until values return to normal.
15. Counsel the patient and family about MH and further precautions. Refer the patient to MHAUS, and submit an Adverse Metabolic Reaction to Anesthesia (AMRA) report to the North American Malignant Hyperthermia Registry at 1-888-274-7899.

Modified from Cherry K et al: Developing and evaluating a trigger response system, *Jt Commiss J Qual Patient Safety* 35(6):331-338, 2009; Malignant Hyperthermia Association of the United States: *Emergency therapy for malignant hyperthermia, May 2008*, available at www.mhaus.org. Accessed May 25, 2009. MHAUS 24-hour hotline: 1-800-MH-HYPER (1-800-644-9737); Fitzpatrick LR: Masseter muscle rigidity, elevated creatinine kinase and rhabdomyolysis following succinylcholine administration: a case report, *AANA* 76(5):349-354, 2008.

and the scheduled procedure; confirms that the operative and anesthesia permits are properly signed; identifies and communicates any patient allergies; ensures that the surgical site is marked; and ensures that current reports of laboratory tests and diagnostic studies are complete and in the chart.

In many OR suites, a preoperative preparation or *holding area* is used for insertion of arterial, central venous, or pulmonary arterial catheters and placement of epidural catheters or peripheral nerve blocks. Nursing personnel from the OR, PACU, or anesthesiology department may staff this area. The purpose of this area is to improve patient care delivery, optimize flow of patients, and provide supportive patient care.

A patient should never be left alone in the OR suite. When an anesthetized patient is in the OR, a perioperative nurse should always be immediately available to provide assistance if needed. During the insertion of IV, arterial, central venous, or pulmonary arterial catheters, the nurse assists as required.

During induction of anesthesia, particularly with urgent and emergency surgical procedures, the patient is presumed to have a "full stomach." The perioperative nurse should be ready to apply cricoid pressure to prevent regurgitation of stomach contents and assist the anesthesia provider in visualizing the vocal cords. When cricoid pressure is used to prevent aspiration, it should not be released until the intubation is accomplished, the cuff on the ETT is inflated, and proper placement of the ETT has been verified. When two anesthesia providers are present, one of them usually provides this support.

OR personnel should never move an unconscious patient without first coordinating the positioning or move with the anesthesia provider. When the patient is positioned for surgery, the perioperative nurse collaborates with the anesthesia provider in checking the arms and legs to ensure that no pressure points exist and that the extremities are appropriately positioned and padded (see Chapter 5). After positioning, prepping, and draping, the time-out is conducted and documented.

Before transporting the patient from the OR to the PACU, the circulating nurse, in most institutions, calls the PACU to give a preliminary status report of the patient's condition. This report includes the surgical procedure performed, type of anesthesia care provided, information specific to the patient's preoperative diagnosis and subsequent outcome related to intraoperative intervention, and any special equipment required (e.g., ventilator, T-piece, arterial pressure monitor). Postanesthesia recovery care and functions are described in Chapter 9.

REFERENCES

American Association of Nurse Anesthetists: AANA archives-library: a brief look at nurse anesthesia history, available at www.aana.com. Accessed June 24, 2009.

American Society of Anesthesiologists: Practice guidelines for management of the difficult airway, *Anesthesiology* 98:1269–1277, 2003.

Association of periOperative Registered Nurses (AORN): Recommended practices for documentation of perioperative nursing care. In *Perioperative standards and recommended practices,* Denver, 2009a, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for managing the patient receiving moderate sedation/analgesia. In *Perioperative standards and recommended practices,* Denver, 2009b, The Association.

Bankert M: *Watchful care: a history of America's nurse anesthetists,* New York, 2000, Continuum Publishing Company.

Bazzell L et al: Consciousness monitoring: a standard for the future? *OR Nurse* 2(7):36–38, 2008.

Beavers RA et al: Analysis of the application of cricoid pressure: implications for the clinician, *J Perianesth Nurs* 24(2):92–102, 2009.

Burkard J, Vacchiano CA: Regional anesthesia, In Nagelhout JJ, Plaus KL, editors: *Nurse anesthesia*, ed 4, St Louis, 2010, Saunders.

Burns SM et al: Unintentional hypothermia: implications for perianesthesia nurses, *J Perianesth Nurs* 24(3):167–176, 2009.

Chawla J, Burneo JG: Somatosensory evoked potentials—clinical applications. e-medicine, *Neurology*, December 2008, available at emedicine.medscape.com/article/1139393-overview. Accessed June 26, 2009.

Chung F et al: Elimination of preoperative testing in ambulatory surgery, *Anesth Analg* 108:467–475, 2009.

Cousins MJ, Bridenbaigh PO, editors: *Neural blockade in clinical anesthesia and pain medicine*, Philadelphia, 2009, Lippincott, Williams & Wilkins.

DeLamar LM: Preparing your patient for surgery, *Topics in Advanced Practice Nursing eJournal, Medscape* 5(1), 2005.

Dixon BA, O'Donnell JM: Is your patient susceptible to malignant hyperthermia? *Nursing* 36(12):26–27, 2006.

Dosch M: Anesthesia equipment. In Nagelhout JJ, Plaus KL: *Nurse anesthesia*, ed 4, St Louis, 2010, Saunders.

ECRI Institute: Risk management, quality improvement, and patient safety, Risk Management Report, 2009, July, Vol. 2, 1-15.

Faut-Callahan M, Hand WR: Pain management. In Nagelhout JJ, Plaus KL, editors: *Nurse anesthesia*, ed 4, St Louis, 2010, Saunders.

Ghoneim MM et al: Awareness during anesthesia: risk factors, causes and sequelae: A review of reported cases in the literature, *Anesth Analgesia* 108:527–535, 2009.

Gross JB et al: Practice guidelines for sedation and analgesia by non-anesthesiologists. A report by the American Society of Anesthesiologists Task Force on Sedation and Analgesia by Non-Anesthesiologists, *Anesthesiology* 84:459–471, 1996.

Hadzic A, Vlodka JD: *Peripheral nerve blocks: principles and practice;* New York Society of Regional Anesthesia, New York, 2004, McGraw-Hill.

Hamm CW, Maye J: Neuroanantomy, neurophysiology and neuroanesthesia. In Nagelhout JJ, Plaus KL: *Nurse anesthesia*, ed 4, St Louis, 2010, Saunders.

Haselman MA: Dexmedetomidine: a useful adjunct to consider in some high-risk situations, *AANA* 76(5):335–339, 2008.

Hartrick CT et al: Evaluation of a single dose, extended-release epidural morphine formulation for pain after knee arthroplasty, *J Bone Joint Surg Am* 88:273–281, 2006.

Hernandez JH et al: Scientific advances in the genetic understanding and diagnosis of malignant hyperthermia, *J Perianesth Nurs* 24:19–34, 2009.

Kain ZN et al: Family-centered preparation for surgery improves perioperative outcomes in children, *Anesthesiology* 106:65–74, 2007.

Karlet MC: Musculoskeletal system anatomy, physiology, pathophysiology, and anesthesia management. In Nagelhout JJ, Plaus KL: *Nurse anesthesia*, ed 4, St Louis, 2010, Saunders.

Kastanias P et al: What do adult surgical patients really want to know about pain and pain management? *Pain Manag Nurs* 10(1):22–31, 2009.

Koch BE: Nurse anesthesia: a history of challenge, In Nagelhout JJ, Plaus KL: *Nurse anesthesia*, ed 4, St Louis, 2010, Saunders.

Kossick MA: Clinical monitoring I: Cardiovascular. In Nagelhout JJ, Plaus KL: *Nurse anesthesia*, ed 4, St Louis, 2010, Mosby.

Lennmarken C, Sandin R: Neuromonitoring for awareness during surgery, *Lancet* 363:1747–1748, 2004.

Litman RS, Rosenberg H: Malignant hyperthermia: update on susceptibility testing, *JAMA* 293:2918–2924, 2005.

Liu SS, Ngeow JE, Yaduea JT: Ultrasound-guided regional anesthesia and analgesia: a qualitative systematic review, *Reg Anesth Pain Med* 34(1): 47–59, 2009.

LMA airway instruction manual, 2004, available at www.lmana.com. Accessed June 25, 2009.

Lynn, RR: Anesthesia. In Rothrock JC & Seifert PC, editors: *Assisting in surgery: patient-centered care*, Denver, 2009, Competency and Credentialing Institute.

Malignant Hyperthermia Association of the United States. 2005, available at www.mhaus.org. Accessed June 25, 2009.

Malignant hyperthermia susceptibility testing via RYRI gene sequencing. 2005, available at www.preventiongenetics.com/. Accessed June 25, 2009.

Marley RA: Outpatient anesthesia. In Nagelhout JJ, Plaus KL: *Nurse anesthesia*, ed 4, St Louis, 2010, Saunders.

Moon RE, Camporesi EM: Respiratory monitoring, In Miller RD, editor: *Anesthesia*, ed 6, Philadelphia, 2005, Churchill Livingstone.

Murphy MJ et al: Identification of risk factors for postoperative nausea and vomiting. I: the adult perianesthesia patient, *J Perianesth Nurs* 21(6): 377–384, 2006.

Nagelhout JJ: Neuromuscular blocking agents, reversal agents and their monitoring. In Nagelhout JJ, Plaus KL: *Nurse anesthesia*, ed 4, St Louis, 2010, Saunders.

Nagelhout JJ, Plaus KL: *Nurse anesthesia*, ed 4, St Louis, 2010, Saunders.

Naguib M, Lien CA: Pharmacology of muscle relaxants and their antagonists, In Miller RD, editor: *Anesthesia*, ed 6, Philadelphia, 2005, Churchill Livingstone.

National Quality Forum (NQF): *Safe practices for better healthcare—2009 update: A Consensus Report*, Washington, DC, 2009, NQF.

Patten SP: Apply cricoid pressure correctly, *OR Nurse* 1(3):72, 2007.

Roy-Byrne P et al: Brief intervention for anxiety in primary care patients, *J Am Board Fam Med* 22(2):175–186, 2009.

Salinas FV et al: Analgesics. In Evers AS, Maze M, editors: *Anesthetic pharmacology physiologic principles and clinical practice*, Philadelphia, 2004, Churchill Livingstone.

Sebel PS et al: The incidence of awareness during anesthesia: a multicenter United States study, *Anesth Analge* 99:833–839, 2004.

Smykowski L: A novel PACU design for noise reduction, *J Perianesth Nurs* 23(4):226–229, 2008.

Stanski DR, Shafer SL: Measuring depth of anesthesia. In Miller RD, editor: *Anesthesia*, ed 6, Philadelphia, 2005, Churchill Livingstone.

Stoelting RK, Hillier SC: Local anesthetics. In *Pharmacology and physiology in anesthetic practice,* ed 4, Philadelphia, 2005a, Lippincott-Raven.

Stoelting RK, Hillier, SC: Pharmacokinetics and pharmacodynamics of injected and inhaled drugs. In *Pharmacology and physiology in anesthetic practice,* ed 4, Philadelphia, 2005b, Lippincott-Raven.

Stoelting RK, Miller RD: Preoperative preparation and intraoperative management. In *Basics of anesthesia,* ed 5, New York, 2006a, Churchill Livingstone.

Stoelting RK, Miller RD: Preoperative medication. In *Basics of anesthesia,* ed 5, New York, 2006b, Churchill Livingstone.

Theroux MC: Malignant hyperthermia. In Litman RS, editor: *Pediatric anesthesia, the requisites in anesthesiology*, Philadelphia, 2004, Saunders.

Tobias JD, Litman RS: Pediatric regional anesthesia. In Litman RS, editor: *Pediatric anesthesia, the requisites in anesthesiology*, Philadelphia, 2004, Saunders.

Tonnesen H et al: Smoking and alcohol interventions before surgery: evidence for practice, *Br J Anaesthesia* 102(3):297–306, 2009.

Valdez-Lowe C et al: Pulse oximetry in adults, *AJN* 109(6):52–60, 2009.

Zoremba M et al: Day case surgery and incidence of transient neurological symptoms after spinal anesthesia with prilocaine–influence on patient's satisfaction, *Ambulatory Surg*, 15-1, April 2009.

CHAPTER 5

Positioning the Patient for Surgery

PAULINE ANNE HEIZENROTH

OVERVIEW

Proper patient positioning is essential for safe, successful surgical procedures. Many institutions require confirmation of the correct patient position during the time-out. An essential surgical team role, among others, is to ensure uncompromised and physiologically safe patient positioning. To do so, the team must understand the systems affected by positioning and their associated risks. Surgery is performed on all anatomic areas and the body may be positioned in multiple and sometimes unnatural configurations to expose a surgical site. Positioning, combined with anesthesia and its physiologic effects, can result in patient harm if safety factors are not paramount. This chapter discusses risks and prevention strategies associated with standard surgical positions.

The goals of surgical positioning include providing optimal exposure and access to the surgical site, maintaining body alignment, supporting circulatory and respiratory function, protecting neuromuscular and skin integrity, and allowing access to intravenous sites and anesthesia support devices. Meeting these goals while maintaining the patient's comfort and safety is the responsibility of every member of the surgical team.

ANATOMIC AND PHYSIOLOGIC CONSIDERATIONS

The perioperative nurse must understand thoroughly the anatomic and physiologic changes associated with positioning the patient. Numerous factors affect these changes: the particular surgical position; the length of time the patient is in that position; the OR bed, padding, and positioning devices used; the anesthesia given; and the operative procedure. These changes most frequently involve (1) the skin and underlying tissue, (2) the musculoskeletal system, (3) the nervous system, (4) the cardiovascular system, (5) the respiratory system, and (6) other vulnerable areas, such as the eyes, breasts, perineum, and fingers.

Skin and Underlying Tissue

The physical forces used to establish and maintain a surgical position can injure the skin and underlying tissue. These forces include *pressure, shear,* and *friction*. Additionally, OR conditions such as moisture, heat, cold, and negativity further increase the vulnerability of the skin and underlying tissues to injury.

- *Pressure* is the force placed on underlying tissue. Pressure can occur from the weight of the body as gravity presses it downward toward the surface of the bed. Pressure also results from the weight of equipment resting on or against the patient, such as drills, Mayo stands, surgical instruments, rigid edges of the OR bed or its attachments, or vertical posts for self-retaining retractors. Positioning devices, such as stirrup bars, leg or arm holders, and edges of laminectomy frames, can rest against the patient under tension. Surgical team members as well can lean on the patient and cause various degrees of pressure.
- *Shear* is the folding of underlying tissue when the skeletal structure moves while the skin remains stationary. A parallel force creates shear, unlike the perpendicular force created by pressure. This can occur when the head of the bed is raised or lowered and when the patient is placed in Trendelenburg's (head-down, supine) or reverse Trendelenburg's (head-up, supine) position. As gravity pulls the skeleton down, any stretching, folding, and tearing of the underlying tissues as they slide with the skeleton can occlude vascular perfusion, which can lead to tissue ischemia.
- *Friction* is the force of two surfaces rubbing against one another. Friction on the patient's skin can occur when the body is dragged across bed linen instead of being lifted. Friction can denude the epidermis and make the skin more susceptible to higher stage pressure ulcer formation, pain, and infection.
- *Moisture,* in excess, can worsen the effects of pressure, shear, and friction. Maceration occurs when prolonged moisture on the skin saturates the epidermis to the point that connective tissue fibers dissolve and can be easily torn apart. The skin becomes weakened and more vulnerable to the detrimental effects of external forces. In surgery, maceration can occur by the patient perspiring or lying in a pool of prep solution, blood, irrigation solution, urine, or feces. If this moisture also is located in an area of high pressure, the risk of pressure ulcer expansion into higher stages increases. If friction occurs on macerated skin, it becomes more vulnerable to denuding into the dermal layer. Every effort should be made to avoid pooling of prep solution. Prolonged exposure to the chemicals in the skin prep under the pressure area also can increase the likelihood of chemically induced contact dermatitis.
- *Heat* on the body surface can increase the metabolism of the tissue, and increase oxygen and nutritional demands. With every 1° C rise in skin temperature, there is a corresponding 10% rise in tissue metabolism (Aronovitch, 2007). If the tissue is also under pressure, constriction of vessels may impede blood flow enough that those demands are not met. Preexisting vascular impairment and the hypotensive effects of anesthesia may lead to further cellular tissue damage. This is especially true when the heated surface is under the

weight of the body. Excessive heat can cause thermal damage as well, resulting in burns.

- *Cold* environmental conditions, such as those found in the OR, can lead to hypothermia. Major surgery can cool the patient further by exposing the core of the body to cold air. A cold core temperature can lessen peripheral circulation, reducing oxygen delivery to the skin and underlying tissue.
- *Negativity* occurs when layers of materials, such as extra sheets or blankets, are placed over the OR mattress or padding. Extra linen can add rigidity and diminish the pressure-reducing properties of the mattress or padding. It is absorbent and abrasive and can produce high and inconsistent pressure. Eliminating extra layers of material between the patient and the OR bed mattress can reduce sacral pressure readings.

Pressure Ulcers. The National Pressure Ulcer Advisory Panel (NPUAP) defines a pressure ulcer as localized injury to the skin and/or underlying tissue, usually over a bony prominence, as a result of pressure or pressure in combination with shear and/or friction (NPUAP, 2007). A number of contributing or confounding factors also are associated with pressure ulcers; the significance of these factors is yet to be elucidated.

Pressure ulcers (also referred to as "pressure sores," "bed sores," and "decubitus ulcers") have been recognized and studied since the 1800s and possibly much earlier (History box). The impact that pressure ulcers have on patients and healthcare institutions is enormous. Patients often endure needless pain, suffering, and lost productivity. Despite all our advances in knowledge and technology to prevent pressure ulcers, their prevalence seems to be on the rise.

In October 2008, the Centers for Medicare & Medicaid Services (CMS) decided to halt reimbursing hospitals for many preventable hospital-acquired conditions which they called "never events." Among those conditions were stage III and IV pressure ulcers that develop after admission (CMS, 2008).

As it costs more to treat pressure ulcers than to prevent them, much research has focused on trying to determine the causes of pressure ulcer development and effective strategies to prevent them. Both *extrinsic* and *intrinsic* factors interact to contribute to the overall risk of developing pressure sores. Extrinsic factors are the physical forces and conditions to which the patient is subjected during surgery. These include pressure, including its intensity and duration; the anesthesia given and its effects; the particular surgery; the position itself; and safety measures used. *Intrinsic* factors are the health and the body structure of

HISTORY

Pressure Ulcers through the Centuries

One of the most emphasized aspects of surgical positioning has been that of maintaining tissue integrity by preventing pressure ulcers. In the past, terms for this condition included *decubitus ulcers* and *bedsores.* The early term, *decubitus,* is a Latin derivative of the word *cumbere,* which means "to lie down." In 1749 a Frenchman, Quesnay, coined the term *bedsores* to distinguish between sores caused by lying down and sores caused by other diseases. *Decubitus ulcer* and *bedsore* both implied that recumbency was the primary reason for this condition. The true source of the injury, *pressure,* can be achieved, however, through other means (e.g., sitting in a wheelchair; unrelieved pressure from a rigid surface, such as an appliance or cast). *Pressure sore* and *pressure ulcer* became the more accurate terms used to describe this condition.

Pressure ulcers are known to have been a problem as far back as the time of the pharaohs. Pressure ulcers were discovered on the mummy of an Egyptian princess. The earliest known documentation was from Hippocrates, about 400 BC, who described debridement of ulcers and healing by secondary intention. Much ahead of his time, Ambrose Paré, a sixteenth century French surgeon, documented how he successfully cured a pressure ulcer by encouraging and feeding his patient, providing pain relief and sleep medications, debriding the wound, and using pillows for pressure relief. In the 1800s Brown-Séquard identified pressure and moisture as causing ulceration of the skin, and Paget described these ulcers as the sloughing and death of a part resulting from pressure. In 1930 Lanis determined that 32 mm Hg is the average capillary pressure at arterial inflow. This value is still accepted as the threshold beyond which tissue trauma occurs. In 1946 Guttman appreciated the importance of relieving pressure in the bedridden patient by initiating a lifting and turning team on a spinal cord injury unit in England. In 1953 Husian showed that there was an inverse relationship between pressure and time for development of pressure ulcers. In studies using rats, he found that low pressures maintained for long periods produced more tissue damage than high pressures for short periods. He also found that the smaller the surface area over which the compressive force was applied, the greater was the damage to tissue. In 1959 Kosiak experimented with dogs and found that their tissue, when subjected to 60 to 70 mm Hg pressure for an average of 2 hours, began to show microscopic damage. Two-hour turning schedules were used to reduce pressure ulcer development in bedridden patients. In the late 1950s, a British nurse, Doreen Norton, developed and tested the first pressure ulcer assessment tool, the Norton scale. After she presented her study findings at a conference in 1962, the tool was widely disseminated and is still used today.

The findings of these early studies laid the foundation for many of the pressure ulcer definitions, descriptions, and prevention strategies practiced today. Continued research and technologic advances in support materials have focused on reducing the incidence of pressure ulcers originating in all settings, including the OR.

Modified from Allman RM: Pressure sores among the elderly, *New Engl J Med* 320:850-853, 1989; Black J et al: National Pressure Ulcer Advisory Panel's updated pressure ulcer staging system, *Dermatol Nurs* 19(4):343-349, 2007; Copeland-Fields LD, Hoshiko BR: Clinical validation of Braden and Bergstrom's conceptual schema of pressure sore risk factors, *Rehab Nurs* 14(5):257-260, 1989; Dealey C: *The care of wounds: a guide for nurses,* Ames, IA, 2005, Blackwell Publishing; Goodman T et al: Skin ulcers: overview and nursing implications, *AORN J* 50(1):24-37, 1990; Levine JM: Historical notes on pressure ulcers: the cure of Ambrose Paré, *Decubitus* 5(2):23-24, 26, 1992; Makleburst J: Pressure ulcers: etiology and prevention, *Nurs Clin N Am* 22(2):359-375, 1987; Melner SE, Lueckenotte AG: *Gerontologic nursing,* ed 3, St Louis, 2006, Mosby; Narcete TA et al: Pressure sores, *Am Fam Phys* 28(3):135-139, 1983; Souther SG et al: Pressure, tissue ischemia, and operating room pads, *Arch Surg* 107(10):544-547, 1973; Torrance C: *Pressure sores: aetiology, treatment, and prevention,* London, 1983, Croom Helm.

the patient. These compose an individual's risk and tolerance for the negative effects of pressure during surgery.

EXTRINSIC FACTORS. Pressure is the physical force responsible for pressure ulcer formation. Its intensity and duration affect the ultimate outcome of the tissue's integrity. An inverse relationship exists between pressure and time. The greater the pressure, the shorter the amount of time it takes to cause ischemic changes. Pressures greater than 32 mm Hg (capillary interface pressure) can occlude the flow of the arterioles, which nourish and oxygenate the tissue at the capillary level. An individual can endure relatively substantial pressure for a short time or lighter pressure for a longer time without sustaining tissue damage. A point will be reached, however, when tissue no longer can withstand the pressure (especially if it is >32 mm Hg), and cells die from lack of oxygen and nutrients. Such prolonged pressure can result in tissue ischemia manifested as a pressure ulcer.

The intensity of pressure depends on the surface area being compressed. The smaller the surface area to which pressure is applied, the greater the intensity of force (pressure per surface area). For example, compression of tissue between an external surface and a bony prominence of the body tends to create high forces of pressure in the local tissue surrounding that bony prominence. Pressure ulcers are most likely to develop around such protruding bony prominences as the heels, elbows, and sacrum in the supine position. Often the tissue injury is highest in the deep areas immediately adjacent to the bone. Deeper ischemia progresses outward toward the skin and, therefore, damage may not appear for several days. If pressure can be distributed more evenly over other surfaces of the body, the force of the pressure in those more vulnerable areas can be reduced. This theory encourages manufacturers to create OR mattresses, overlays, and padding materials that are designed to distribute the forces of pressure more evenly (see OR Beds later in this chapter for a more detailed discussion).

The longer a patient is on the OR bed, the greater is the risk of an OR-acquired pressure ulcer (Scott and Buckland, 2005; Schultz, 2005; Sewchuk et al, 2006; Aronovitch, 2007; Nixon et al, 2007; Walton-Geer, 2009). Duration on the OR bed is considered more a causative factor than is intensity of the pressure. Healthy individuals may tolerate high external pressures (e.g., 100 mm Hg) over bony prominences for short periods, but long, constant, and unrelieved pressure is most responsible for microscopic necrosis. Reduced pressures over extended periods still may cause tissue damage, particularly if tissue tolerance is diminished. Thus frequent repositioning of an immobilized patient can protect against the adverse effects of pressure. Repositioning a patient every 2 hours has long been the standard to diminish the negative effects of pressure in the immobile patent.

Patients in the OR, however, cannot be repositioned easily without jeopardizing access to the operative site and the integrity of the sterile field. Case-based exceptions to this would include limited repositioning of extremities and/or the head when such changes would not interfere with the procedure or sterile field. The perioperative nurse should anticipate such circumstances and ensure that preventive measures are taken to reduce pressure ulcer risks to the extent possible. Pressure-relieving OR mattresses or overlays may reduce pressure in dependent areas. Applying padding around rigid surfaces in contact with the patient and suspending vulnerable areas off the bed surfaces can reduce localized pressure. Because heels have been known to develop pressure ulcers even on pressure-relieving devices, the current Agency for Healthcare Research and Quality (AHRQ) *Clinical Practice Guidelines* recommend suspending the heels by placing a pillow under the length of the lower legs to raise the heels off the bed (AHRQ, 2009).

Patients undergoing regional or general anesthesia are at increased risk because normal muscle tone and pain sensations that enable the body to adjust itself in response to excess pressure are disabled. Patients often are placed in positions that they would not be able to tolerate comfortably if they were awake or even asleep, without the presence of anesthetics. Anesthesia also alters blood pressure, tissue perfusion, and oxygen and carbon dioxide exchange. All these anesthetic side effects can worsen the impact of pressure forces, particularly if other co-morbid conditions are present.

As noted, the hypotensive effects of anesthetic agents reduce tissue perfusion and thus reduce the exchange of oxygen and carbon dioxide. Aronovitch (2007) cites research in which diastolic pressures in surgical patients of less than 60 mm Hg have been associated with pressure ulcer development.

Hypothermia is the frequent result of the cool OR environment, exposure of external and internal body surfaces, and infusion and irrigation with unwarmed solutions. This causes peripheral vessels to constrict to conserve core temperature and increases the patient's heat metabolism. This heightened metabolism leads to increased tissue needs for oxygen, nutrients, and metabolic waste removal. When tissue is under pressure, these needs are not easily met. If a warming blanket is used under the patient in the area where pressures are greatest, tissue requirements become even more intense, and the impact of tissue ischemia may be more profound. Research has shown that the use of a warming blanket under the patient can be the greatest predictor of pressure ulcer development (Scott et al, 2001; Scott and Buckland, 2005; Aronovitch, 2007). Once the hypothermic patient emerges from general anesthesia and starts to shiver, oxygen requirements can rise 200% to 500%, increasing risk of myocardial infarction (Dunn, 2005).

Minimizing intraoperative hypothermia is clearly imperative. Ways to offset hypothermia in the OR and reduce its detrimental effects include using forced-air warming therapy over the patient to minimize unnecessary skin exposure and warming irrigation fluids, especially those used deep inside the body cavity. Intravenous fluids can be warmed by inserting a fluid warming coil or by placing most of the IV fluid tubing under the forced-air warming device (O'Connell, 2006).

The surgery being performed may itself have an impact on pressure ulcer development. Procedures that involve significant blood loss, extracorporeal circulation, and clamping of major vessels can contribute to the lack of blood flow to tissue under pressure. Patients who have cardiac surgery face a high risk for pressure ulcers. This is attributed to the diagnostic procedures these patients undergo, relatively long surgical times, and potential for restricted movement postoperatively (Sewchuk et al, 2006).

The positioning devices used also can increase pressure ulcer development. Rigid, unpadded objects that press against a body surface, such as stirrup bars, compressed beanbags, or rolled sheets, can cause tissue injury if the pressure is not relieved periodically.

Negativity, as noted earlier, can override the pressure-relieving capabilities of mattresses and padding (Schultz, 2005; Sewchuk et al, 2006; Aronovitch, 2007; Walton-Geer, 2009). Placing a warm blanket under a patient may be soothing initially, but if a surgical procedure is long, pressure to the bony prominences resting on the blanket will be higher than if only a sheet and draw sheet are used. Additionally, wrinkles and folds can cause further pressure points.

When a patient is placed in a shear-producing position (e.g., semi-Fowler) before being prepped and draped, measures should be taken to reduce shear forces. One technique is to lift the patient slightly, momentarily, to allow skin to realign with its surrounding skeletal structures. When the patient is placed in these positions *during* a surgical procedure, however, interventions to reduce shearing are limited. Reducing the time that shearing forces are in place is the best countermeasure to reduce tissue injury.

INTRINSIC FACTORS. Intrinsic factors can lower a patient's tissue tolerance to pressure and decrease the time and pressure required for tissue breakdown. Certain preexisting conditions are regarded as intrinsic risk factors for OR-induced pressure ulcer development. These conditions include respiratory and circulatory disorders, diabetes mellitus, anemia, malnutrition (serum albumin levels 3.5 g/dl or less), advanced age, body size (obesity; thin, frail build), body temperature (hypothermia), impaired mobility, and smoking (Scott and Buckland, 2005; Schultz, 2005; Sewchuk et al, 2006; Aronovitch, 2007; Nixon et al, 2007; Walton-Geer, 2009).

Various scales exist to determine pressure ulcer risk. One that is widely used is the Braden scale (Table 5-1). This scale scores a patient's potential to develop pressure ulcers based on various intrinsic factors. A scale such as the Braden scale can be used during the preoperative assessment to guide perioperative nursing interventions. The Evidence for Practice box explains how to interpret the Braden scale score and use the score to plan perioperative interventions. The Braden scale has been tested for reliability and validity. It cannot be shortened or altered without possibly lessening its reliability or accuracy. Copyright restrictions also prohibit alterations (Braden and Maklebust, 2005).

Assessment for pressure ulcer risk factors and development occurs during three periods: *preoperative, intraoperative,* and *postoperative*. Preoperative assessment for intrinsic risk factors using a scale such as the Braden scale can help to determine if the patient may be at higher risk for tissue breakdown and thus guide the nurse in the degree of padding and thermoregulation required. Consideration of expected OR events must be included in such assessments. Research indicates that *all* surgical patients should be considered at some risk because of variables inherent to the OR experience that often cannot be controlled. The most obvious variable is that the main method used for pressure ulcer prevention, changing the position of the patient, is often not an option in the OR. Other variables include the need for vasoactive medications, the patient's hemodynamic state, and the length of the procedure. The intraoperative assessment can include variables that occur during surgery that may have an impact on tissue perfusion, such as length of surgery, rigidity of positioning devices and length of time used, amount of blood loss, hypothermia, and anesthetic events such as ongoing diminished blood pressure. This information should be communicated in the hand-off report to the nurse in the postanesthesia care unit (PACU) or ambulatory recovery. Included in postoperative assessment would be inspections for altered tissue integrity. These inspections continue until discharge.

EVIDENCE FOR PRACTICE

Braden Scale Assessment of Pressure Ulcer Risk: Perioperative Implications

When using the Braden scale (see Table 5-1) to assess pressure ulcer risk, the tool should not be altered. Because the tool has been tested for reliability and validity in its complete form, minor changes to shorten or otherwise alter it may affect the accuracy of results. The lower the score, the greater the risk of developing pressure ulcers. The levels of risk according to scores are as follows (Braden and Maklebust, 2005):

- 19-23, not at risk
- 15-18, mild risk
- 13-14, moderate risk
- 10-12, high risk
- ≤9, very high risk

All surgical patients should be considered at risk for pressure ulcer development. If during the preoperative assessment a patient's score is 18 or lower, the patient is at an increased risk for skin breakdown. The perioperative nurse should do the following with *all* surgical patients:

1. Before positioning, assess skin for evidence of diminished tissue integrity, particularly in areas over bony prominences.
2. Pad and protect any fragile skin areas, and limit the amount of time these areas are under pressure to the extent possible.
3. Pad under or around all areas in contact with a firm surface.
4. For immobile patients, perform passive range-of-motion exercises every 1½ to 2 hours to any accessible limbs and slightly reposition the head if this does not interfere with the surgical procedure or the sterile drapes.
5. Reassess skin postoperatively, document findings, and communicate any changes to appropriate personnel.

During preoperative assessment, if the patient has a score of 18 or lower and an existing pressure ulcer (any grade/stage), has areas of skin breakdown over bony prominences, or has had muscle flap surgery, the perioperative nurse *additionally* should do the following:

1. Support and protect all existing wound dressings.
2. Arrange for the patient to be placed on a specialty bed designed for extreme pressure reduction postoperatively (e.g., alternating air mattress, flotation support bed).

STAGING. The NPUAP (2007) recently revised its guidelines for identification and staging of pressure ulcers:

- *Suspected deep tissue injury:* Deep tissue injury (DTI) may be characterized by a purple or maroon localized area of discolored intact skin or a blood-filled blister attributable to damage of underlying soft tissue from pressure and/or shear. Presentation may be preceded by tissue that is painful, firm, mushy, boggy, and warmer or cooler as compared to adjacent tissue.

  Further description. Deep tissue injury may be difficult to detect in individuals with dark skin tones. Evolution may include a thin blister over a dark wound bed. The wound may evolve further and become covered by thin eschar. Evolution may be rapid, exposing additional layers of tissue even with optimal treatment.

TABLE 5-1

Braden Scale for Predicting Pressure Sore Risk

Category	1 Point per Square	2 Points per Square	3 Points per Square	4 Points per Square	Scores*
SENSORY PERCEPTION Ability to respond meaningfully to pressure-related discomfort	**COMPLETELY LIMITED** Unresponsive (does not moan, flinch, or grasp) to painful stimuli, owing to diminished level of consciousness or sedation, *or* limited ability to feel pain over most of body surface	**VERY LIMITED** Responds only to painful stimuli. Cannot communicate discomfort except by moaning or restlessness, *or* has a sensory impairment that limits ability to feel pain or discomfort over half of body	**SLIGHTLY LIMITED** Responds to verbal commands but cannot always communicate discomfort or need to be turned, *or* has some sensory impairment that limits ability to feel pain or discomfort in one or two extremities	**NO IMPAIRMENT** Responds to verbal commands. Has no sensory deficit that would limit ability to feel or voice pain or discomfort	**SCORE** _____
MOISTURE Degree to which skin is exposed to moisture	**CONSTANTLY MOIST** Skin is kept moist almost constantly by perspiration or urine. Dampness is detected every time patient is moved or turned	**MOIST** Skin is often but not always moist. Linen must be changed at least once a shift	**OCCASIONALLY MOIST** Skin is occasionally moist, requiring an extra linen change approximately once a day	**RARELY MOIST** Skin is usually dry. Linen requires changing only at routine intervals	**SCORE** _____
ACTIVITY Degree of physical activity	**BEDFAST** Confined to bed	**CHAIRFAST** Ability to walk severely limited or nonexistent. Cannot bear own weight or must be assisted into chair or wheelchair	**WALKS OCCASIONALLY** Walks occasionally during day but for very short distances, with or without assistance. Spends most of each shift in bed or chair	**WALKS FREQUENTLY** Walks outside room at least twice a day and inside room at least once every 2 hr during waking hours	**SCORE** _____
MOBILITY Ability to change and control body position	**COMPLETELY IMMOBILE** Does not make even slight changes in body or extremity position without assistance	**VERY LIMITED** Makes occasional slight changes in body or extremity position but unable to make frequent or significant changes independently	**SLIGHTLY LIMITED** Makes frequent, although slight changes in body or extremity position independently	**NO LIMITATIONS** Makes major and frequent changes in position without assistance	**SCORE** _____
NUTRITION Usual food intake pattern	**VERY POOR** Never eats a complete meal. Rarely eats more than one third of any food offered. Eats ≤2 servings of protein (meat or dairy products) per day. Takes fluids poorly. Does not take a liquid dietary supplement, *or* is NPO or maintained on clear liquids or IV for >5 days	**PROBABLY INADEQUATE** Rarely eats a complete meal and generally eats only about half of any food offered. Protein intake includes only 3 servings of meat or dairy products per day. Occasionally takes a dietary supplement, *or* receives less than optimum amount of liquid diet or tube feeding	**ADEQUATE** Eats more than half of most meals. Eats a total of 4 servings of protein (meat, dairy products) each day. Occasionally refuses a meal, but usually takes a supplement if offered, *or* is on a tube-feeding or total parenteral nutrition (TPN) regimen, which probably meets most nutritional needs	**EXCELLENT** Eats most of every meal. Never refuses a meal. Usually eats a total of ≥4 servings of meat and dairy products. Occasionally eats between meals. Does not require supplementation	**SCORE** _____
FRICTION AND SHEAR	**PROBLEM** Requires moderate to maximum assistance in moving. Complete lifting without sliding against sheets is impossible. Frequently slides down in bed or chair, requiring frequent repositioning with maximum assistance. Spasticity, contractures, or agitation leads to almost constant friction	**POTENTIAL PROBLEM** Moves feebly or requires minimum assistance. During a move, skin probably slides to some extent against sheets, chair, restraints, or other devices. Maintains relatively good position in chair or bed most of time but occasionally slides down	**NO APPARENT PROBLEM** Moves in bed and in chair independently and has sufficient muscle strength to lift up completely during move. Maintains good position in bed or chair at all times		**SCORE** _____
				Total Score	_____

*See Evidence for Practice box on page 147 for scoring implications.

From Barbara Braden and Nancy Bergstrom, ©1988. Reprinted with permission.

- *Stage I:* A stage I pressure ulcer presents as intact skin with nonblanchable redness of a localized area, usually over a bony prominence. Darkly pigmented skin may not have visible blanching; its color may differ from that of the surrounding area.
  Further description. When a grading system is used, stage I is graded as a partial-thickness injury pressure ulcer. The area may be painful, firm, soft, and warmer or cooler compared to adjacent tissue. Stage I ulcers may be difficult to detect in individuals with dark skin tones and may indicate "at risk" persons (a heralding sign of risk).
- *Stage II:* A stage II pressure ulcer is characterized by partial-thickness loss of dermis presenting as a shallow open ulcer with a red-pink wound bed without slough. It also may first appear as an intact or open/ruptured serum-filled blister.
  Further description. A stage II ulcer also may present as a shiny or dry shallow ulcer without slough or bruising.* This stage should not be used to describe skin tears, tape burns, perineal dermatitis, maceration, or excoriation. When a grading system is used, stage II is graded as a partial-thickness injury pressure ulcer.
- *Stage III:* A stage III pressure ulcer is characterized by full-thickness tissue loss. Subcutaneous fat may be visible but bone, tendon, or muscle is not exposed. Slough may be present but does not obscure the depth of tissue loss. Stage III ulcers may include undermining and tunneling.
  Further description. The depth of a stage III pressure ulcer varies by anatomic location. The bridge of the nose, ear, occiput, and malleolus do not have subcutaneous tissue; stage III ulcers in these locations can be shallow. In contrast, areas of significant adiposity can develop extremely deep stage III pressure ulcers. Bone/tendon is not visible or directly palpable. When a grading system is used, stage III is graded as a full-thickness injury pressure ulcer.
- *Stage IV:* A stage IV pressure ulcer presents with full-thickness tissue loss with exposed bone, tendon, or muscle. Slough or eschar may be present on some parts of the wound bed. These ulcers often include undermining and tunneling.
  Further description. The depth of a stage IV pressure ulcer varies by anatomic location. The bridge of the nose, ear, occiput, and malleolus do not have subcutaneous tissue; stage IV ulcers in these locations can be shallow. Stage IV ulcers can extend into muscle and/or supporting structures (e.g., fascia, tendon, or joint capsule); osteomyelitis is possible. Exposed bone/tendon is visible or directly palpable. When a grading system is used, stage IV is graded as a full-thickness injury pressure ulcer.
- *Unstageable:* Full-thickness tissue loss in which the base of the ulcer is covered by slough (yellow, tan, gray, green, or brown) and/or eschar (tan, brown, or black) in the wound bed may render a wound unstageable.
  Further description. Until enough slough and/or eschar is removed to expose the base of the wound, the true depth (and therefore the stage) cannot be determined. Stable (dry, adherent, intact without erythema or fluctuance) eschar on the heels serves as "the body's natural (biological) cover" and should not be removed. When a grading system is used, an unstageable wound is graded as a full-thickness injury pressure ulcer.

*Bruising indicates suspected deep tissue injury.

Stage I or stage II pressure ulcers may be evident immediately after surgery. These areas must be kept free from additional pressure for healing to occur and to keep them from advancing to higher stages. They are sometimes misidentified and treated inappropriately. Stage I pressure ulcers can resemble normal reactive hyperemia (excessive redness) that generally fades on its own in one half to three fourths of the time that the area was under pressure, with little or no permanent tissue damage. Reactive hyperemia must be distinguished from a stage I pressure ulcer. In reactive hyperemia, the healthy tissue blanches when compressed. As the compression is released, the blood rushes back to the area, causing it to become erythematous again. Stage I pressure ulcers do not blanch when compressed. This is a serious sign, indicating that the compromised tissue is not receiving adequate oxygen and nutrients. The blistering that sometimes occurs in stage II pressure ulcers is often misidentified as a chemical or thermal burn. The lack of contact with a chemical or thermal agent in that area and its location under a bony prominence or near where a hard surface had been during surgery can help distinguish it as a pressure ulcer. A study by Nixon and colleagues (2007) found that nonblanching erythema in the postoperative patient significantly increased the odds of developing a pressure ulcer of stage II or higher.

Full manifestation of pressure ulcers may be delayed from hours to days after the triggering injurious event. Given this delayed manifestation, the connection that the surgical experience was the triggering event may be overlooked. Lack of awareness of an early pressure injury can lead to a delay of pressure relief and treatment. Inappropriate treatment can contribute to advancing the stage of the pressure ulcer.

In many pressure ulcers, deep tissue damage begins at the bony prominence and progresses to the skin. When the deeper necrosis finally erupts at skin level, what first appeared to be a stage I pressure ulcer or intact, but bruised skin may actually be a suspected DTI. As Black and colleagues (2007) describe, NPUAP added this new category to identify a form of pressure ulcer in which deeper tissues (the muscle and deep tissue adjoining the bony prominence that was under pressure) die first. Sloughing follows into the fat and when it finally includes the skin, the underlying tissue is empty, exposing the bone. What appeared as a closed-pressure ulcer exposes itself as a full-thickness stage IV pressure ulcer. Not all DTIs, however, evolve into stage IV pressure ulcers. If these DTIs are identified early enough and relieved of additional pressure, some of the injured tissue may be salvaged.

When a pressure ulcer has reached its highest stage, that stage does not reverse as it heals. In other words, as a stage III pressure ulcer epithelializes, it does not sequentially revert from stage III to stage II, stage I, and stage 0. When it is a stage III, it could worsen to a stage IV, but it can never reverse to a lower stage. The process of healing can be documented only by the improved characteristics of the healing wound (i.e., depth, width, presence of granulation tissue, "closed" versus "open").

Pressure alopecia (pressure-induced hair loss of the scalp) can result from prolonged local pressure to the scalp during and after surgery. Symptoms can occur between postoperative days 3 and 28 (Warner and Martin, 2006). Occipital scalp pain, swelling, exudate, crusting, or focal ulceration may precede actual loss of hair. Pressure alopecia is most commonly reported in cases that require prolonged intubation and head immobilization. In cardiac surgery, anesthesia induction-to-extubation time may extend more than 24 hours. The longer

the surgical time, the greater the risks are that alopecia will be permanent. Repositioning the patient's head every 30 minutes and using soft, contoured head padding can reduce the potential for pressure-induced local alopecia.

Musculoskeletal System

The patient's musculoskeletal system may be subjected to unusual stress during operative positioning. Normal range of motion is maintained in an alert patient by pain and pressure receptors that warn against overstretching and twisting of ligaments, tendons, and muscles. The tone of opposing muscle groups also acts to prevent stress and strain to the muscle fibers. When pharmacologic agents such as anesthetics and muscle relaxants depress pain as well as pressure receptors and muscle tone, the normal defense mechanisms cannot guard against joint damage or muscle stretch and strain. A positioning safety goal is to keep the body as naturally aligned as possible, while providing adequate access to the surgical site. The perioperative team needs to be aware of resistance to range of motion and not extend a joint beyond what is absolutely necessary.

Every time a patient is transferred to or from the OR bed, the alignment of the body needs to be maintained. This is especially true when the transfer involves moving the patient from a supine position to lateral or prone. Quick, jerky movements of unsupported limbs can cause strain to the muscles and ligaments and should be avoided.

Nervous System

Nervous system depression accompanies the administration of anesthetic agents and other drugs. The degree of depression depends on the type of regional anesthesia or the level of general anesthesia. Pain and pressure receptors may be affected regionally or systemically. Most important for the perioperative nurse to remember is that when nervous system depression occurs, the body's communication and command system becomes totally or partially ineffective. Compensatory reactions to changes in physical status no longer naturally occur. Lifesaving physiologic adaptive mechanisms are altered. The stresses of operative positioning are not automatically compensated.

Peripheral Neuropathies. Peripheral nerves can be injured during positioning, resulting in impaired sensory function or motor function, or both. The basic injuries to peripheral nerves in clinical practice are stretch-related injuries, compression, and lacerations (Burnett and Zager, 2004). Stretching and compression tend to be principle factors in position-induced nerve injuries. Prolonged stretching from hyperabduction of an extremity or compression results in ischemia, which can progress to necrosis. In addition, collateral damage to the surrounding tissue and capillaries can affect circulation and nourishment to the nerves. These pathologic forces combine to cause structural or functional damage to the nerves. Depending on the degree of damage, subsequent injuries may be temporary or permanent.

During surgery, all patients are at risk for nerve injury if sustained compression is placed on nerves. Numerous patient characteristics have been identified, however, as potentially increasing the risk for intraoperatively acquired neuropathies. These include diabetes mellitus, peripheral vascular disease, alcoholism, smoking, malnutrition, pernicious anemia, previous nerve injuries or neuropathies (e.g., carpal tunnel syndrome, thoracic outlet syndrome), arthritis, obesity, thin body habitus, and male gender (for ulnar nerve injuries) (Goodkin and Mesiwala, 2005; Tuncali et al, 2005; Faust et al, 2005; Winfree and Kline, 2005; Barnett et al, 2007; Edgecombe et al, 2008). Possible associated risk factors include lengthy surgical procedures, the use of abdominal-pelvic self-retaining retractors, long duration in the lithotomy position, sternal retraction from a median sternotomy, surgical procedures in which shoulder braces are used for support while the patient is in steep Trendelenburg's position, prolonged hospitalization, hypotension, hypothermia, and prolonged bed rest postoperatively (Goodkin and Mesiwala, 2004; Faust et al, 2005; Warner and Martin, 2006; Barnett et al, 2007; Rozet and Vavilala, 2007). Damage usually is not discovered until the patient reaches the PACU. Sometimes there is a delayed onset of symptoms in which the injury does not appear until days or weeks after the suspected insult. This delay can lead to some confusion as to whether the injury occurred during surgery or convalescence. The most commonly reported OR-related nerve injuries involve the upper extremities (primarily the ulnar nerve and the brachial plexus) and the lower extremities (primarily the common peroneal, sciatic, and femoral nerves).

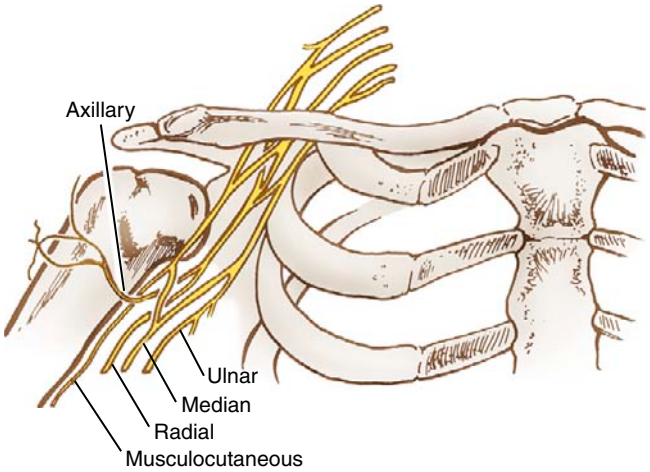


FIGURE 5-1 Brachial plexus on the right with associated bone structures and nerve branches that extend down the right arm.

UPPER EXTREMITY NEUROPATHIES. Upper extremity neuropathies arise from lesions to the brachial plexus and the nerves that emerge from it. The brachial plexus consists of a bundle of nerve cords that traverse the shoulder and innervate the lower shoulder, arm, and hand (Figure 5-1). This bundle originates from cervical spinal nerves C5-C8. The nerve cords emerge to form peripheral nerves. The axillary nerve innervates the deltoid muscle. The musculocutaneous nerve innervates the biceps muscle. Three main peripheral nerves traverse down the arm to the fingers: median, radial, and ulnar (Figure 5-2).

The *median nerve* passes through the antecubital space to the fingers and provides sensory and motor ability to the distal and palmar surfaces of the thumb and adjacent two fingers. A normally perceived pinprick to the palmar surface of the distal index finger generally would show that the median nerve was intact (Figure 5-3).

The *radial nerve* loops around the posterior humerus before it passes through the antecubital space to the fingers. It provides motor and sensory function to the triceps and the

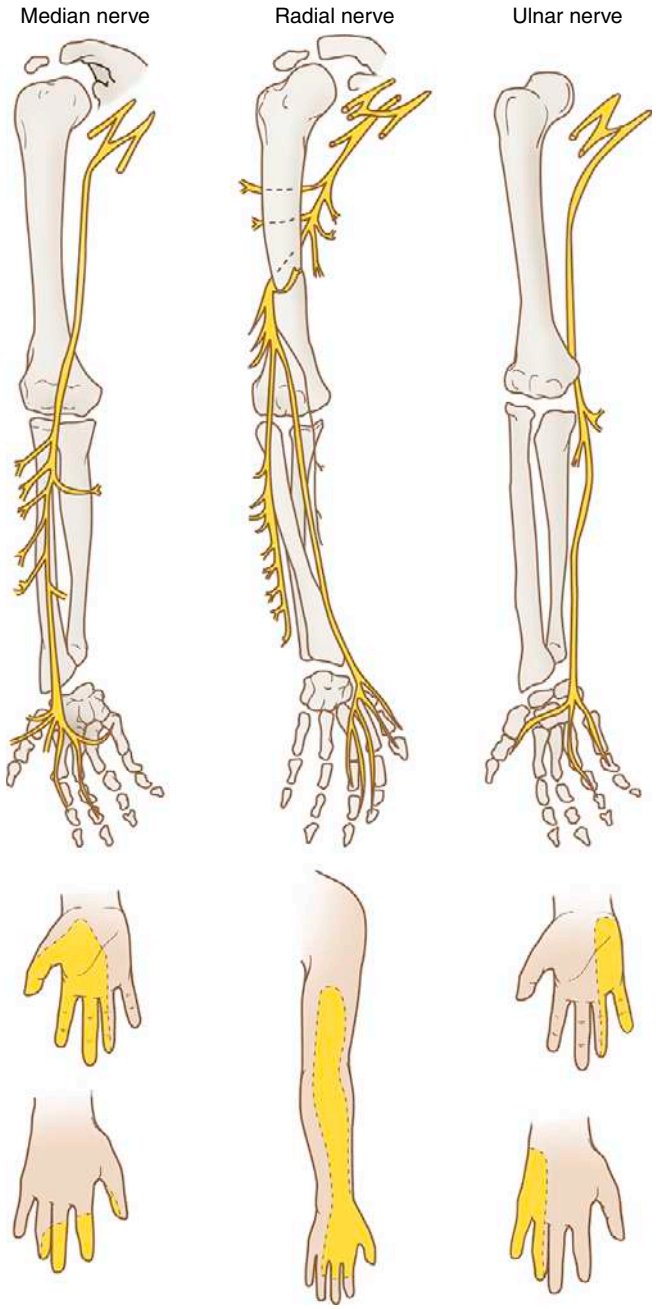


FIGURE 5-2 Median, radial, and ulnar nerves and nerves of the right arm with areas of sensory distribution shaded.

muscles of the posterior forearm and hand. Injury to this area can cause difficulty extending the wrist and thumb. If the distal thumb can be actively extended, this generally indicates an intact radial nerve (see Figure 5-3).

The *ulnar nerve* traverses behind the elbow and innervates the third, fourth, and fifth fingers and the muscles of the medial forearm. It is responsible for wrist flexion and, along with the radial nerve, enables the thumb to oppose the other four fingers. A normally perceived pinprick over the plantar surface of the distal fifth finger generally indicates an intact ulnar nerve (see Figure 5-3).

Injury to any of these nerves along their course can result in sensory or motor defects in areas they innervate. In surgical

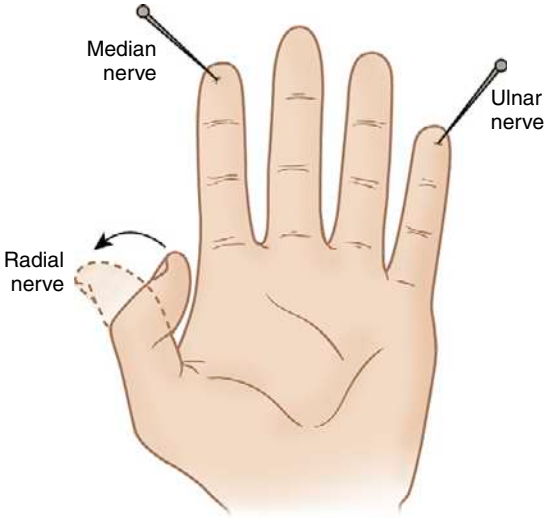


FIGURE 5-3 A quick way to check for injuries to the major peripheral nerves of the upper extremity. The ability to actively extend the thumb indicates an intact radial nerve. A normally perceived pinprick to the distal palmar surface of the index finger indicates an intact median nerve. A normally perceived pinprick to the distal palmar surface of the fifth finger indicates an intact ulnar nerve.

positioning, the most common areas of injury are the brachial plexus and the ulnar nerve (Faust et al, 2005). The major reason for this is that the brachial plexus resides in the shoulder, which is subject to abduction, manipulation, and sometimes pressure, depending on the position. As the ulnar nerve circles behind the elbow, it lies superficially in the shallow cubital tunnel of the humerus, where it is subject to pressure, and to stretching from flexion of the elbow.

The following improper positioning techniques can place the brachial plexus at risk for injury:

- Placing the arms on armboards that extend beyond a 90-degree angle to the body
- Using an armboard that is at a higher or lower level than the OR bed
- Surgical team members leaning against the shoulder or the arm while it is tucked against the body
- Shoulder braces used to support the patient in steep Trendelenburg's position, which can place pressure on the brachial plexus if the braces are medial or lateral to the acromioclavicular joint
- If, in lateral position, the dependent shoulder and arm are compressed under the rib cage
- Extreme lateral rotation of the patient's head, which can pull and compress the brachial plexus at its cervical origin

The brachial plexus also can be injured by the separation of the sternum during cardiac procedures that require median sternotomy. When the sternum is split, a retractor is used to separate it, allowing access to the heart. This separation forces the ribs to move laterally. If internal mammary artery dissection is done as part of the procedure, there is additional asymmetric retraction of the rib cage. The first rib compresses the brachial plexus nerve bundles and, in particular, the nerve cord that emerges into the ulnar nerve. When brachial plexus and ulnar neuropathies develop as a result, they generally are not preventable by proper positioning of the patient's arm (Warner and Martin, 2006).

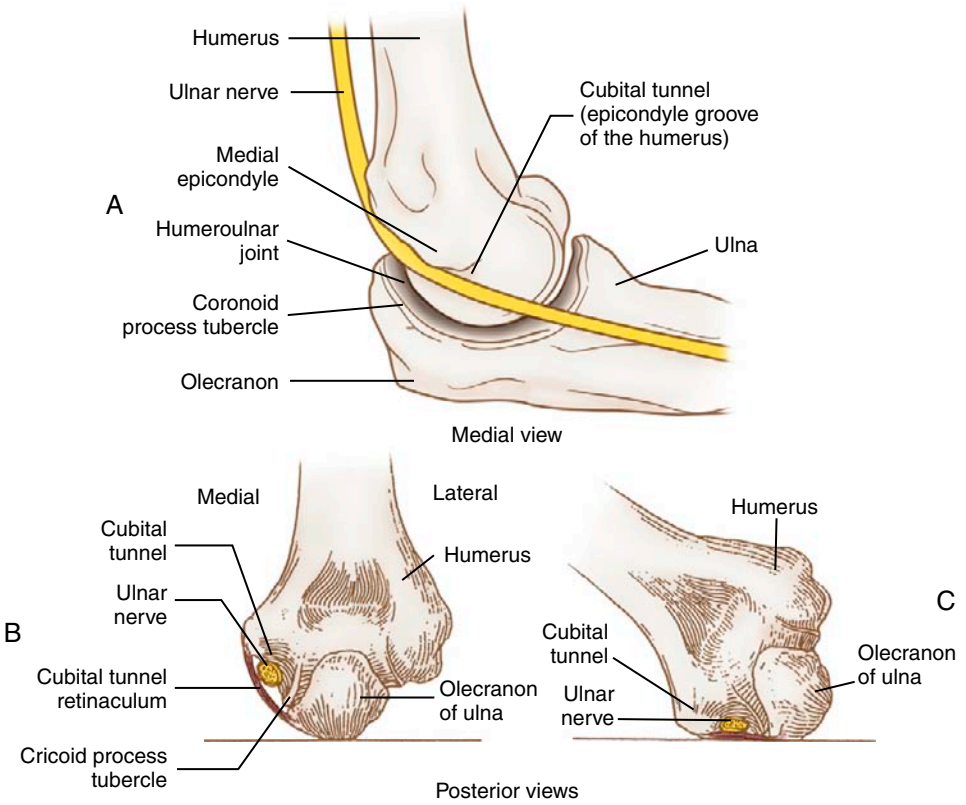


FIGURE 5-4 The ulnar nerve at the cubital tunnel. **A**, Medial view. **B**, Posterior view. Note cubital tunnel retinaculum over the ulnar nerve in the cubital tunnel. **C**, Posterior view with elbow tilted on medial side. Note the ulnar nerve compressed.

Isolated ulnar nerve injuries occur primarily from pressure on the vulnerable location of that nerve at the elbow. The ulnar nerve becomes quite superficial as it passes behind the elbow, nesting in the epicondyle groove of the humerus that makes up the cubital tunnel. There is a 2:1 predominance of ulnar nerve injuries in male versus female patients. Warner and Martin (2006) offer three anatomic differences between the elbows of men and women that probably contribute to this statistic:

1. The tubercle of the coronoid process is larger in men than in women, creating a smaller cubital tunnel around the ulnar nerve (Figure 5-4).
2. Men have less adipose tissue over the medial aspect of the elbow compared with women with similar body fat composition; this provides less natural padding to that area.
3. Men have a thicker, more developed cubital tunnel reticulum, which can further reduce the space for the ulnar nerve in the cubital tunnel. This becomes a greater risk when the elbow is flexed.

The main goal in protecting the ulnar nerve is to eliminate pressure on it. As Figure 5-4, *C* illustrates, pressure on the medial aspect of the elbow can compress the ulnar nerve. Figure 5-5 illustrates ways to prevent this pressure. Position the patient's arm on the armboard with the palms up (supinated) and the fingers extended (Figure 5-5, *A*). This places the olecranon of the elbow on the flat surface of the armboard instead of on the cubital tunnel, which contains the ulnar nerve. When the arm of a supine patient rests on the trunk, direct trauma can occur to the ulnar nerve as the weight of the arm presses the flexed elbow against the surface of the bed. Placing padding under the upper arm, proximal to the elbow (Figure 5-5, *B*), leaves a free space under the elbow, eliminating pressure on the nerve. When a patient is prone with arms pronated on armboards, the ulnar nerve is vulnerable to pressure from the elbow. Placing padding proximal and distal to the elbow (Figure 5-5, *C*) frees the nerve from pressure. If the patient has a history of thoracic outlet syndrome or pain when lifting the arms overhead, the arms should not be pronated, but rather restrained and tucked alongside the trunk.

Ulnar neuropathies may manifest symptoms in the immediate postoperative period. Sometimes symptoms fail to appear until 2 to 7 days after surgery, however, which makes it difficult to isolate an exact event that triggered the complication. The postoperative course cannot be completely ruled out as a causative or contributing factor. Some patients are forced to lie on their backs for prolonged periods postoperatively because of devices such as endotracheal tubes and abdominal drains. Often they rest with their elbows flexed and their hands on their chest. This places pressure on that superficial section of the ulnar nerve under the elbow, which may cause or contribute to nerve injury during the postoperative period.

Many OR-induced peripheral upper extremity nerve injuries can be avoided by properly securing the arms if there are procedure-related reasons to tuck them at the patient's side (Denholm, 2009). The arms should be tucked in such a way as to prevent them from sliding down the side of the OR bed and contacting the bed edge or rigid bed attachments. An effective technique to prevent arm slippage during surgery is to wrap the draw sheet smoothly around the arm, extending to above the

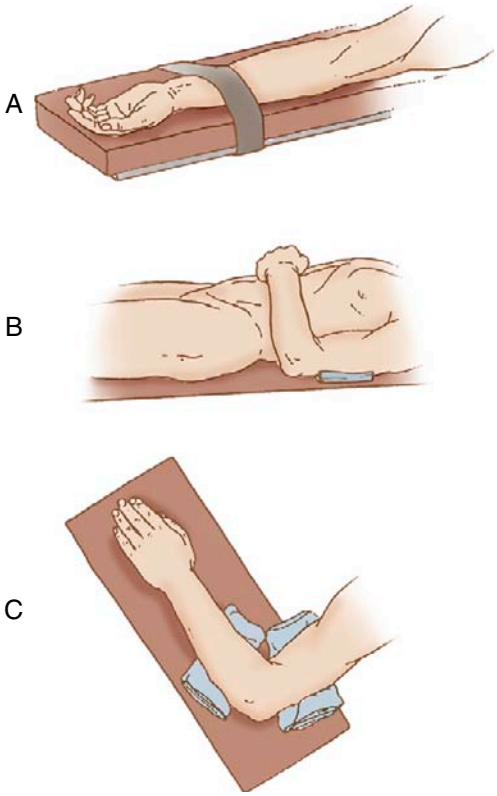


FIGURE 5-5 Three ways to protect the ulnar nerve. **A**, Arm of supine patient on armboard with palm up. **B**, Elbow lifted free from bed surface by padding upper arm when arm is resting on trunk. **C**, Arm of prone patient pronated on armboard. Padding above and below elbow frees the ulnar nerve from the pressure of the armboard surface.

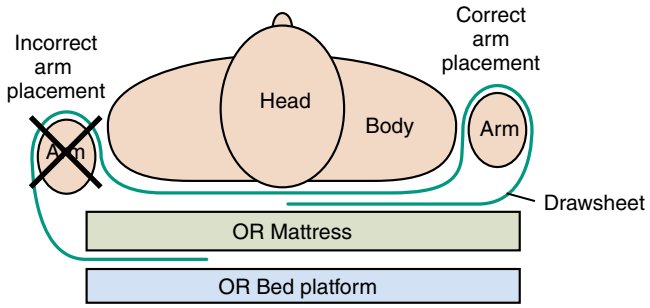


FIGURE 5-6 Correct method for tucking arms in at the patient's side.

elbow, and then tuck the draw sheet under the patient's body instead of under the mattress (Figure 5-6). Tucking the draw sheet is best accomplished with an assistant on the other side of the OR bed to roll the patient's body over enough to tuck the draw sheet underneath it. The elbows are slightly flexed, the palms facing inward, and the wrists in a neutral position. Care should be taken to ensure that the draw sheet is not tucked so tightly as to cause pressure to the arms. A tight fold pressing on the elbow could cause an isolated ulnar nerve injury.

Complete and thorough documentation of intraoperative measures taken to protect vulnerable nerves should include the following details:

- How the arms were secured and by whom
- The location of padding
- The angle of armboards (approximate degree of extension from body), the position of the palms, and the location of arm straps
- Times and type of repositioning or passive range of motion done
- Presence of distal pulses, color, and temperature of arms and hands when procedure is long or extremity is compressed, or both

Upper extremities should be evaluated postoperatively and any changes from the preoperative condition reported and documented.

LOWER EXTREMITY NEUROPATHIES. These neuropathies result most frequently from prolonged lithotomy positioning and tend to manifest symptoms within hours after surgery. The common peroneal, sciatic, and femoral nerves are most frequently implicated.

Intraoperative risk factors include the length of time the patient is in the lithotomy position (including high or exaggerated lithotomy) and the degree the extremities are positioned beyond their comfortable range of motion when the patient is awake. Different types of stirrups vary in the degree to which they control hip flexion (see Lithotomy section later for further discussion). Hip extension should be limited to only the amount required for adequate access to the operative area.

The *common peroneal nerve* branches from the sciatic nerve behind the knee and becomes superficial as it wraps around the lateral head of the fibula (Figures 5-7, 5-8, and 5-9). At this level, it is quite vulnerable to direct compression by stirrup bars. This risk increases in extremely thin patients who have minimal overlying tissue in this area. It is important to ensure that the lateral head of the fibula does not rest against stirrup bars or any other rigid surface. Compressive leg wraps (i.e., pneumatic compressive devices, elastic wrappings, or stockings) also can apply pressure on this nerve if the wrapping is too tight in this area. In addition, pressure behind the knee can compress the common peroneal and tibial nerves where they pass through the popliteal fossa; therefore only *soft* padding or pillows should be used for knee support. The ability to dorsiflex the great toe (point it upward) generally indicates that the common peroneal nerve is intact.

The *sciatic nerve* originates from the L4-S3 spinal nerve roots and travels down the buttock and posterior thigh before it divides into the common peroneal and tibial nerves (see Figure 5-7). It may be injured by the stretching that occurs during hyperflexion of the hip. A patient who has undergone total hip replacement surgery may have some preexisting sciatic nerve damage as a result of excessive rotation of the femur during the operative procedure. Additionally, patients with a history of hip trauma who have had surgery such as open reduction and internal fixation may be at increased risk for sciatic neuropathy because of the potential presence of scar tissue around the nerve area. The branches of the sciatic nerve travel from the thigh to the hamstring; the ability to flex the thigh generally indicates an intact sciatic nerve.

The *femoral nerve* arises from the L2-L4 spinal nerve roots and passes through the medial thigh. Injury to the deep femoral nerve may occur more as a result of inappropriate placement of abdominal-pelvic retractors and vaginal retractors in the pelvic cavity than inappropriate positioning (Irvin et al, 2004). The femoral nerve and obturator nerve can be subjected

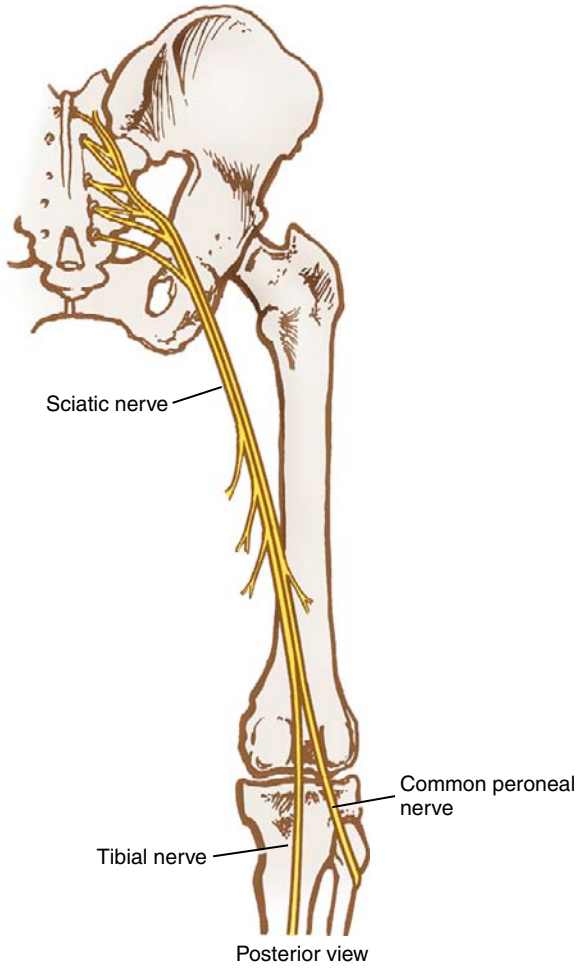


FIGURE 5-7 Posterior view of right sciatic nerve and right thigh and upper leg. Note the division of the sciatic nerve into the tibial and common peroneal nerves.

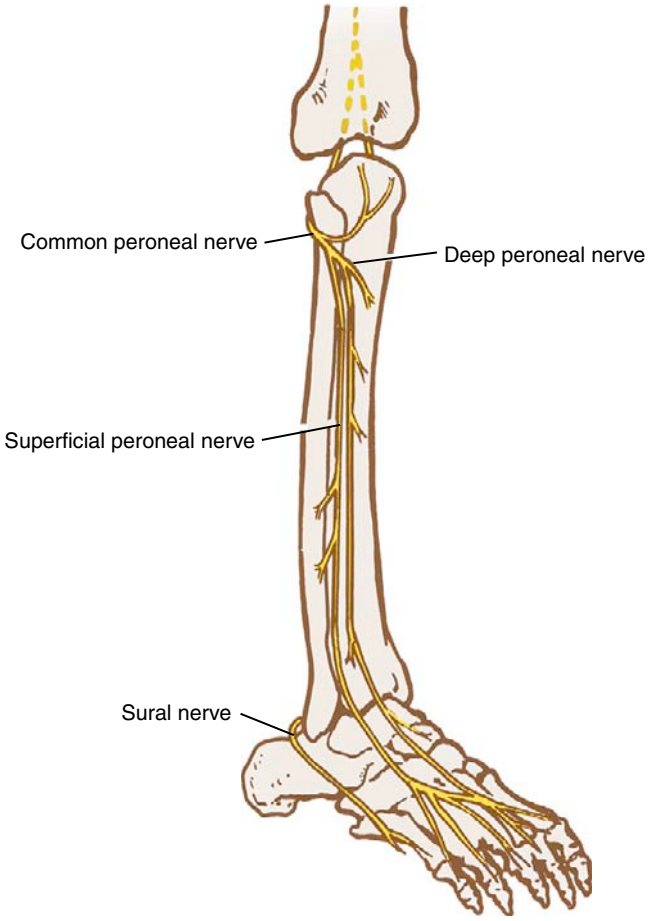


FIGURE 5-8 Lateral view of right leg. Note the common peroneal nerve pathway around the lateral fibular head. This nerve is susceptible to injury when the patient is in lateral position. Also note the sural nerve in the heel area. This nerve is susceptible to injury from stirrup straps.

to excessive stretching and injury, however, as a result of inappropriate lithotomy positioning (see Figure 5-9). The ability to flex the thigh to the trunk generally indicates an intact femoral nerve.

The *obturator nerve* originates from the L2-L4 nerve roots. It passes through the obturator foramen of the ischium to innervate the adductor group of muscles in the inner thigh. It can be subjected to excessive stretching when the patient is in lithotomy position. Scrubbed personnel may lean against the inner thigh while holding vaginal or anal retractors, causing additional stretching and compression of the nerve. The ability to adduct the leg generally indicates an intact obturator nerve.

The *tibial nerve* branches from the sciatic nerve behind the knee and traverses along the posterior tibia to the foot. There it bifurcates into the medial and lateral plantar nerves. Normal sensation to the plantar surface of the foot and the ability to curl the toes downward generally indicate an intact tibial nerve.

The perioperative nurse should document measures taken to protect the lower extremities from injury, such as the following:

- Location and type of padding used (i.e., pillow to support knees or calves, padding under heels)
- Type of stirrups used, names of persons placing legs in stirrups
- Type of lithotomy position (low, standard, high, or exaggerated)
- Presence of distal pulses, color, and temperature of legs and feet
- Use of sequential compressive devices (SCDs) or antiembolic compression stockings

The lower extremities should be evaluated postoperatively. Any changes from the preoperative condition should be reported and documented.

The use of intraoperative neurophysiologic monitoring is a method of preventing peripheral nerve injuries in the upper and lower extremities during procedures in which there is a high risk of such injuries. One type of monitoring used in the OR is somatosensory evoked potential (SSEP). The goal is to establish a baseline of the patient's normal nerve function along selected pathways and then to monitor them at continuous intervals during the procedure. Any emerging insult to these nerve structures or pathways can then be identified and corrective measures taken before permanent nerve injury occurs (Research Highlight) (Labrom et al, 2005; Devlin and Schwartz, 2007).

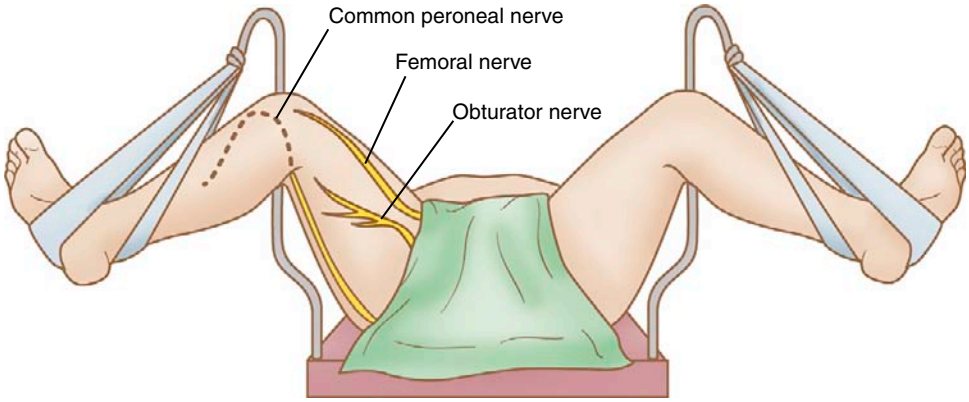


FIGURE 5-9 Nerves of the inner thigh. The femoral and obturator nerves can be overstretched by hyperextending the hips or by staff leaning against the thighs. If the lateral knee rests against a stirrup bar, the common peroneal nerve can be compressed.

RESEARCH HIGHLIGHT

SSEP Monitoring as a Tool to Prevent Intraoperative Peripheral Nerve Injuries

Studies over the past 25 years have demonstrated the benefits of using somatosensory evoked potentials (SSEPs) as an intraoperative tool to prevent peripheral nerve injuries, primarily to the ulnar nerve and the brachial plexus. SSEP monitoring provides early detection of impending neuropathies, allowing enough time for corrective interventions. Three recent studies further corroborate such findings.

Chung et al (2008) studied 230 patients undergoing lumbosacral spinal surgeries in prone position on the Andrews or Jackson spinal bed. Fourteen significant SSEP-negative changes were detected in the upper extremities that immediately returned to normal with repositioning of the arms. There was no documented position-related neuropathy in any of the 230 patients studied. In a study done by Kamel et al (2006) of 929 patients undergoing spinal surgery, upper extremity SSEP monitoring was performed about every 30 minutes. Position-related upper extremity SSEP-negative changes occurred in 68 patients (6.1%), whose average length of time in position ranged from about 4¾ to 9 hours. The SSEP changes were reversed by modifying arm positions. None of these patients developed a new postoperative deficit in the affected arm. Schwartz et al (2006) conducted a retrospective review of 3806 patients who underwent anterior cervical spine surgery in supine position. Neurophysiologic monitoring was done throughout the procedures as well as before and after each of the following maneuvers: neck extension for intubation, shoulder taping, neck extension for surgical exposure, and arm traction. Sixty-nine of these patients exhibited significant neurosurgical changes suggesting impending nerve injuries. Interventional strategies included releasing shoulder countertraction, loosening drapes used to tuck the arms at the side, repositioning the arms, limiting shoulder abduction, flexing the neck, and padding the shoulders, arms, and wrists as appropriate. None of those 69 patients incurred a postoperative position-related neurologic deficit.

Modified from Chung I et al: Upper-limb somatosensory evoked potential monitoring in lumbosacral spine surgery: a prognostic marker for position-related ulnar nerve injury, *Spine J,* 9(4): 287-295, 2009; Kamel IR et al: The use of somatosensory evoked potentials to determine the relationship between patient positioning and impending upper extremity nerve injury during spine surgery: a retrospective analysis, *Anesth Analg* 102:1538-1542, 2006; Schwartz DM et al: Neurophysiological identification of position-induced neurologic injury during anterior cervical spine surgery, *J Clin Monit Comput* 20:437-444, 2006.

Vascular System

Anesthesia and changes in position both affect the vascular system. These effects become more dramatic in patients with cardiovascular disease, hypovolemia, or obesity.

General anesthesia causes peripheral vessels to dilate by depressing the sympathetic nervous system. This dilation causes an overall decrease in blood pressure as blood pools in dependent areas of the body. In general anesthesia, these effects are systemic, whereas in regional anesthesia, such as spinal and epidural, effects are more limited to the areas anesthetized.

Position changes affect where the pooling of blood occurs. Muscle tone and peripheral vascular resistance are no longer effective to counteract the force of gravity on blood pooling. Blood pooling shifts to whatever part of the body is lowest.

The anesthesia provider can treat some of the hypotensive effects of positioning with pharmacologic agents and increased intravenous infusion. Vital signs, intravenous intake, and urinary output need to be monitored closely. Position changes may need to be delayed until blood pressure stabilizes.

Venous thromboembolism (VTE) is a serious complication of surgical positioning. Compression to deep and peripheral vessels (i.e., tight safety strap or wrist straps) can predispose the patient to VTE. When the legs are in a dependent position (i.e., legs lowered during knee arthroscopy, sitting position), venous return slows, and thrombosis can occur. SCDs or compressive antiembolic stockings can reduce this risk. Thrombosis also can occur as a result of hyperabduction of the arms beyond 90 degrees. Subclavian and axillary vessels pass through the brachial plexus; vessel constriction can occur by compression between the clavicle and the first rib. Radial pulses therefore need to be checked whenever arms are extended to ensure that the pulse is not obliterated.

The vascular status of upper and lower extremities should be assessed preoperatively. Measures taken to reduce assessed risks should be documented. Vascular status should be evaluated

intraoperatively and postoperatively. Any changes from the preoperative condition should be reported and documented.

Respiratory System

The respiratory system can be compromised during positioning. In almost all positions, except semi-Fowler, sitting, and reverse Trendelenburg's, the abdominal viscera are shifted upward toward the diaphragm. Consequently, the diaphragm shifts upward and outward such that it contributes only about two thirds of the ventilatory force and significantly reduces tidal volume (the volume of air inhaled or exhaled) (Faust et al, 2005). Patients who are obese or pregnant or have pulmonary disease have additional respiratory compromise in these positions. Any patient who experiences dyspnea should have the head of the bed elevated during transport and during local, regional, or spinal anesthesia if this does not interfere with surgical access. During general anesthesia, the anesthesia provider generally ventilates these patients mechanically.

External chest movement during surgery needs to be as unrestricted as possible to avoid even further reduction in tidal volume. The placement of arms across the chest should be avoided or very time-limited. Arms resting on the chest not only restrict chest expansion but also place pressure on the ulnar nerve at the elbow area. Some positions (i.e., lateral, fracture bed) require the placement of tape or straps around the chest area to secure the patient to the OR bed. In such cases, the perioperative nurse must ensure that tape or straps is not excessively tight. Anesthesia personnel closely monitor the respiratory status of these patients.

The portions of the lung that are perfused with blood also are affected by position. As blood is pumped into the lungs, the areas that are most dependent have a greater pulmonary arterial pressure. The greater the pressure, the greater is perfusion. The alveoli in the bases of the lungs are more compliant and ventilation is generally highest in those areas. An even distribution of ventilation and perfusion (ventilation-perfusion ratio) is needed for efficient gas exchange. If the position causes a pathologically compromised area of the lung to be dominant and most perfused, the balance between perfusion and ventilation may be disrupted and respiratory status diminished. The rest of the lung fields may or may not have the capacity to compensate. Oxygen therapy or mechanical ventilation can help to compensate, but the amount of time a patient can tolerate a certain position and maintain adequate gas exchange may be limited.

Monitoring respiratory status should always include pulse oximetry. In some cases, intraoperative arterial blood gas monitoring is necessary.

Other Vulnerable Areas

Other body structures, including the eyes, breasts, genitalia, and fingers, are placed at risk during positioning and warrant special discussion.

Eyes. Eye injuries during positioning can range from corneal abrasions to blindness. The eyes do not always close during anesthesia, so they are vulnerable to abrasion from the movement of the face on the sheets, pillows, or drapes in certain positions and from being brushed by intravenous lines, masks, fingers, or the clothes of personnel. When the patient is unconscious, the eyelids should be taped shut to reduce this risk. Eye patches or shields can provide additional protection.

Eyes should be checked to ensure that they are not under pressure when the prone or lateral position requires the face to be in a dependent position. Direct pressure on the globe of the eye may displace the intraocular lens in a patient who has had cataract surgery. Direct pressure on the eye, coupled with systemic hypotension, can cause central retinal artery occlusion, which can result in temporary or permanent blindness. The prone position itself, even without pressure on the eyes, can increase intraocular pressure, which in turn can lead to ischemic optic neuropathy, particularly when prone Trendelenburg's position is maintained for a prolonged period (Research Highlight) (Walick et al, 2007).

RESEARCH HIGHLIGHT

Vision Loss Associated with Prone Positioning

Perioperative vision loss (PVL) is a rare, but devastating complication sometimes seen after prone positioning. The American Society of Anesthesiologists Task Force on Perioperative Blindness reported in 2006 that central retinal artery occlusion (CRAO) and posterior or anterior ischemic optic neuropathy (ION) occur in 0.2% of spinal surgeries performed in prone position. According to the Task Force, studies and case reports suggest higher risk factors for these complications are found in patients with co-morbidities of diabetes, carotid artery disease, glaucoma, hypertension, and preoperative anemia. The literature suggests that prolonged procedures, substantial blood loss, or both are also associated with perioperative visual loss. Walick et al (2007) studied the impact of the prone position on intraocular pressure (IOP). They found that the flat prone position increased IOP and tilting the head down to a Trendelenburg's prone position increased ION significantly more. They determined that the longer the subject was in these positions, the higher was the IOP, which can in turn decrease perfusion pressure to the optic nerve. Lee et al (2006) found that some patients who underwent surgery in prone position with Mayfield pins supporting the head (eyes were free of pressure) also acquired PVL, demonstrating that ION can occur even in the absence of pressure on the globe of the eye. These studies suggest that the prone position itself is a factor in ION and that additional pressure to the globe of the eye can also cause CRAO, two position-related complications that may lead to postoperative blindness.

Modified from American Society of Anesthesiologists Task Force on Perioperative Blindness: Practice advisory for perioperative visual loss associated with spine surgery, *Anesthesiology* 104(6):1319-1328, 2006; Lee LA et al: The American Society of Anesthesiologists postoperative visual loss registry, *Anesthesiology* 105(4):652-659, 2006; Walick et al: Changes in intraocular pressure due to surgical positioning, *Spine* 32(23):2591-2595, 2007.

To minimize the risk of postoperative blindness, the American Society of Anesthesiologists Task Force on Perioperative Blindness (2006) recommends avoiding direct pressure on the eyes and face. With the patient in prone position, the head should be in a neutral forward position, higher than the heart when possible, and significant neck flexion, extension, or rotation is avoided.

Breasts. In the prone position, female breasts are compressed between the weight of the body and the bed or ventral chest supports. If the breasts are displaced laterally, their medial

FIGURE 5-10 This figure illustrates "ramping" the obese patient's torso to facilitate optimal airway alignment. An imaginary horizontal line between the earlobe and the sternum *(dashed line)* references the proper position. Distortion of the upper arm *(solid lines)* precludes standard placement of blood pressure cuff.

borders can be stretched and injured. If the patient has a mammary prosthesis, direct pressure can rupture the implant. Soft ventral supports on the lateral sides of the breasts, diverting the breasts toward the midline, are generally better tolerated (Faust et al, 2005; Warner and Martin, 2006).

Genitalia. Crush injuries can occur to genitalia in certain positions. With male patients, prone position on a laminectomy frame can compress genitalia between the pelvis and the frame. Patients positioned supine on the fracture bed have the pelvis stabilized by a vertical post placed close to the perineum. This post should be placed between the genitalia and the uninjured leg so that pressure is not directly on the genitalia. If the post is not well padded, intense pressure placed on the pelvis during traction of the injured leg can crush and severely injure the genitalia and pudendal nerve. Loss of penile sensation has been reported after improper positioning on the fracture bed (Warner and Martin, 2006).

Fingers. Fingers are vulnerable to injury during surgical positioning. If the arms are tucked at the patient's side, the fingers should be straightened with palms toward the patient's body. Curled fingers can put pressure on the finger joints.

Risk for finger injury can also occur during lithotomy positioning. If the fingers hang over the edge after the leg section of the OR bed is lowered, there is a risk for fingers to be caught in the joint of the bed as the leg section is raised at the end of the procedure. This could result in a crushing injury or even amputation of the fingers. To prevent this, the leg section should only be raised with the fingers visualized and secured away from the OR bed leg section hinge.

Obesity

Obesity is an important consideration in positioning. Degree of obesity is based on the body mass index (BMI). The body mass index is determined by dividing the weight (in kilograms) by the height (in square meters). Obesity and morbid obesity are considered to be BMI >30 and 40 kg, respectively (Ogunnaike and Whitten, 2006). Morbid obesity is associated

PATIENT SAFETY

Key Considerations in Positioning Morbidly Obese Patients

The following complications may occur more frequently in this population:

- Deep vein thrombosis (DVT) and pulmonary embolism
- Ventilation impairment with diminished pulmonary functional residual capacity in all surgical positions except sitting
- Higher rates of perioperative ulnar nerve palsies, brachial plexus neuropathies, and pressure ulcers
- Lower limbs falling off bed, causing lateral femoral cutaneous nerve injuries
- Sciatic nerve palsies from tilting the bed sideways
- Postoperative back pain from buttocks acting as a fulcrum for legs, extending the lumbar spine

The following interventions can enhance the morbidly obese patient's safety:

- Provide OR bed made to accommodate patient's size and weight or secure two OR beds together adjacently.
- Use transfer aids such as rollers or backboards. Have numerous staff members available to assist during transfer and positioning maneuvers.
- Use two safety straps if patient size exceeds the limit for regular-sized safety strap. Place one safety strap across the thighs and the other over the lower legs.
- Elevate the head, upper body, and shoulders to facilitate the airway when supine.
- Pad armboards to match the higher elevation of the shoulders to avoid stretching the brachial plexus.
- Support the knees with pillows to reduce strain on back.
- Use SCDs or antiembolism stockings on lower extremities.

Modified from Denholm B: Tucking patient's arm and general positioning, *AORN J* 89(4):755-757, 2009; Guss D, Bhattacharyya T: Perioperative management of the obese orthopaedic patient, *J Am Acad Orthop Surg* 14(6):425-432, 2006; Helgeson LE: Obesity and nutritional disorders. In Fleisher LA, editor: *Anesthesia and uncommon diseases,* ed 5, Philadelphia, 2006, Saunders; Ogunnaike BO, Whitten CW: Anesthesia and obesity. In Barash PG et al, editors: *Clinical anesthesia,* ed 5, Philadelphia, 2006, Lippincott Williams & Wilkins.

with considerable perioperative risks (Patient Safety). Given fat distribution around the morbidly obese patient's back and shoulders, positioning interventions are necessary to gain control of the supine patient's airway. This is done by what has been called "ramping," which is building a ramp of cushioning materials (e.g., pillows, linen, foam wedge) to elevate the head, neck, and shoulders above the chest and into alignment with the airway. To create the correct plane, an imaginary horizontal line can be drawn between the earlobe and the sternum, as noted in Figure 5-10. Alignment in the correct plane enables the anesthesia provider to gain control of the airway by aligning the oral, laryngeal, and pharyngeal axes, as illustrated in Figure 5-11 (Fleisher, 2006). This position is sometimes referred to as the "head-elevated laryngoscopy position" (HELP) as it facilitates laryngoscopy and intubation (Ogunnaike and Whitten, 2006). (See Chapter 11 for a discussion of other special considerations in positioning bariatric patients.)

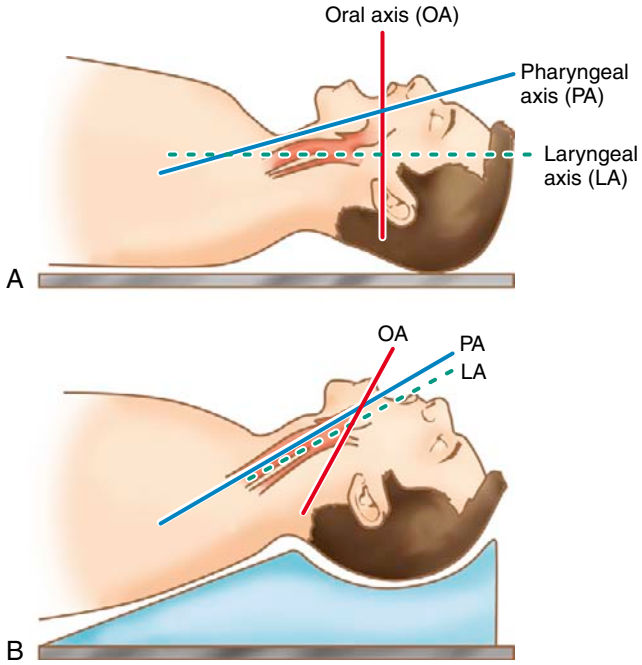


FIGURE 5-11 Head position for endotracheal intubation in an obese patient. **A**, When the head is flat, there is no alignment of the oral, pharyngeal, and laryngeal axes, making exposure of the glottis opening difficult for direct laryngoscopy. **B**, With ramping, the three axes align, forming the shortest distance and straightest line from the incisor teeth to the glottis opening.

Perioperative Nursing Considerations

Assessment

Assessment for positioning needs should be done before the patient is transferred to the OR bed (AORN, 2009). The perioperative nursing assessment includes a patient interview, physical examination, and review of medical records. Key points of assessment related to surgical positioning include age, height and weight, skin condition, nutritional status, preexisting conditions (e.g., conditions of the vascular, endocrine, respiratory, circulatory, neurologic, or immune system), and physical/mobility limits (e.g., prostheses, implants, range of motion). It also should be determined if there are any particular areas of discomfort that may be affected by a particular position and what interventions might avoid or reduce that discomfort.

Assessment will also highlight special patient needs and accommodations for vulnerable patients, including the following:

1. Geriatric patients, whose thin skin layer and increased arteriosclerosis make them more prone to skin breakdown caused by pressure
2. Pediatric patients, whose size and weight must be considered when selecting positioning aids
3. Patients with respiratory and circulatory disorders, diabetes mellitus, malnutrition, advanced age, and anemia because they are more prone to skin breakdown caused by pressure
4. Patients with mobility limitations caused by congenital anomalies, preexisting injuries, arthritis, or prosthetic implants
5. Patients with edema, infection, cancer, conditions of lowered cardiac or respiratory reserves, or who are morbidly obese or have poor general health
6. Patients with demineralizing bone conditions, such as malignant metastasis or osteoporosis, which places them at higher risk for skeletal fractures
7. Patients who will be subjected to the following:
   - Lengthy surgical procedures (≥2 hours), because of the increased risk of pressure-related injuries
   - Lengthy time in the lithotomy position, because of the increased risk of lower extremity nerve injury
   - Vascular surgery, because optimal blood perfusion already may be compromised as a result of the patient's disease process
   - Excessive sustained pressure to certain body areas, because of the surgical procedure or retraction
   - Cool environment or exposure of large body surfaces or both, because of the risk of hypothermia and its related complications

Nursing Diagnosis

The encompassing nursing diagnosis related to the care of the patient during surgical positioning is the risk for perioperative positioning injury. Other applicable nursing diagnoses may include the following:

- Impaired Comfort
- Impaired Transfer Ability
- Risk for Falls
- Risk for Impaired Skin Integrity
- Impaired Tissue Integrity
- Hypothermia
- Impaired Spontaneous Ventilation
- Impaired Physical Mobility
- Risk for Peripheral Neurovascular Dysfunction

Outcome Identification

The outcome identified for safe surgical positioning may be stated as "the patient is free from signs and symptoms of perioperative-positioning injury." To achieve this outcome, the perioperative nurse implements actions to ensure that the patient will:

- Experience a safe transfer to and from the OR.
- Be warm and comfortable.

- Not experience tingling, numbness, or pain unrelated to the surgical procedure.
- Maintain skin and tissue integrity consistent with preoperative status.
- Maintain a respiratory status consistent with preoperative status.
- Regain normal physical mobility postoperatively.
- Maintain normal peripheral neurovascular function.

Planning

The perioperative nurse plans activities to protect the patient from injury and provide physiologic support and comfort, while still allowing for optimal exposure and access to the surgical site. Although carrying out safe surgical positioning involves all members of the surgical team, the nurse plans and coordinates this teamwork. Knowledge of any preexisting risk factors that may affect positioning strategies (e.g., obesity, diabetes, paralysis, advanced age) should be considered when planning for additional assistance and support devices or padding.

The exact location of the operative site must be identified so that access to that site remains unobstructed. If a secondary surgical procedure is involved, such as a graft donor site, that area needs to be exposed and accessible as well. There are times, however, when the incision site cannot be exposed during initial positioning. In those cases, plans are made to reposition the anesthetized patient quickly and smoothly.

Planning for the patient's comfort involves communicating with the patient regarding potential areas for discomfort and possible remedies. An awake patient receiving a local anesthetic can communicate comfort of the position before, during, and immediately after the procedure. In some cases, all or part of the positioning for a patient who is to be anesthetized can be done before induction if it does not interfere with the anesthesia process. A patient might be placed in the lithotomy position before induction if he or she has a history of discomfort with leg abduction or lower back pain. If this is done, privacy must be ensured by covering the patient with a sheet or blanket and covering or pulling the blinds on room windows. A Sample Plan of Care for patient positioning is below.

Implementation

Nursing actions in positioning should reflect an individualized plan of care designed to ensure injury prevention, while maintaining optimal surgical access, patient comfort, and physiologic support. Patient comfort measures include physical

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Risk for Perioperative Positioning Injury

OUTCOME
The patient will be free from injury related to perioperative positioning.

INTERVENTIONS
- Verify surgical site and planned surgical position. Confirm correct patient position during the time-out.
- Identify and document risk factors that may predispose the patient to position-related injuries. Communicate these during the preop briefing.
- Identify areas of potential discomfort/limitations in mobility and possible remedies. Note condition of patient's skin and presence of peripheral pulses, as applicable.
- Check OR bed for proper functioning and availability of all needed attachments.
- Obtain any needed positioning aids and padding materials; verify that these are clean and in working order.
- Ensure a safe transfer between the transport vehicle to OR bed, and document mode of transfer.
- Safely secure the patient to the OR bed without compromising circulation underneath restraining straps.
- Provide warmth, privacy, and reassurance.
- If the patient is repositioned after being anesthetized, support all body parts, and maintain body alignment throughout the move.
- Use slow, smooth movements in making all position changes.
- Avoid pulling or dragging the patient; use lifting techniques instead.
- Pad or suspend bony prominences and all pressure-prone areas.
- Protect the eyes and anatomic areas containing superficial vessels and nerves.
- Secure the patient to the OR bed to prevent falls or slippage of extremities over the OR bed's edge.
- Monitor physiologic effects of position changes and be prepared to intervene when necessary.
- Ensure access to airway, intravenous catheters, and monitoring devices.
- Prevent pooling of fluids under dependent areas or any area under pressure.
- During long procedures, periodically do passive range of motion on accessible extremities if it does not interfere with the surgical procedure or sterile drapes.
- Maintain normothermia.
- Ensure that no equipment or personnel create pressure on the patient during the procedure.
- Periodically recheck position, straps, and padding to ensure that nothing has slipped or moved.
- At the end of the procedure, reposition slowly for patient's hemodynamic accommodation.
- Secure patient and remain at patient's side when emerging from anesthesia.
- Document patient position and pressure and injury prevention interventions including the following:
  - Position of extremities
  - Type and location of safety straps, positioning aids, and padding materials
  - Frequency of passive range of motion and other injury prevention interventions
  - Use and location of warming or cooling blankets or devices
  - Positional changes made during procedure (e.g., supine to lithotomy to supine)
  - Adverse physiologic responses to positions, and interventions taken
- Transfer patient using a team approach and a secured transfer vehicle.
- Reassess tissue integrity; document and verbally communicate any changes during hand-off report.

and emotional aspects. Direct communication with the patient regarding his or her positioning concerns helps to reassure the patient and provides the nurse with possible comfort strategies. Providing warmth and privacy help the patient feel protected.

Assemble all necessary positioning aids, such as padding, pillows, bed accessories, and stirrups, before the patient's induction as positioning takes place immediately after the anesthetic is administered. All positioning devices must be clean and working properly (AORN, 2009). Additional personnel should be available if needed for lifting or turning the patient.

When the patient enters the OR, the circulating nurse uses two patient identifiers and verifies correct person, procedure, and operative site. Institutional procedures for preventing wrong site, wrong procedure, and wrong person surgery must be followed. The patient is then prepared for transfer onto the OR bed. During transfer, the OR bed and transport vehicle should be next to each other and locked. At least one individual stands on either side to assist the patient during transfer. If the patient is unable to assist in the transfer, a lifting device is used or a four-person lift is done, using a draw sheet and supporting the head and feet.

Falls are a risk during all stages of patient transfer and positioning. Prevention of falls is a National Patient Safety Goal (Beyea, 2005). Falls can occur easily during transfers if the transport vehicle and OR bed are not locked. Falls also can occur while the patient is on the OR bed, whether awake or anesthetized. An awake patient may not fully appreciate the narrowness of the OR bed and can continue to move beyond the bed edges. A team member must stand on either side of the patient until the safety strap is applied. Falls also are a risk during induction and emergence from anesthesia. Lighter stages of anesthesia can result in patient movement. Often the movement is strong enough that safety straps alone do not offer adequate security. The nurse remains at the patient's side during both induction and emergence as a fall-prevention strategy and to assist the anesthesia provider in other activities. Infants and toddlers are particularly at risk because standard safety straps frequently are not used given their small stature. Other means to secure a pediatric patient are employed, depending on the area needed for surgical access.

When the patient is on the OR bed, the safety strap is placed about 2 inches above the knees. The strap should be snug, but not so tight as to place pressure on nerves or restrict venous return. One should be able to slide a flat hand or two fingers comfortably beneath the strap. The patient's ankles must not be crossed because vessel and nerve constriction and skin pressure may result. The patient should be reminded of this because many patients automatically cross their ankles while lying down. The nurse should verify that the ankles are not crossed after anesthesia is administered.

If the patient is repositioned, movement is slow and smooth, ensuring that the whole body is supported. Quick, jerky movements can cause musculoskeletal injury and put the patient at risk for bruises, pinches, abrasions, fractures, or falls. Any lateral, anterior, or posterior movement of the patient on the OR bed is done by lifting the patient with the draw sheet rather than by pulling or dragging the patient. Vulnerable areas, such as eyes, breasts, perineum, and fingers, are protected during all movements (see Other Vulnerable Areas section earlier in this chapter).

When the desired position is obtained, the patient is again secured so that movement off the OR bed cannot occur. Safety straps and other support accessories are rechecked. Padding or adjustment is done at this point, the last opportunity to do so before prepping and draping. Review how the position may cause certain body parts to sustain more gravitational weight. If a pillow elevates the knees, for example, the heels bear additional weight from the calves. Heel padding may be needed to relieve this additional pressure. Alternatively, placing the pillow under the calves elevates the knees and lifts the heels off the surface of the OR bed at the same time.

During the procedure, the perioperative nurse monitors and assists with any required modification to the position. Periodically, the nurse checks pressure points that are accessible and adjusts the patient or protective padding as needed. Passive range of motion may be done to accessible extremities. This is particularly important during procedures that last 2 or more hours. If the patient needs to be repositioned during the procedure, the circulating nurse and anesthesia provider coordinate the change and protect the patient from injury. The position, any repositioning, all padding, positioning devices, and methods used to secure the patient to the OR bed are documented.

Evaluation

After the surgical procedure is completed, all pressure sites, especially those under bony prominences, are checked before transfer to PACU. Any changes in the skin integrity are documented and verbally communicated during the hand-off report so that appropriate interventions occur immediately to reduce further injury. The mode of transfer, time of discharge, and patient status on discharge are documented. The successful implementation of the plan of care is measured by the positive patient outcomes listed under the Outcome Identification section.

OR BEDS

Modern OR beds are designed to support and accommodate various anatomic configurations required in surgical positioning. Their height can be raised or lowered, they can tilt laterally, and they can be placed in the Trendelenburg's or reverse Trendelenburg's position. Generally, OR beds are electrically or battery operated with a manual mechanical backup. They have roller wheels, which allow them to be moved easily, and lockable brakes.

OR Bed Parts and Accessories

General OR beds have a flat platform divided into three major sections: the head, torso, and leg sections. Each section has a corresponding removable mattress pad, which usually attaches to the main platform with Velcro or straps. The area between each section is called a "break." Raising or lowering sections is called "breaking the OR bed."

Along the edges of the bed are flat metal side rails that separate at each break and run horizontally along both sides of the entire bed. Armboards lock directly onto the side rails at any level of the bed. The side rails also accommodate sockets and clamps that can secure a multitude of attachments, including stirrups, anesthesia screens, armboards, and various retractors. Underneath the bed platform is a tunnel that runs under the entire body and leg sections to support x-ray cassettes. In

newer models, the entire bed platform is radiopaque to accommodate the use of intraoperative fluoroscopy.

The OR bed width is narrow to allow easy access to the operative site. For some patients, this width may not be enough to support their body adequately. All OR beds have weight limitations. Make sure the bed you use will accommodate your patient's weight.

The torso section is attached to the base of the OR bed because this section supports the heaviest parts of the body: the chest, abdomen, and pelvis. This section also has a break in the center at hip level that can be flexed or lowered to allow the head and chest areas to be elevated or lowered. At this central break in the torso section, there is a crossbar, called a *kidney bridge* (body elevator), that can be raised or lowered for kidney or gallbladder exposure. The kidney bridge is concave and can accommodate lateral braces that slide vertically onto the bridge to maintain the patient in a lateral position. The distal portions of the torso section's platform and mattress have a concave perineal cutout to accommodate access to the perineum when the patient is in the lithotomy position. Drainage trays may be inserted into this section for gynecologic, urologic, and proctologic procedures.

The head section of the OR bed can be flexed, lowered, or removed. It is connected to the bed by two horizontal posts that fit into corresponding grooves in the front of the torso section. Special headrests can slide into these grooves for specific procedures.

The leg section of the OR bed can be flexed or lowered. It folds beneath the torso section to allow leg room for a sitting surgeon to gain access to the perineal area when the patient is in lithotomy position. The leg section also has grooves in the distal-most platform to accommodate a foot extension for tall patients. If needed, the foot extension attachment can be flexed upward to provide plantar support. The distal grooves also accommodate the head section in case the patient must be positioned on the OR bed with the head at the typical location of the feet. Because the leg section protrudes farther away from the base than the head section does, such positioning allows for movement of a fluoroscopy *C*-arm around the patient's chest and abdomen. The head section may also be placed at the foot of the OR bed to enable the patient to be positioned with the buttocks in the perineal cutout immediately on transfer to the OR bed; this extends the leg section so that the patient's legs do not hang over the end of the bed and eliminates the need for the patient to be moved down on the bed after induction.

Multiple positioning accessories assist in achieving desired positions and cushioning pressure points. Examples are various headrests, stirrups, arm supports, hand tables, footboards, and foot extensions. Foam and gel pads and overlays are available in various shapes and sizes designed for specific areas of the body.

New state-of-the-art OR beds and accessory devices can accommodate most types of surgical positioning needs, and the need for additional specialty beds has declined. For example, the traditional orthopedic fracture bed has multiple movable and removable parts and suspended frames; special orthopedic extensions and accessories that duplicate functional features of traditional orthopedic fracture beds are now available for some OR beds. Nevertheless, exceptions remain. Although urologic procedures can be performed on a general OR bed set up in the lithotomy position, specialty urology beds are still beneficial to the OR because they have built-in drainage trays and radiologic equipment.

Mattress Materials and Their Pressure-Reducing Properties

OR mattresses must meet certain basic characteristic requirements: durable, versatile, nonflammable, resistant to bacterial growth, radiolucent with low x-ray attenuation, compatible with warming and cooling devices, covered with flexible nonallergic antistatic fabric, have pressure-reduction capabilities, and preferably be constructed without latex.

Durability leads to increased longevity and cost-efficiency. The cover should be made of durable but pliable material that is easily washed, resistant to deterioration from various prep solutions and chemical cleaning agents, resistant to the effects of heat, and can reduce friction and shear. Covers should be waterproof and completely intact. Seams should be heat sealed or bonded instead of stitched to inhibit entry of liquids into the core of the mattress. The mattress core also should be resistant to fungal and bacterial growth.

Versatility of the mattress pad can be evaluated by its ability to flex easily and extend with the OR bed platform. The more lightweight it is, the easier the pad is to remove and reposition. Some pads must be stored horizontally because of gel components.

Pressure reduction and pressure redistribution are prime considerations in OR mattress pads. Neither the position of the patient nor the time spent on the OR bed can be altered easily. Using effective pressure-reducing mattresses and positioning devices along with performing initial and ongoing assessment of the patient's tissue integrity are the most effective methods to prevent pressure ulcers during surgery. With more attention being directed toward optimal pressure relief, manufacturers are improving OR mattresses to be more protective of tissue integrity. However, as Scott and Buckland (2005) point out, the technology for pressure redistribution surfaces in the OR environment has not reached the same levels of sophistication as it has for simple bed mattresses and chair cushions. This is probably because many other restrictive qualities are required for OR bed surfaces, such as stability, infection control, decontamination, radiologic translucency, and the means for resuscitation.

As mentioned earlier, distributing pressure over a larger surface of the body decreases the force of that pressure. Overall interface pressure can be reduced by providing even pressure distribution without "bottoming out" (i.e., flattening or collapsing such that parts of the body actually rest on the underlying surface, which defeats the purpose of the mattress). Generally, the thinner the foam, the easier it is to "bottom out." Mattress materials vary widely in their pressure-reducing characteristics. Some examples of materials currently available follow.

Standard Foam OR Mattress Pads. Standard foam OR mattress pads have greatly improved in quality. They are usually purchased with OR beds, but replacement pads can be purchased. Years ago, these mattresses were about 2 inches thick, made of standard foam, and covered with a relatively rigid vinyl covering. Today's mattresses are often more than 2 inches thick and afford greater protection against the effects of pressure. They have a soft, pliable waterproof cover. The more pliable the cover, the greater the patient benefits from pressure-reducing

properties of the foam or other mattress material. Many pads are made with new advanced foam technology that reduces "bottoming out." These foams have contouring properties, which allow the bony prominences to sink into the surface of the foam so that they no longer are the sole "landing gear." As other body surfaces also are in contact with the resting surface, the overall interface pressures lessen. Pliable pad covers allow body surfaces more contact with the foam and help reduce shear. The many benefits of these pads have caused some manufacturers to use them as their new "standard" for OR pads.

Bariatric OR Bed Pads and Surgical Stretchers. Some bed pads are made specifically for bariatric patients. The pads are about 4 inches thick. Manufacturers claim the foam contours to the patient's body in all areas it contacts, to "immerse" the patient in the foam and thus distribute pressure over more of the body surface. Various products accommodate patients weighing from 400 to 700 pounds.

Gel Products. Gel products, made of dry polymer elastomer gels, generally are used as overlays to mattress segments and positioning devices. Some OR bed mattress pads are made with a layer of gel over the foam and a pliable cover. Gel products seem to reduce shearing because they are more pliable, similar to the qualities of body fat. They support weight while tending to prevent shearing and "bottoming out" (Walton-Geer, 2009). Compared with a standard OR mattress, gel pads do reduce pressure ulcers (Schultz, 2005). Gel pads, however, are expensive, heavy, and slow to adapt to temperature; they therefore are more practical for spot protection and as overlays for smaller positioning devices. Gel products also are available as lightweight foam-shaped pieces for specific positioning needs.

Fluid OR Pad. This OR mattress uses multiple individual, fluid-filled sacs within the pad to conform to body contours and to distribute pressure evenly.

STANDARD SURGICAL POSITIONS

This section discusses standard positions and variations in terms of requirements for certain surgical procedures, unique risks that they present to various body systems, and nursing interventions to diminish risks. The Risk Reduction Strategies box provides an abbreviated summary of standard surgical positions.

Supine

The supine (dorsal recumbent) position is the most common. The patient lies with the back flat on the OR bed. The arms may be tucked at the side or placed on armboards. The supine position is the most natural position of the body at rest and is the position in which the patient is usually anesthetized.

RISK REDUCTION STRATEGIES

Risks and Interventions of Surgical Positions

Position	Risks	Interventions
Supine	1. Pressure to head, shoulders, elbows, back, sacrum, coccyx, and heels	1. Pressure-reducing OR mattress; additional padding as needed
	2. Pressure to peripheral vessels and nerves, primarily brachial plexus and ulnar nerves	2. Armboards level with OR mattress, <90-degrees extension and palms up; ankles uncrossed
Trendelenburg's	*Risks in addition to those for supine:*	
	1. Diminished lung capacity	1. Close respiratory monitoring
	2. Venous pooling shifts toward head	2. Slow, smooth postural transitions to diminish cardiovascular effects
	3. Sliding and shearing	3. Flex knees slightly; limit time in position
Reverse Trendelenburg's	*Risks in addition to those for supine:*	
	1. Deep vein thrombosis (DVT) in lower extremities	1. SCDs or antiembolic stockings
	2. Sliding and shearing	2. Padded footboard
Fracture bed	1. Pressure to foot and ankle in traction	1. Adequate padding; appropriate foot cuff inflation
	2. Pressure to genitalia	2. Properly padded and positioned perineal post
Lithotomy	1. Hip dislocations, fractures, and muscle and nerve injuries	1. Securely fasten stirrups to OR bed; avoid hyperabduction of hips and leaning against inner thighs; avoid candy cane stirrups when possible; avoid leg contact with stirrup bars; limit time in position
	2. Pressure injuries to foot, ankles, and knees	2. Use stirrups that disperse support and pressure over wide areas; check distal pulses before and after positioning
	3. Back strain	3. Buttocks should not hang off edge of torso section of bed
	4. Diminished lung capacity	4. Close respiratory monitoring
	5. Venous pooling shifts toward head	5. Slow, smooth postural transitions to diminish cardiovascular effects
	6. DVT in lower extremities	6. SCDs or antiembolic stockings if in position >2 hr
	7. Crushed fingers	7. Ensure fingers are away from break of bed when leg section is elevated

RISK REDUCTION STRATEGIES

Risks and Interventions of Surgical Positions—cont'd

Position	Risks	Interventions
Fowler's (sitting)	1. Pressure to scapulae, sacrum, coccyx, ischium, back of knees, and heels	1. Pressure-reducing OR mattress; additional padding as needed
	2. Air embolism if venous sinus is opened	2. Doppler probe over chest wall; insert central venous catheter; saline-soaked sponges available
	3. Shearing	3. Momentarily tilt torso slightly away from OR bed to allow skin to realign with skeletal structures
	4. DVT in lower extremities	4. SCDs
	5. Venous pooling shifts toward lower body	5. Slow, smooth postural transitions to diminish cardiovascular effects
Semi-Fowler's (beach chair)	*Risks similar to Fowler's position, but generally not as severe:*	Same interventions
Prone	1. Pressure to cheeks, eyes, ears, breasts, genitalia, patellae, and toes	1. Pressure-reducing OR mattress; additional padding as needed; check ears, cheeks, eyes, and genitalia for pressure; tape eyes closed
	2. Falls and dislodgment of airway and monitoring cords and intravenous lines	2. Lock both beds; use a minimum of 4 people for turning patient; secure airway and all cords and lines
	3. Diminished lung capacity	3. Chest rolls and close respiratory monitoring
	4. Injury to shoulders, arms, and upper extremity nerves	4. Arms never hang off side of OR bed; arms on armboard are flexed and pronated with upper arm <90 degrees to OR bed; pads placed above and below elbow to free ulnar nerve
Prone variations	*Risks in addition to those for prone:*	
Jackknife	1. DVT in lower extremities	1. Check distal pulses before, during, and after positioning; if position maintained for extended time, SCDs or antiembolic stockings
Kneeling and knee-chest	*Risks in addition to those for prone:*	
	1. Extreme pressure on knees and ankles	1. Additional padding to these areas
	2. DVT in lower extremities	2. Check distal pulses before, during, and after positioning; SCDs or antiembolic stockings
Lateral, lateral chest, and lateral kidney	1. Pressure to structures on dependent side: ears, shoulder, ribs, hips, greater femoral head, knees, and ankles	1. Pressure-reducing OR mattress; additional padding as needed; check that earlobes are not folded over; place pillow between knees and under ankles; be sure neck is in alignment
	2. Risk of tilting and falling during procedure	2. Flex dependent leg for support; support abdomen and back to prevent lateral movement; may require additional straps or wide tape to secure patient further in addition to hip area
	3. Brachial plexus injury	3. Place padded roll under lower axilla; position lower shoulder slightly forward; support lower arm on armboard with palm up; support upper arm on elevated armboard or pillow
	4. Venous pooling shifts toward dependent side	4. Slow, smooth postural transitions to diminish cardiovascular effects
	5. Diminished lung capacity of dependent lung	5. Ventilator support provider includes positive end-expiratory pressure (PEEP); anesthesia inserts double-lumen endotracheal tube to ventilate dependent lung if thoracotomy performed
	6. DVT in lower extremities	6. Check distal pulses before, during, and after positioning; SCDs or antiembolic stockings

Supine position allows access to the major body cavities (peritoneal, thoracic, pericardial). It also allows access to the head, neck, and extremities. Vulnerable pressure areas in the supine position are the occiput, scapulae, olecranon, thoracic vertebrae, sacrum, coccyx, and calcaneus (Figure 5-12).

A safety strap is placed approximately 2 inches above the knees. A sheet or blanket is placed between the safety strap and the patient's skin. The strap is applied with enough tension to secure the patient to the OR bed without compromising circulation under the strap. The head generally rests on a small pillow or head cushion to support cervical alignment, reduce occipital pressure, and reduce strain on neck muscles.

When the arms are placed on armboards, the armboards are padded, with the pad level equal to that of the OR bed. Extension should be less than a 90-degree angle to prevent stretching and compression of the brachial plexus. Wrist straps should be

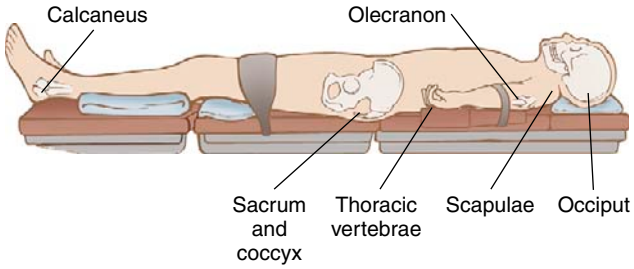


FIGURE 5-12 Potential pressure areas: supine position. A pillow under the calves frees popliteal areas and heels from pressure.

soft and nonocclusive. (See Figure 5-5 and Upper Extremity Neuropathies section for more details.)

Sometimes the patient's legs need to be flexed in a frog-leg fashion to provide access to the groin, perineum, and medial aspects of the lower extremities. To do so, the thighs are externally rotated, and the knees are flexed and supported with a pillow under each leg. Sometimes a special contoured positioning pad is used instead of pillows. This position may be used when access to the genitals is required during abdominal gynecologic and urologic procedures. During coronary artery bypass graft procedures, this position allows access for harvesting the saphenous vein.

In the supine position, blood volume to the heart and lungs increases, compared with the erect position, because venous blood from the lower body flows back to the heart without the counterforce of gravity. This increased blood volume is what increases cardiac output and workload. The weight of the chest in obese patients can cause increased intrathoracic pressure and increase cardiac workload further. If a patient has cardiovascular deficiencies, this position increases the risk for cardiac failure further.

Increased pressure on the inferior vena cava from abdominal viscera, abdominal masses, or a fetus in a pregnant woman may decrease blood return to the heart; if so, blood pressure lowers. The inferior vena cava lies slightly to the right of the vertebral column. Tilting the patient slightly to the left by placing a small roll or wedge under the right flank diverts the weight away from the vena cava. An example is tilting a supine cesarean section patient slightly to the left until the fetus is delivered.

Respiratory function is compromised in supine position because the tidal volume is less than that in the erect posture. The supine position allows more even distribution of ventilation from the apex to the base of the lungs. Anterior and upward excursion of the chest during inspiration is not greatly impeded except in obese patients, whose chest wall weight significantly compresses the rib cage. The abdominal viscera lessen diaphragmatic excursion, particularly when an abdominal retractor is used and packs are placed toward the diaphragm.

Trendelenburg's

Trendelenburg's position is a variation of the supine position in which the upper torso is lowered and the feet are raised. This position enhances visualization of the pelvic organs during open or laparoscopic surgeries in the lower abdomen or pelvis. Trendelenburg's position may also be used to improve circulation to the cerebral cortex and basal ganglia when blood pressure suddenly decreases. In this position, the knees are often bent by flexing the leg section of the bed to keep the patient

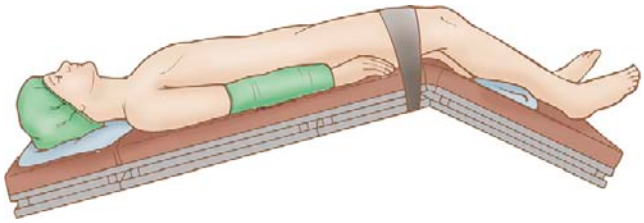


FIGURE 5-13 Trendelenburg's position.

from sliding (Figure 5-13). The patient must have the knees over the break in the bed to maintain safe anatomic positioning. As the lower section of the bed is elevated, the Mayo stand is raised to prevent pressure on the feet.

Shearing is a significant risk in this position. The skeletal structure slides up toward the head of the bed. If the patient is draped, lifting the patient to realign the tissue cannot be done. If necessary, shoulder braces may be used to limit upward sliding; however, they pose their own risk to the brachial plexus (as described in Upper Extremity Neuropathies section earlier) and are used with caution. To protect the brachial plexus from compression injury if shoulder braces must be used, it is important to ensure that braces are well padded and placed above the supraclavicular joint, but not on the soft tissue of the neck. Braces should *not* be used if the arms are extended on armboards.

Any variation of Trendelenburg's position should be maintained only as long as necessary. In this position, blood pools in the upper torso, increasing blood pressure and intracranial pressure. Although the head-down position facilitates drainage of secretions from the bases of the lungs and oropharyngeal passages, the weight of the abdominal viscera further impedes diaphragmatic movement; as the abdominal viscera push the diaphragm up and compress the lung bases, pulmonary compliance and tidal volume diminish. Fluid shifts into the alveoli, causing edema, congestion, and atelectasis. Slow, smooth postural transitions allow sufficient time for the body to adjust to physiologic changes. Hypotension may result if the patient is not returned slowly to supine position.

Reverse Trendelenburg's

Reverse Trendelenburg's position is described as the head-up, feet-down, supine position (Figure 5-14). It is frequently used to provide access to the head and neck and to facilitate gravitational pull on the viscera, away from the diaphragm and toward the feet. When the foot of the bed is tilted toward the floor, a padded footboard supports the patient's body.

For patients having thyroid, neck, or shoulder surgery, a pillow or soft roll is placed horizontally under the shoulders to hyperextend the neck. The knees can be slightly flexed to counteract sliding forward and to minimize shearing. The arms generally are tucked at the side to allow for closer access to the surgical site.

In reverse Trendelenburg's position, respiratory function is similar to that in the erect position. Venous circulation may be compromised by extended time in the legs-downward position. When this is anticipated, superficial venous return can be aided by preoperative application of SCDs, antiembolic stockings, or elastic bandages. If the legs are wrapped, compression of the common peroneal nerve at the head of the fibula must be avoided. Return to the supine position from reverse

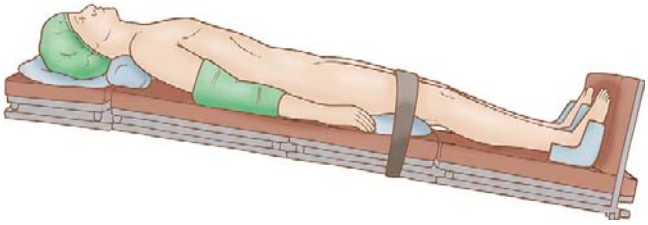


FIGURE 5-14 Reverse Trendelenburg's position with soft roll under shoulder for thyroid, neck, and shoulder procedures.

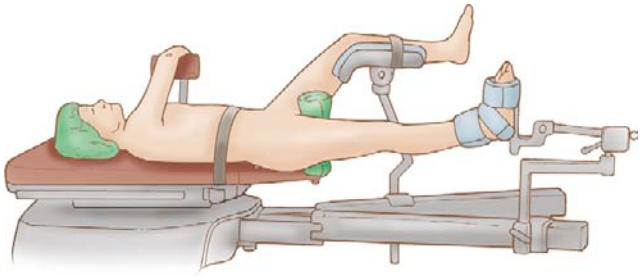


FIGURE 5-15 Fracture bed position. The unaffected leg is raised, abducted, and supported in a padded leg rest.

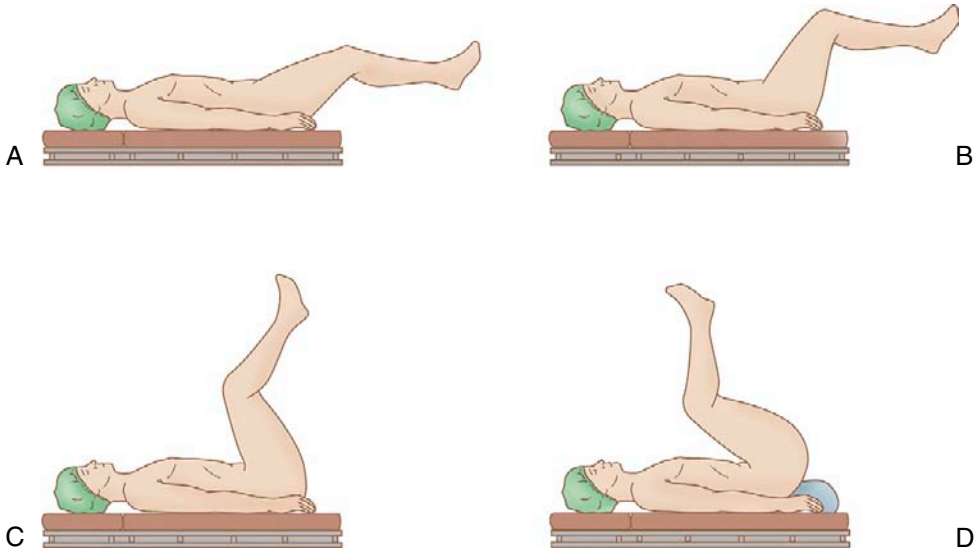


FIGURE 5-16 Four basic types of lithotomy position with progressively increasing leg elevation. **A**, Low. **B**, Standard. **C**, High. **D**, Exaggerated.

Trendelenburg's position should be accomplished slowly and smoothly to avoid overload to the cardiovascular system.

Fracture Bed Position

The orthopedic fracture bed allows the patient to be positioned for hip fracture surgery or closed femoral nailing (Figure 5-15). The patient may be transferred into the OR in the hospital bed with traction applied. The patient is usually anesthetized before transfer to the fracture bed. During transfer, manual traction is often applied to the injured leg. Distal lower extremity pulses should be evaluated before, during, and after positioning on the fracture bed.

The patient is positioned supine with the pelvis stabilized against a well-padded vertical perineal post. Pressure on the genitalia from the perineal post can otherwise injure genital structures. Pressure on the perineal and pudendal nerves can cause fecal incontinence and loss of perineal sensation.

Traction is achieved by restraining the foot of the injured leg in a well-padded, bootlike device that is connected to the traction bar so that the leg may be rotated, pulled into traction, or released, as surgery requires. One method of securing the foot in this device is the use of a boot-shaped cuff that wraps around the entire foot and connects to the traction device. The cuff is inflated with air to secure the foot. Another method is to cushion the foot and secure it to the device with restraining straps, ACE bandages, or a self-adhering wrap. Regardless of the method used, excessive pressure can be placed on the foot and ankle, especially while traction is being applied. Adequate padding must be used. If the boot-shaped cuff is used, care should be taken that it is not inflated beyond the manufacturer's recommendations. The unaffected leg rests on a well-padded, elevated leg holder or is secured in a well-padded, bootlike device. *C*-Arm fluoroscopy examinations can be done during surgery because the unaffected leg is abducted well out of the field.

The arm on the operative side is generally secured over the patient's body in a padded sling or a post-supported arm holder to reduce obstruction of the operative area. Care is taken to avoid pressure on the ulnar nerve. The edges of the sling should not sit on the bend of the elbow. If a post supports the arm holder, the post and arm holder should be distal to the elbow, freeing the cubital tunnel from pressure.

Lithotomy

The lithotomy position is used for gynecologic, rectal, and urologic procedures. With the patient supine, the legs are raised and abducted to expose the perineal region. The legs are placed in stirrups to maintain this position. There are four levels of lithotomy: low, standard, high, and exaggerated (Figure 5-16).

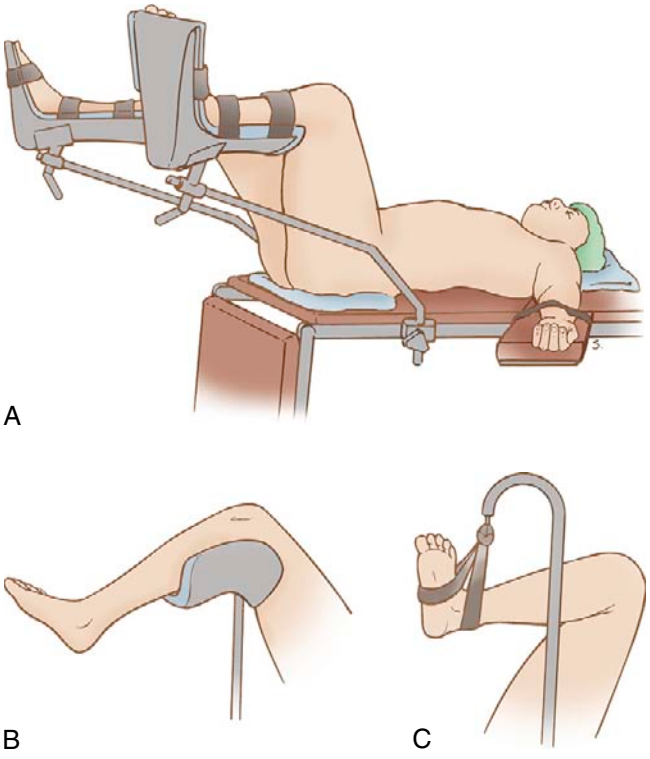


FIGURE 5-17 **A**, Lithotomy position using boot-type stirrups. **B**, Knee-crutch stirrup. **C**, Candy cane stirrup.

Low lithotomy is used for most urologic procedures and for procedures that require access to the perineum and abdomen simultaneously. The thighs are elevated approximately 30 to 45 degrees. *Standard lithotomy* is the most commonly used position for gynecologic procedures. The thighs are flexed approximately 90 degrees from the trunk, and the calves remain horizontal. For improved perineal access, some surgeons prefer a *high lithotomy* position. The thighs are often flexed beyond 90 degrees, and the legs are suspended high toward the ceiling. The *exaggerated lithotomy* position is sometimes used for transperineal access to the retropubic area. This extreme position moves the legs completely out of the way of the surgical field. The thighs are flexed toward the abdomen, the calves are suspended vertically, and the pelvis is flexed vertically at the spine, propped upward on a pillow or pad.

Stirrups are checked before use to ensure they are securely fastened to the side rails of the OR bed. Slippage of the stirrups or dropping of the legs during stirrup adjustments could cause hip dislocation, muscle or nerve injury, or bone fractures. Both stirrups should be at equal height and attached to the OR bed at the same level (Figure 5-17). The legs should be raised simultaneously to prevent strain on the patient's lower back; this requires two people so that both legs are totally supported throughout the move. Each person should grasp the sole of the foot with one hand and support the calf near the knee with the other. The legs are raised and the knees flexed in slow, smooth movements.

When the legs are secured in the stirrups, the mattress of the leg section of the OR bed is removed and the leg section platform is lowered. The buttocks should be even with the edge of the perineal cutout section of the OR bed to reduce the risk of lumbosacral strain.

The arms are supported on armboards (Figure 5-17, *A*), placed across the trunk, or tucked at the patient's side. When the arms are tucked, extreme caution is taken when the leg section of the bed is elevated back to a horizontal position at the conclusion of the procedure. If not, hands and fingers can be caught in the break of the bed and pinched or crushed.

Various types of stirrups are used for lithotomy positioning (Figure 5-17). The most common include posts with knee crutches, candy cane–shaped bars with straps that wrap around the ankles and plantar surface of the foot, and boot-type stirrups that cradle the lower foot and heel, and extend to the midcalf area. The type stirrup used can create unique hazards.

Knee-crutch stirrups (Figure 5-17, *B*), in which the weight of the leg rests solely on knee supports, can cause pressure on the posterior tibial and common peroneal nerves, and the popliteal artery in the popliteal fossa. This pressure predisposes the patient to complications, such as neuropathies and compartment syndrome (Patient Safety).

When using candy cane stirrups (Figure 5-17, *C*), the knees can drop close enough to the vertical stirrup bars that the lateral or medial side of each knee or calf rests against the bars. This can cause pressure on the common peroneal nerve as it curves laterally over the fibula, and this may result in footdrop and a lack of sensation below the knee. If the medial aspect of the knee or calf rests against a stirrup bar, the saphenous branch of the femoral nerve can be compressed against the tibia. Padding the stirrup bars can soften the rigidity of the bars, but does not totally eliminate pressure if the legs rest against the stirrup bars.

The relaxed hips of an anesthetized patient may separate further than they comfortably would if the patient were awake. When the legs hang freely in candy cane stirrups, there is risk of external rotation of the hips and hyperabduction. Hips should not be flexed more than 90 degrees. Exaggerated rotation and flexion can stretch the sciatic and obturator nerves and strain the hip joint and muscles.

When relatively thin ankle straps support the weight of the entire leg, pressure increases on the ankles and distal sural and plantar nerves. Neuropathies of the foot and pressure ulcers at ankle support sites can result. Using wide straps or cradling the feet with gel or foam padding before placing them in the stirrup straps may reduce the localized pressure to the nerves. Heavier leg weight in obese patients adds to the pressure on the ankle supports. Compartment syndrome can be the undesired outcome for a patient kept in high or exaggerated lithotomy position for many hours (Roeder et al, 2005).

Boot-type stirrups (see Figure 5-17, *A*) support the foot and calf, distribute pressure more evenly, and reduce the risk of extreme localized pressure on any one area of the foot or leg. They also allow for controlled and limited abduction.

Special care is needed for the patient who has limited range of motion attributable to a hip prosthesis, cast, amputation, or obesity. Severe hip flexion and abduction of the joint is avoided. The stirrup should be as low as possible and tilted slightly outward. Preexisting lumbar backache can be worsened in this position if the buttocks or lower back is not adequately supported. Several folded towels placed under the lumbar spine before induction of anesthesia can retain lordosis and reduce lower back strain. An exception is the patient with palpable

PATIENT SAFETY

Preventing Compartment Syndrome

Acute compartment syndrome can develop if a surgical position diminishes perfusion to an extremity. This syndrome is characterized by ischemia, hypoxic edema, and elevated tissue pressure within the fascial compartments of the extremity, leading to further damage to muscles and nerves. As this process occurs at a cellular level in tissues, distal pulse rates and capillary refill times may initially appear normal, but then rapidly escalate to a dangerous condition. The syndrome may progress to rhabdomyolysis with resulting renal damage, permanent nerve damage, loss of limb, or even death. The most effective means of terminating this syndrome is a decompressive fasciotomy.

FACTORS THAT CONTRIBUTE TO CAUSING COMPARTMENT SYNDROME

- An armboard strap that is too tight or arms tucked too tightly at the patient's side
- Elevation of an extremity coupled with systemic hypotension
- Compression on an elevated extremity by straps or leg wrappings that are too tight
- Pressure from the weight of an extremity against an edge of a leg-holding device
- Pressure from the arm of a surgical assistant holding an extremity too tightly
- Excessive popliteal pressure from a knee-crutch stirrup
- Prolonged lithotomy position (especially >5 hours)
- Kneeling 90/90 position (prone with hips and knees each flexed at 90 degrees) (Figure 5-23, p. 171)
- Excessive flexion of the knees or hips greater than 90 degrees (knee-chest or "tuck" position; exaggerated lithotomy position)

PREVENTIVE INTERVENTIONS

- Avoid excessively tight straps on extremities.
- Limit time in lithotomy position (especially high or exaggerated lithotomy).
- Place legs in well-padded, adequately supported stirrups, avoiding pressure on calf or popliteal fossa.
- Consider changing from a 90/90 kneeling position to a 45/45 position (Figure 5-24).

Modified from Denholm B: Tucking patient's arm and general positioning, *AORN J* 89(4):755-757, 2009; Edgcombe et al: Anaesthesia in the prone position, *Br J Anaesth* 100(2):165-183, 2008; Leek BT et al: The effect of kneeling during spine surgery on leg intramuscular pressure, *J Bone Jt Surg, Am* 89(9):1941-1947, 2007; Warner MA, Martin JT: Patient positioning. In Barash PG et al, editors: *Clinical anesthesia,* ed 5, Philadelphia, 2006, Lippincott Williams & Wilkins.

tender points in the lumbar region. The pressure of a pad in this area may cause too much distress. Elevating the legs may aggravate the pain of a herniated nucleus pulposus. In each of these situations, the patient may be placed in the lithotomy position before induction to assess areas of discomfort and implement appropriate therapeutic measures before the procedure begins. If the patient will be in this position for longer than 2 hours, SCDs or antiembolic stockings are applied to the patient's legs.

The lithotomy position poses significant risks for respiratory and circulatory compromise. Risks increase as the position is exaggerated for radical surgery of the groin, vulva, or prostate. Extreme flexion of the thighs impairs respiratory function by increasing intraabdominal pressure against the diaphragm, decreasing tidal volume. The elevated legs cause blood to pool in the trunk of the body during the procedure. This effect is greater when hip and knee flexion is extreme, as in high or exaggerated lithotomy positions. Blood loss during surgery may not be immediately noticed because of this increased trunk volume. However, when the legs are lowered and 500 ml or more of blood is diverted to more total leg circulation, circulating volume is reduced, and blood pressure may decrease. Anesthetics affect the nervous system by depressing normal compensatory mechanisms and hemodynamic adjustment may not be achieved easily.

The arms must not impede chest movement and respiration. The weight of the limbs on the chest, especially in infants and children, may fatigue muscles used in respiration and induce respiratory problems. In addition, elevation of the legs pushes abdominal viscera toward the diaphragm. Lowering the head of the bed can exaggerate this shift further as diaphragmatic excursion is reduced.

Releasing the patient from the position must be done slowly and with adequate assistance. The legs must be taken out of the stirrups and lowered simultaneously, with support given to the joints; this helps prevent the lumbosacral musculature from being stretched and strained, which could cause the pelvis and limbs to become unstable. The legs should be lowered slowly to allow for gradual hemodynamic adjustment as more blood shifts into the lower extremities. Distal lower extremity pulses should be evaluated before, during, and after this position.

Semi-Fowler

Semi-Fowler (lawn chair or beach chair) position may be used for some cranial, shoulder, nasal, abdominoplasty, or breast reconstruction procedures. This position is accomplished first with the patient supine. The upper body section of the bed is flexed 45 degrees, and the leg section is lowered slightly, flexing the knees. The arms may rest on a pillow in the lap or be secured on armboards parallel to the OR bed. A footboard may be attached to act as a footrest and prevent footdrop. The entire OR bed is then tilted.

When this position is used for shoulder surgery, the arm of the affected shoulder is prepped and draped to allow for intraoperative shoulder manipulation. The head and cervical spine are aligned and supported to prevent neuromuscular strain. Rotation of the head in the opposite direction of the shoulder the surgeon is manipulating can cause injury to the brachial plexus. A shoulder chair attachment allows for vertical torso support; it also has drop-away shoulder panels, which can be removed on the affected side during shoulder procedures to allow full access to the shoulder. This attachment also includes a padded head restraint, which secures the head from forward and lateral movement while the patient is in semi-Fowler position, and arm supports (Figure 5-18).

Diaphragmatic excursion improves in this position compared with the supine position. Although pressure points

FIGURE 5-18 Shoulder chair with drop-away shoulder support panels to allow surgical access to shoulder while maintaining torso support. Padded U-shaped head restraint with adjustable Velcro straps holds head secure and reduces undue stress on the neck when the back section is positioned.

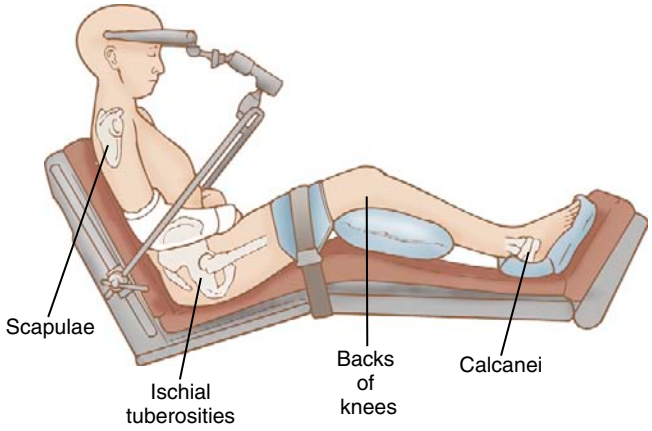


FIGURE 5-19 Potential pressure areas: Fowler's (sitting) position.

remain similar to those of the supine position, additional pressure is placed on the ischial tuberosities, calcanei, and coccyx.

Fowler's

Fowler's (sitting) position is used for some ear and nose procedures and craniotomies involving a posterior or occipital approach (Figure 5-19). This position is accomplished initially with the patient supine. Slowly, the upper body section of the OR bed is raised 90 degrees, while the knees are slightly flexed as the leg section is lowered. A footrest prevents footdrop. The arms either rest in the lap on a pillow with the elbows flexed at 90 degrees or less, or are on padded armboards. The cervical, thoracic, and lumbar sections of the spine are in alignment when the position is established. When this position is used for posterior fossa craniotomy or cranial ventricular procedures, a special craniotomy headrest is used to secure and immobilize the head. (A general discussion of pin fixation of the head is given in the Prone section.)

The main pressure points in Fowler's position include the scapulae, ischial tuberosities, calcanei, and coccyx. Also, pressure increases on the sciatic nerve. Padding is placed at the lumbar area and under the elbows, knees, buttocks, and heels. The popliteal space needs to be checked to ensure that no pressure is sustained from the edge of the mattress at the bottom of the torso section.

This position poses significant circulatory compromises and risks. Blood pooling occurs in the lower torso and legs, which causes significant orthostatic hypotension and diminished perfusion to the brain. Venous return from the lower extremities is impeded and such hindrance causes increased risk of VTE. SCDs or antiembolic stockings are used to support venous return.

With the operative site elevated compared with the heart, gravity causes a negative venous gradient between the operative site and the right atrium; this creates a potential for an air embolism if a venous sinus is opened. During a craniotomy, this potential increases when tissue is dissected free from the cranium, bone removed, the dura tacked up, or a highly vascular tumor bed entered. Additional monitoring for venous air embolism includes insertion of a central venous catheter into the pulmonary artery or right atrium and placement of a Doppler probe over the chest wall. If air embolism is diagnosed, the scrub person irrigates the surgical site quickly with normal saline to prevent further venous aspiration of air into the vein. The exposed area should be packed with saline-soaked sponges or cottonoids. If the air embolism occurred during bone entry, bone wax should be placed immediately over the exposed bone to seal it. The anesthesia provider may aspirate air from the right atrium through the central venous line. The perioperative nurse assists and supports the endeavors of the anesthesia provider and scrub team.

Respirations are probably least impeded in Fowler's position than in any other surgical position. It is important to ensure that if the arms are resting on a pillow in the lap and secured with tape, this position does not restrict chest movement. Flexion of the head and neck is avoided to prevent kinking of the endotracheal tube and subsequent airway obstruction.

When the procedure concludes, repositioning the patient back to supine position is done slowly so that the patient makes hemodynamic adjustments gradually. Distal lower extremity pulses are evaluated before, during, and after this position.

Prone

In the prone position, the patient is lying with the abdomen on the surface of the OR bed mattress (Figure 5-20). Modifications of the position allow approaches to the posterior cranium, posterior spine, rectal area, and dorsal areas of the extremities.

Anesthesia is induced with the patient in supine position, usually on the transport vehicle. Before the patient is turned, the anesthesia provider secures the endotracheal tube with tape, applies eye ointment in each eye, and tapes the eyelids closed to prevent corneal abrasions. The transport vehicle is locked adjacent to the locked OR bed. Four people using the "log-roll" technique can accomplish turning the supine patient to prone position safely, smoothly, and gently. The anesthesia provider supports the head and neck during the turn. A second person stands at the side of the transport vehicle with hands at the patient's shoulders and buttocks to initiate the roll of

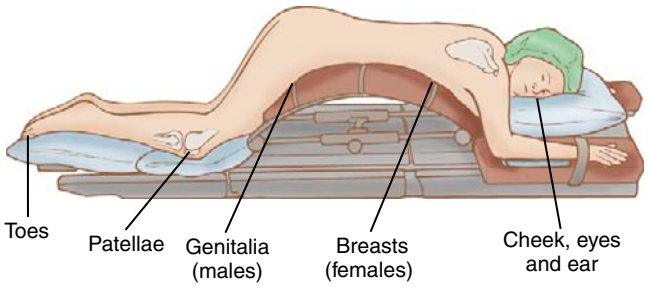


FIGURE 5-20 Wilson frame. Potential pressure areas: prone position using laminectomy frame for spinal procedures.

the patient. A third person stands at the opposite side of the OR bed, with arms extended to support the chest and lower abdomen as the patient is log-rolled laterally onto his or her abdomen. The fourth person stands at the foot of the transport vehicle to support and turn the legs. At the completion of the turn, the transport vehicle is removed.

The perioperative nurse must not allow the patient's arms to hang over the edge of the bed as the radial nerve can be compressed by the weight of the humerus. The arms are placed on armboards or secured at the sides. If the arms are to remain at the patient's side, they should be close to the body and secured with the draw sheet pulled smoothly around the arms and tucked under the patient's body. The elbows face upward in this position, so there is less risk of pressure on the ulnar nerve from the mattress; however, compression still can occur from a draw sheet that is too tight or from scrubbed personnel leaning on the elbow. Padding the elbow minimizes this risk. When the arms are placed on armboards, the arms are brought down and forward slowly, with minimal abduction to prevent shoulder dislocation and brachial plexus injury. Armboards are at the same height as the OR bed or at a lower parallel line to the OR bed, and the arms should rest with elbows flexed and hands pronated. Elbows should not be flexed beyond 90 degrees to avoid stretching the ulnar nerve. Pads should be placed distal and proximal to the elbow so that the ulnar nerve is not in contact with the armboard (see Figure 5-5, *C*). The following pressure points are checked: the cheeks, eyes, ears, female breasts, male genitalia, knees, and toes.

Head Support in Prone Position. Protection of the head and neck while in prone position is extremely important in order to prevent serious complications. Turning the head allows for fair access to the airway and endotracheal tube, and is safe for most patients, provided pressure on the dependent eye is protected (Faust et al, 2005). However, Rozet and Vavilala (2007) note the following concerns with turning the head. Manipulation of the head and neck may lead to mechanical stress on the arteries that supply blood to the brain and spinal cord. The vertebral arteries that pass through the narrow foramina in the transverse processes of the cervical spine can be occluded during extreme head manipulation. Hyperflexion of the head and neck should not exceed a thyromental distance (distance between the thyroid cartilage and chin) of two to three finger-breadths. Head rotation should be limited to a maximum of 45 degrees away from the body. Hyperextension, hyperflexion, lateral flexion, or rotation must be avoided as these can lead to brain stem and cervical spine ischemia, which in turn can result in quadriparesis and quadriplegia. Patients with osteophytes, arthritis, or vascular atherosclerosis are at higher risk of cerebral ischemia from inappropriate head and neck manipulation.

Face pillows and facial helmet devices enable the patient to be positioned with the head facing straight down while the patient is prone, thus in natural spinal alignment. Such devices are either made of foam that is hollowed out to conform somewhat to the contour of the face or are simply foam blocks with cutouts for the eyes, nose, and mouth to prevent pressure to those structures. Openings on the side allow access to the endotracheal tube. Some of these devices are available with mirrors, which enable the anesthesia provider to see the facial structures during the surgery. The weight of the head is supported by the foam at the forehead, cheeks, and chin. These areas must be monitored for signs of pressure. Studies show that interface pressures are lower on devices that contour the face (Atwater et al, 2004; Grisell and Place, 2008).

A horseshoe headrest is another device used to stabilize the head in prone position. This attachment fits onto the OR bed in place of the removable head section. It stabilizes the head by supporting the cheeks and forehead. Its advantage is that the entire head, face, and airway can be accessed and observed by the anesthesia provider without the obstruction of the OR bed. Its disadvantage is that the head is not fixed in place, so that it can move. The head may become unstable during adjustments to the OR bed, which may make it difficult to keep pressure off the eyes (Faust et al, 2005).

Pin fixation of the head (e.g., Mayfield head positioner) is frequently used for craniotomies in prone position (as well as in other positions). The head is supported by three pins that are tightened into the skull. This allows complete stabilization of the head without the risk of pressure to the eyes or other facial structures. However, the tightening of the pins on the scalp has a profound stimulative effect that causes tachycardia and hypertension. Since such a hemodynamic effect could be detrimental, with increased intracranial pressure or cerebral aneurysm, a local anesthetic is injected into the skin before pin fixation (whether the patient is awake or anesthetized). Patients under general anesthesia must have their anesthesia deepened before application of pins (Rozet and Vavilala, 2007). Goodkin and Mesiwala (2004) describe some additional complications. Entering veins within the skull might cause air embolism; therefore the pin sites should be lubricated. Perforation of the skull can occur in patients with thin skulls (especially children) or if the pins are overtightened. Special pins are used for children. Perforation of the skull may injure the middle meningeal artery, causing an epidural hematoma or a middle meningeal arteriovenous fistula. In patients who have had previous cranial surgery or shunts, care is taken not to reenter previous pin or bur hole sites, or craniotomy plates, and not to puncture a shunt valve or tubing.

A risk implicit with both the horseshoe headrest and the pin fixation device is inadvertent dropping of the head before it is stabilized in the device. The head is held by one person until it is secured in the device. The person holding the head should have no other responsibility until it is secured in the positioning device.

The respiratory system is most vulnerable in the prone position because normal anterior lateral respiratory movement is restricted, and the compressed abdominal wall and rib

FIGURE 5-21 Axis Jackson® system uses hinged technology to position the patient in various prone and semikneeling positions for spinal surgery.

cage inhibit normal diaphragmatic movement. This position requires ventilator assistance and chest support.

When placed in prone position, the patient is placed on a laminectomy frame (such as a Wilson frame, pictured in Figure 5-20), on a special prone spinal frame (Figure 5-21), or on chest rolls that extend lengthwise from the acromioclavicular joint to the iliac crest. These positioning devices raise the chest and permit the diaphragm to move more freely so the lungs may expand. They reduce intraabdominal pressure by allowing some open space for the abdomen. Pressure on the inferior vena cava also lessens. This in turn reduces blood loss by decreasing epidural venous pressure. Supports must not press against male genitalia. Female breasts should be angled toward the sternum to reduce stretching or compression. These areas are checked after final positioning to ensure that they are free from pressure. A bolster or pillow under the pelvis can decrease abdominal pressure on the inferior vena cava, especially in obese patients with large abdominal girths. A cushion or pillow is placed under the ankles to prevent pressure on the toes. The safety strap is placed across the dorsal aspects of the thighs so that the patient is secured but superficial venous return is not impaired.

Prone positioning can be initially hazardous when the anesthetized patient is turned from supine to prone position. Endotracheal tubes, intravenous lines, and monitoring devices may dislodge easily. Normal compensatory mechanisms are depressed and the patient cannot readily adjust to imposed hemodynamic changes and the resulting hypotension. Goodkin and Mesiwala (2004) discuss three types of complications associated with prone position. The first is trauma. Crush injuries can occur to the extremities during the roll from supine to prone and back. Pressure necrosis can occur to the skin, peripheral nerves, and brachial plexus. Pressure on the eyes can cause blindness (see Research Highlight: Vision Loss Associated with Prone Positioning). The second is venous air embolism, which can occur when the surgical site is above the level of the heart. The third is associated with anesthesia administration. If an airway problem occurs as a result of a kinked, dislodged, or obstructed endotracheal tube, reintubation and emergency airway management are extremely difficult from this position. Also, the dependent position may cause swelling of the tongue, resulting in macroglossia.

The Wilson frame (pictured in Figure 5-20) is useful during spinal decompression because it can arch the back, reversing the effects of normal lumbar lordosis, and be adjusted to cause the lumbar intralaminal spaces to open. The Jackson spinal surgery bed is also used in many hospitals for posterior spinal surgery when the opposite positioning effect is needed. For example, when screws, plates, or rods are placed in the patient's spine for fusion, a normal physiologic alignment of the spine is required. The torso rests on a chest pad and two hip pads, allowing the abdomen to hang free with the back straight. The legs are either supported on a flat platform or flexed and supported by a sling. A hinged spinal frame (Figure 5-21) can be used, rather than the Wilson or Jackson frames, as it allows the back to be either arched or flat. There are special positioning considerations when using all spinal frames, such as avoiding hyperextension of the shoulders, which can compress the brachial plexus. Manufacturer's guidelines must be followed meticulously.

Returning the patient to supine position onto the PACU stretcher requires a four-person log-roll technique. If a laminectomy frame was used, it can be tilted in the direction of the stretcher to initiate the move. Skin integrity is checked over all pressure point areas. Distal extremity pulses are evaluated before, during, and after prone positioning.

Jackknife

The jackknife or Kraske position is a modification of the prone position often used for hemorrhoidectomy and pilonidal sinus procedures (Figure 5-22). The patient's hips are placed on a bolster or pillow over the break in the lumbar

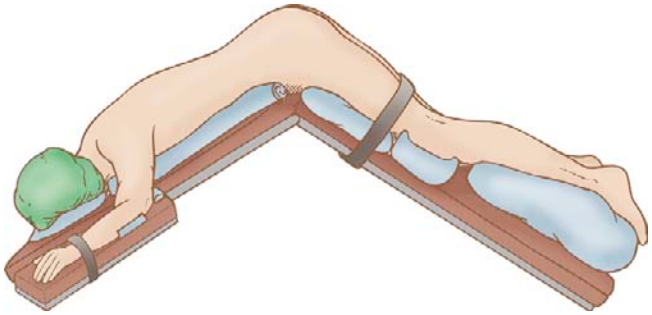


FIGURE 5-22 Jackknife (Kraske) position.

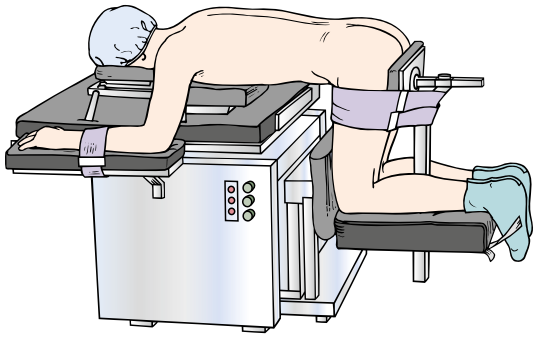


FIGURE 5-23 Frame for supporting patient in 90/90 kneeling position for spinal surgery.

section of the OR bed and the bed is flexed at a 90-degree angle, raising the hips and lowering the head and trunk. The patient's head, chest, and feet need the usual prone supports in this position. Chest rolls placed from under each shoulder to the iliac crest relieve pressure on the brachial plexus from the clavicle. A pillow is placed under the lower legs to prevent pressure on the toes. The safety strap is placed across the posterior thighs.

For anal procedures, the buttocks may be separated with strips of 3-inch tape secured firmly at the level of the anus a few inches from the midline on either side. These strips are pulled tight simultaneously and then fastened to the underside of the bed surface. The strips are released at the end of the procedure to facilitate wound closure.

This position causes circulatory changes because the head and the feet are in dependent positions, causing cephalad and caudad venous pooling. SCDs or antiembolism stockings assist in venous return and decrease the risk of VTE.

Respirations are severely compromised because anterior lateral chest movement is restricted. In addition, pressure is exerted on the diaphragm from the abdominal viscera and that stress worsens with pressure from the flexed OR bed.

When the procedure is completed, the OR bed is straightened very slowly so that the body can adjust hemodynamically. Four people use the log-roll technique to turn the patient supine. Distal lower extremity pulses are evaluated before, during, and after this position.

Kneeling and Knee-Chest

The kneeling and knee-chest ("tuck") positions are used primarily for spinal surgery such as thoracic and lumbar laminectomy and diskectomy (Figure 5-23). The kneeling position requires an extension of the prone position in which the hips and knees are both flexed about 90 degrees. The knee-chest position flexes the hips and knees greater than 90 degrees. The advantage of this position is that it enables the abdomen to hang free, reducing pressure on the abdomen and inferior vena cava. This eases ventilation and reduces bleeding by minimizing pressure on the epidural veins. It also provides good exposure of the posterior spine.

SCDs or antiembolism stockings are placed on the patient, and induction and intubation are performed with the patient supine on the transport vehicle. Transferring the anesthetized patient into kneeling position requires the coordinated effort of at least four people in the manner described for prone position; the knees, however, must be placed gently on a well-padded support platform. A safety strap is placed around the posterior area of the thighs, avoiding compression of the nerves and vessels in the popliteal fossa (St-Arnaud and Paquin, 2008). The knees and chest bear the weight of the body. Various frames are designed to support the patient in this position. Stabilization of the hips and buttocks is provided either by lateral supports on both sides of the hip or by a posterior support at the back of the buttocks. All manufacturers' instructions for safe positioning of the patient in a particular frame are followed to avoid some of the potential complications associated with this position.

Pressure points are a vital consideration for this position. They include the eyes, ears, chin, anterior rib cage, female breasts, anterior iliac crests, male genitalia, anterior tibial aspects of the calves, dorsal feet, toes, and knees. All of these areas need to be well padded and supported. Pedal and radial pulses are assessed before, during, and after positioning to ensure adequate perfusion of all four extremities.

Complications associated with this position are similar to those for prone position, but with added concern for the effects of legs being lower than the body and the weight of the hips and thighs resting on bent knees. The knees are under significantly more pressure than in any other position. Injury to the knee joints and necrosis to the skin and muscles around the knee may result. Hypotension occurs because of the pooling of blood into the lower extremities. This can be somewhat counteracted by the use of SCDs or antiembolism stockings. However, the longer this position is maintained, the higher is the risk for thrombosis and pulmonary embolism. Also, compartment syndrome and rhabdomyolysis (with associated renal damage) have been reported as complications, particularly when the knees are more deeply flexed as in the knee-chest or "tuck" position (see Patient Safety: Preventing Compartment Syndrome). These risks increase in the obese patient (Leek et al, 2007; Edgecombe et al, 2008). A 45/45 suspended position (i.e., hips and knees flexed at 45 degrees and legs suspended in a sling) may mitigate the risk of compartment syndrome for procedures that require a kneeling or knee-chest position (Leek et al, 2007). A modular OR bed system uses a hinged frame to place the patient in a 45/45 suspended prone position (see Figure 5-21), which offers the surgical access benefits of the kneeling position while limiting some of its associated risks. This bed system allows access for C-arm fluoroscopy and can accommodate patients in various other positions as well.

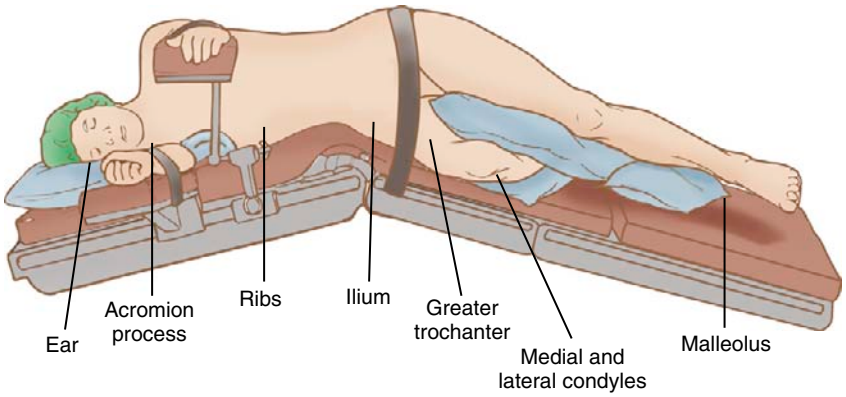


FIGURE 5-24 Potential pressure areas: lateral kidney position.

Lateral

In the lateral (lateral recumbent, lateral decubitus, or Sims) position, the patient lies on the nonoperative side, providing access to the upper chest, kidney (Figure 5-24), or upper section of the ureter. Reference to right or left lateral position relates to the side on which the patient lies. That is, in the right lateral position, the patient lies with the right side down. In left lateral, the patient is positioned with the left side down.

After induction of anesthesia, with the patient supine on the OR bed, the patient is turned to the side. A four-person team uses a draw sheet that is under the patient to facilitate a safe, smooth, gentle turn so that the nonoperative side is down.

A pillow or cushion is placed under the patient's head to maintain good alignment with the cervical spine and the thoracic vertebrae; this alignment also helps to minimize stretching of the dependent brachial plexus. The bottom leg is flexed at the knee and hip to stabilize the patient on the bed. The top leg is straight or slightly flexed. A pillow is placed lengthwise between the patient's legs. The lateral aspect of the bottom knee is padded to prevent pressure on the common peroneal nerve, located superficially at the head of the fibula. A person should remain at the patient's front and back to steady and support the torso during positioning of the lower extremities.

Pillows, rolled blankets, padded kidney braces, or a surgical positioning system (sometimes referred to as a Vac-Pac, or beanbag) support the torso. A beanbag is a soft pad filled with tiny beads. When suction is attached to a port on the pad, it conforms to the shape of whatever it encircles. A valve is closed to maintain the vacuum. It acts as an immobilizer until air is reintroduced, at which time it softens back into its original shape. While it is rigid, it increases the interface pressures of all tissue it contacts and the risk of pressure ulcer development increases. Large gel pads placed between the beanbag and the skin reduce, but do not eliminate, this risk.

The shoulders, hips, and legs may be secured with wide tape fastened to the platform of the OR bed. The upper arm is placed on an elevated armboard or rests on a pillow in front of the patient. The lower arm is flexed and rests on an armboard. The lower shoulder is brought slightly forward and an axillary roll placed under the rib cage, posterior to the axilla. This places the weight of the chest on the rib cage instead of compressing the lower shoulder and axilla, which otherwise may injure the brachial plexus of the dependent arm. Radial pulses and pulse oximetry are monitored to confirm adequate circulation in the dependent hand and arm. The axillary roll is typically made of rolled linen, a cylindrical gel pad, or a 1-L bag of IV fluid wrapped with linen. There have been reports of pressure ulcers occurring on the dependant thorax after the use of wrapped IV fluid as an axillary roll during shoulder surgery (Keyurapan et al, 2007). Speculation suggests that movement of patients during shoulder surgery may have caused friction and shearing forces on the thorax from the wrapped bag of fluid. This may have been further exacerbated by leakage of fluid from the arthroscopy field down onto the nonoperative dependent chest. The authors recommended that a towel or folded sheet be used in place of the bag of fluid and that care be taken to divert any fluid onto the nonoperative site.

Systolic and diastolic pressures decrease in the lateral position because pharmacologic agents and pathophysiologic processes depress normal compensatory mechanisms. The patient may not readily compensate for abrupt postural changes. Respiratory function is also compromised by the weight of the body on the lower chest, limiting its movement. Distal extremity pulses are evaluated before, during, and after this position and its modifications.

Lateral Chest

The lateral chest position allows an operative approach to the uppermost part of the thoracic cavity. The upper arm is flexed slightly at the elbow and raised above the head to elevate the scapula, to provide access to the underlying ribs, and to widen the intercostal spaces. The uppermost arm may be supported on a raised armboard or pillow. Slanting the upper section of the bed downward places the trachea and mouth at a level lower than the lungs—a position that enables bronchial secretions and fluids from the lung bases to drain into the mouth and not pass into the unaffected side of the chest.

A respiratory effect of this position is that the dependent lung is more perfused because gravitational pooling of blood occurs. The nondependent lung is more easily ventilated, however, because it is less compressed. This results in a ventilation-perfusion mismatch. The anesthesia provider applies positive end-expiratory pressure (PEEP) to both lungs to compensate for this decrease in functional lung capacity.

Lateral Kidney

The lateral kidney position (see Figure 5-24) allows approach to the retroperitoneal area of the flank. While being turned from supine to lateral position, the anesthetized patient is positioned so that the lower iliac crest is just below the lumbar break where the kidney bridge is located. To render the kidney region readily accessible, the kidney bridge is raised, and the bed flexed so that the area between the twelfth rib and the iliac crest is elevated. Raising the kidney bridge depends on the cardiovascular response of the body to increased pressure. The bridge must be raised slowly and blood pressure monitored frequently by the anesthesia provider. The bed is flexed to lower the patient's head and legs. The patient's affected side presents a straight horizontal line from shoulder to hip. In this position, the gravitational force on the head and torso opposes that on the extended limb to facilitate operative exposure.

Diaphragmatic movement is limited by increased intraabdominal pressure from the kidney bridge and by flexion of the lower limbs toward the abdomen. Both the acute angulations of the body in the lateral kidney position and gravity may decrease blood return to the right side of the heart.

To stabilize the torso, well-padded kidney braces may be used. The longer brace is placed anteriorly, against the iliac crest. The shorter one is placed against the back. Wide adhesive tape is placed across the hips and secured to the undersides of the OR bed. Before wound closure, the adhesive strap is released, the kidney bridge lowered, and the bed straightened to facilitate approximation of wound edges.

REFERENCES

Agency for Healthcare Research and Quality: AHRQ Supported Clinical Practice Guideline. No. 3: Pressure ulcers in adults: prediction and prevention, No. 2: Clinical Practice Guideline. Health Services/Technology Assessment Text, available at www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=hstat2.section. 4521. Accessed January 19, 2009.

American Society of Anesthesiologists Task Force on Perioperative Blindness: Practice advisory for perioperative visual loss associated with spine surgery, *Anesthesiology* 104(6):1319–1328, 2006.

Association of periOperative Registered Nurses (AORN): Recommended practices for positioning the patient in the perioperative practice setting. In *Perioperative standards and recommended practices*, Denver, 2009, The Association.

Aronovitch SA: Intraoperatively acquired pressure ulcers: are there common risk factors? *Ostomy Wound Manage* 53(2):57–69, 2007.

Atwater BI et al: Pressure on the face while in prone position: ProneView™ versus Prone Positioner™, *J Clin Anesth* 16:111–116, 2004.

Barnett JC et al: Laparoscopic positioning and nerve injuries, *J Minim Invasive Gynecol 14* :664–672, 2007.

Black J et al: National Pressure Ulcer Advisory Panel's updated pressure ulcer staging system, *Dermatol Nurs* 19(4):343–349, 2007.

Braden BJ, Maklebust J: Preventing pressure ulcers with the Braden Scale, *Am J Nurs* 105(6):70–72, 2005.

Burnett MG, Zager EL: Pathophysiology of peripheral nerve injury: a brief review, *Neurosurgery Focus* 16(5):1–7, 2004.

Beyea SC: Preventing falls in perioperative settings, *AORN J* 81(2): 393–395, 2005.

Centers for Medicare & Medicaid Services: CMS improves patient safety for Medicare and Medicaid by addressing never events, August 4, 2008, available at www.cms.hhs.gov/apps/media/press/factsheet.asp?Counter=3224. Accessed on January 26, 2009.

Denholm B: Tucking patient's arm and general positioning, *AORN J* 89(4):755–757, 2009.

Devlin VJ, Schwartz DM: Intraoperative neurophysiologic monitoring during spinal surgery, *J Am Acad Orthop Surgery* 15(9):549–560, 2007.

Dunn D: Preventing perioperative complications in an older adult, *Holist Nurs Pract* 19(2):54–59, 2005.

Edgecombe H et al: Anaesthesia in the prone position, *Br J Anesth* 100(2): 165–183, 2008.

Faust RJ et al: Patient positioning, In Miller RD, editor: *Miller's anesthesia,* ed 6, vol. 1, Philadelphia, 2005, Saunders.

Fleisher LA, editor: *Anesthesia and uncommon diseases*, ed 5, Philadelphia, 2006, Saunders.

Goodkin R, Mesiwala A: General principles of operative positioning. In Winn HR, editor: *Youmans neurological surgery,* ed 5, vol. 1, Philadelphia, 2004, Saunders.

Grisell M, Place H: Face tissue pressure in prone positioning: a comparison of three face pillows while in prone position for spinal surgery, *Spine J* 7(5):84S–85S, 2008.

Irvin W et al: Minimizing the risk of neurologic injury in gynecologic surgery, *Obstet Gynecol* 103(2):374–382, 2004.

Keyurapan E et al: Pressure ulcers of the thorax after shoulder surgery, *Knee Surg Sport Traumatol Arthrosc* 15:1489–1493, 2007.

Labrom RD et al: Clinical usefulness of somatosensory evoked potentials for detection of brachial plexopathy secondary to malpositioning in scoliosis surgery, *Spine* 30(18):2089–2093, 2005.

Leek BT et al: The effect of kneeling during spine surgery on leg intramuscular pressure, *J Bone Joint Surg Am* (9):1941–1947, 2007.

National Pressure Ulcer Advisory Panel: Pressure Ulcer Stages Revised by NPAUP, February 2007, available at www.npuap.org/pr2.htm. Accessed January 19, 2009.

Nixon J et al: Skin alterations of intact skin and risk factors associated with pressure ulcer development in surgical patients: a cohort study, *Int J Nurs Stud* 44:655–663, 2007.

O'Connell MP: Positioning impact on the surgical patient, *Nurs Clin North Am* 41:173–192, 2006.

Ogunnaike BO, Whitten CW: Anesthesia and obesity, In Barash PG, et al, editors: *Clinical anesthesia*, ed 5, Philadelphia, 2006, Lippincott Williams & Wilkins.

Perioperative Grand Rounds: The inside of a time out, *AORN J* 89(4):808, 2009:808, 656.

Roeder RA et al: Heel and calf capillary-support pressure in lithotomy positions, *AORN J* 81(4):821–830, 2005.

Rozet I, Vavilala MS: Risks and benefits of patient positioning during neurosurgical care, *Anesthesiol Clin* 25(3):631–653, 2007.

Schultz A: Predicting and preventing pressure ulcers in surgical patients, *AORN J* 81(5):985–1012, 2005.

Scott EM, Buckland R: Pressure ulcer risk in the perioperative environment, *Nurs Stand* 20(7):74–86, 2005.

Scott EM et al: Effects of warming therapy on pressure ulcers—a randomized study, *AORN J* 73(9):921–938, 2001.

Sewchuk D, Padula C, Osborne E: Prevention and early detection of pressure ulcers in patients undergoing cardiac surgery, *AORN J* 84(1):75–96, 2006.

St-Arnaud D, Paquin MJ: *Safe positioning for neurosurgical patients: AORN* 87(6):1156–1168, 2008.

Tuncali BE et al: Radial nerve injury after general anaesthesia in the lateral decubitus position, *Anaesthesia* 60(6):602–604, 2005.

Walick KS et al: Changes in intraocular pressure due to surgical positioning: studying potential risk for postoperative vision loss, *Spine* 32(23):2591–2595, 2007.

Walton-Geer PS: Prevention of pressure ulcers in the surgical patient, *AORN J* 89(3):538–548, 2009.

Warner MA, Martin JT: Patient positioning. In Barash PG et al: *Clinical anesthesia*, ed 5, Philadelphia, 2006, Lippincott Williams & Wilkins.

Winfree CJ, Kline DG: Intraoperative positioning nerve injuries, *Surg Neurol* 63:5–18, 2005.

CHAPTER 6

Sutures, Needles, and Instruments

CHARLOTTE GUGLIELMI and SHEILA HUNTER

SUTURE MATERIALS

The development of surgical sutures has been closely associated with the development of the art of surgery. Medical writings of ancient Egyptian and Assyrian cultures dating back to 2000 BC mention the various materials used, to a limited extent, for suturing and ligating. The concept of suturing and ligating also is recorded in the writings of the father of medicine, Hippocrates (born 460 BC). Gut of sheep intestines was first mentioned as suture material by the ancient Greek physician Galen. The Persian physician and philosopher Rhazes is credited with employing surgical gut, or catgut, in AD 900 for suturing abdominal wounds. However, the word *catgut* is a misnomer, and its use is inappropriate. According to the *Oxford English Dictionary,* it refers to the Dutch word *kattedarm,* "cat-intestine." Use of the term *catgut* was adopted by the English around 1560 to 1600 under obscure conditions, possibly connected humorously with caterwauling (History box).

Suture is a generic term for all materials used to sew severed body tissues together and to hold these tissues in their normal position until healing takes place; to *suture* is to stitch together cut or torn edges of tissue (*Mosby's Medical Dictionary,* 2008). A *ligature* is a strand of suture material used to tie off (seal) blood vessels for the prevention of minor bleeding, or to isolate a mass of tissue for excision (cut out). A variety of suture materials are available for ligating, suturing, and closing the wound. The choice of suture takes into consideration several characteristics, such as the following: absorbable versus nonabsorbable, tensile strength, monofilament or multifilament, ease of knot-tying, and reactivity with tissue. An understanding of the characteristics of suture materials, knowledge of the risk factors of wound healing, and awareness of the interactions between tissues and suture materials are essential for proper wound healing. This is important information for all members of the perioperative team.

Characteristics of Suture Material

Key features used to evaluate the general properties of suture material are (1) physical characteristics, (2) handling characteristics, and (3) tissue-reaction characteristics (Box 6-1). The ideal suture material is one that causes minimal inflammation and tissue reaction while providing maximal strength during the lag phase of wound healing (see Chapter 8). Although the ideal suture has not yet been discovered, perioperative nurses should both evaluate the characteristics of suture to determine the ideal choice for surgical patient care and incorporate research findings into their clinical practice.

Physical Characteristics. Physical characteristics of sutures are defined and described by the *United States Pharmacopeia (USP),* which is the official compendium for suture manufacture. Characteristics can be measured or visually determined and include the following properties:

- *Physical configuration:* Suture material can be single-stranded (monofilament) or multi stranded (multifilament), containing numerous fibers rendered into a single thread by twisting or braiding (Figure 6-1).
- *Capillarity:* This is defined as the ability to transmit fluid along the strand.
- *Diameter (size):* Size is measured in millimeters, and expressed in USP sizes with zeroes. That is, the smaller the cross-sectional diameter, the more zeroes; sizes range from #7, the largest, to 11-0, the smallest. Suture sizes 0 to 4-0 are the most commonly used sutures in general surgery. (The surgeon usually selects the finest suture possible for the tissue being closed. The finer diameter [smaller size] provides better handling qualities and small knots. Improved suturing techniques are possible with sutures of finer diameter.)
- *Tensile strength:* This is defined as the amount of weight (breaking load) necessary to break a suture (breaking strength); it varies according to the type of suture material (Table 6-1).
- *Knot strength:* The force necessary to cause a given type of knot to slip, either partially or completely, is the knot strength.
- *Elasticity:* This is defined as the suture's inherent ability to regain original form and length after having been stretched.
- *Memory:* Memory is the capacity of a suture to return to its former shape after being re-formed, as when tied; high memory yields less knot security.

Handling Characteristics. Handling characteristics of suture material are related to pliability (how easily the material bends) and the coefficient of friction (how easily the suture slips through tissue and can be tied). A suture with a high friction coefficient tends to drag through tissue. It is more difficult to tie because its knots do not set easily. Some suture materials are coated to reduce their coefficient of friction. This coating not only improves the way they pull through tissue on insertion but also lessens the force needed to remove the suture after the wound is healed. The coefficient of friction should not be too low, however, because then knots will be loosened too easily.

Tissue-Reaction Characteristics. Because it is a foreign substance, all suture materials cause some tissue reaction. Tissue reaction begins when the suture inflicts injury to the tissue during insertion. In addition, tissue reacts to the suture material itself (Table 6-2). This reaction begins with an infiltration of

HISTORY

The Evolution of Suturing Materials in Surgery

During the sixteenth century, Ambrose Paré reintroduced the use of ligatures to stop hemorrhage and abandoned the use of cauterizing hooks. Subsequently the nurse in the OR became responsible for the time-consuming task of preparing suture material. The following are references to suture and its preparation (or removal from the operative wound) as chronicled in select nursing and medical textbooks.

Year	Breakthrough
1879	Sutures are composed of various materials and are applied in many different ways, according to circumstance. Some surgeons prefer hempen thread or silk; others prefer an animal membrane, such as catgut; and others prefer a fine wire. The advantages claimed for the last-mentioned are that it does not irritate the tissues, and that it does not absorb the secretions.
1890	The method most commonly used by surgeons for the arrest of hemorrhage from an artery of any size is ligation. The artery is picked up by a pair of forceps, and a ligature is tied firmly about it. Ligatures should be about 18 inches long. A ligature is most often made of strong, soft silk, although catgut or wire is sometimes used. Its strength should be tested well, so as to leave no chance of its breaking when strained.
1918	Catgut is wound evenly on glass spools, 1 yard of catgut on each spool, and each spool is placed in a glycerin-jelly jar. Each jar is filled with absolute alcohol; the cap is lightly screwed on; and the jars are placed, cap down, in a 2-quart glass jar and covered with absolute alcohol. The glass jar is placed in a water bath on a gas stove…at a distance from the flame…. The catgut is boiled in alcohol three successive times for 1 hour at intervals of 24 hours.
1961	Skin sutures (black silk thread, fine wire, or metal skin clips) are removed from abdominal wounds on about postoperative day 7, from head and neck wounds on about postoperative day 3 to 5, and from wounds of the extremities on postoperative day 8 to 10. Retention sutures composed of heavy wire and passed deep into muscle tissue usually are not removed until postoperative day 14 to 21. Most patients are apprehensive when they know the sutures are to be removed.
1961	The ligatures used in a surgical operation are of two main kinds: absorbable and nonabsorbable. Absorbable sutures are made of catgut, which is prepared from the muscle coat in the wall of the sheep's intestine. Catgut is now provided already sterilized in ampoules that are stored in antiseptic solution and have to be broken open at the time they are required. When the ampoule is opened, the catgut must be rinsed in warm sterile saline or water to remove the fluid in which it is preserved. This fluid has a penetrating odor because of the cresol in it.
1971	Skin stitches, Mersilene or nylon, are removed when the wound has healed, usually on postoperative day 8 to 10. It is advisable to remove alternate stitches on one day and the remainder the next day if the wound is sound.
1972	The word *catgut* is a misnomer. The Arabic word *kit* means a "dancing master's fiddle," but the word *catgut* has no relation to a cat.

Modified from Ballinger WF et al: *Alexander's care of the patient in surgery,* ed 5, St Louis, 1972, Mosby; Clarke WF: *A manual of the practice of surgery,* New York, 1879, William Wood & Co; Fowler RS: *The operating room and the patient,* ed 3, Philadelphia, 1918, Saunders; Moroney J: *Surgery for nurses,* ed 12, Baltimore, 1971, Williams & Wilkins; Shafer KN et al: *Medical-surgical nursing,* ed 2, St Louis, 1961, Mosby; Taylor S, Worrall O: *Principles of surgery and surgical nursing,* London, 1961, The English Universities Press Ltd; Weeks CS: *Textbook of nursing,* New York, 1890, Appleton.

BOX 6-1

Characteristics of Suture Material

PHYSICAL CHARACTERISTICS
Physical configuration
Capillarity
Fluid absorption ability
Diameter (caliber; also referred to as size)
Tensile strength
Knot strength
Elasticity
Plasticity
Memory

HANDLING CHARACTERISTICS
Pliability
Tissue drag (related to the coefficient of friction)
Knot tying (related to the coefficient of friction)
Knot slippage (related to the coefficient of friction)

TISSUE-REACTION CHARACTERISTICS
Inflammatory and fibrous cell reaction
Absorption
Potentiation of infection
Allergic reaction

Modified from *Ethicon wound closure manual,* Sommerville, NJ, 2004, Ethicon, available at www.jnjgateway.com. Accessed July 12, 2009.

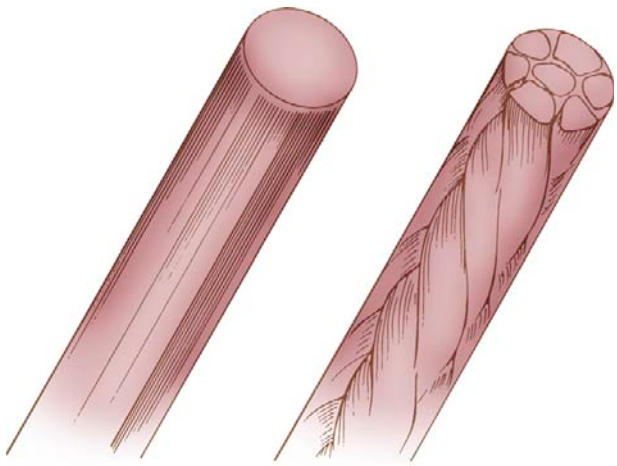


FIGURE 6-1 *Left,* Monofilament suture; *right,* multifilament (braided) suture.

white blood cells into the area; macrophages and fibroblasts then appear; and by about the seventh day, fibrous tissue with chronic inflammation is present. The reaction persists until the suture is encapsulated (nonabsorbable material) or absorbed (absorbable material) by the body.

TABLE 6-1

Relative Straight-Pull Tensile Strength of Suture Materials

	Greatest → Least						
Nonabsorbable	Steel	Polyester (Mersilene)	Nylon (monofilamentous)	Nylon (braided)	Polypropylene (Prolene)	Silk	
Absorbable		Polyglycolic	Polyglactin 910 (Vicryl)		Polydioxanone (PDS)	Poliglecaprone (Monocryl)	Catgut

Modified from *Ethicon wound closure manual,* Sommerville, NJ, 2004, Ethicon, available at www.jnjgateway.com. Accessed July 12, 2009.

TABLE 6-2

Relative Tissue Reactivity to Sutures

	Greatest → Least					
Nonabsorbable		Silk, cotton	Polyester coated	Polyester uncoated	Nylon	Polypropylene (Prolene)
Absorbable	Catgut		Polyglactin 910 (Vicryl)	Polyglycolic acid	Poliglecaprone (Monocryl)	

Modified from *Ethicon wound closure manual,* Sommerville, NJ, 2004, Ethicon, available at www.jnjgateway.com. Accessed July 12, 2009.

TABLE 6-3

Comparison of Absorbable Sutures

Ethicon	Syneture (U.S. Surgical)	Package Color	Configuration	Tensile Strength	Absorption Rate
Surgical gut (plain)	Plain gut	Yellow	Twisted	0% at 2-3 wk	Unpredictable (12 wk)
Surgical gut (chromic)	Chromic gut	Tan	Twisted	0% at 2-3 wk	Unpredictable (12 wk)
Vicryl Rapide (polyglactin 910)		Violet	Braided	0% at 14 days	Complete at 42 days
	Caprosyn (polyglytone 6211)	Pink	Monofilament	0% at 21 days	Complete at 56 days
Monocryl (poliglecaprone)		Rose	Monofilament	20-30% at 2 wk	Complete in 91-119 days
	Dexon S (polyglycolic acid)	Gold	Braided or monofilament	20% at 3 wk	Complete in 60-90 days
	Polysorb (polyester)	Violet	Braided	30% at 3 wk	Complete in 56-70 days
	Dexon II (polycaprolate)	Gold	Braided	35% at 3 wk	Complete in 60-90 days
	Biosyn (polydioxanone)	Red	Monofilament	40% at 3 wk	Complete in 90-110 days
Vicryl (polyglactin 910)		Violet	Braided or monofilament	50% at 3 wk	Complete in 56-70 days
PDS (polydioxanone)		Black	Monofilament	60% at 3 wk	Complete within 6 mo
	Maxon (polyglyconate)	Black	Monofilament	Excellent until 6 wk	Complete within 6 mo

Modified from *Ethicon wound closure manual,* Sommerville, NJ, 2004, Ethicon, available at www.jnjgateway.com. Accessed July 12, 2009; *Syneture absorbable suture,* available at www.syneture.com/syneture/pagebuilder.aspx?topicID=319&xsl=xsl/absorptionPage.xsl. Accessed July 12, 2009.

Types of Suture Material

Suture materials are classified into two broad groups: *absorbable* and *nonabsorbable*.

Absorbable Sutures. The USP defines an absorbable surgical suture as follows: …sterile, flexible strand prepared from collagen derived from healthy mammals, or from a synthetic polymer…. It is capable of being absorbed by living mammalian tissue but may be treated to modify its resistance to absorption…. It may be modified with respect to body or texture. It may be impregnated with a suitable coating, softening, or antimicrobial agent. It may be colored by a color additive approved by the federal Food and Drug Administration.

Absorbable sutures can be digested (by enzyme activity) or hydrolyzed (broken down by reaction with water in tissue fluids) and assimilated by the tissues during the healing process. Absorbable sutures vary in treatment, color, size, packaging, and resistance to absorption, according to their purpose. Types of absorbable suture include plain or chromic surgical gut, collagen, and glycolic acid polymers (Table 6-3).

SURGICAL GUT. Surgical gut is obtained from the collagen of the submucosal layer of the small intestine of sheep or the intestinal serosa of cattle or hogs. The processed strands or ribbons of collagen are either untreated (plain, type A) or treated with chromium salts (chromic, type C).

Chromatization delays absorption of the suture in living mammalian tissue. The strength of the chromium salt content and the duration of the chromatizing process are accurately controlled and tested. Proper chromatizing of gut ensures the integrity of the suture and maintenance of its strength during the early stages of wound healing. It enables a wound with slow healing power to heal sufficiently before the suture is entirely absorbed.

The elaborate processes of mechanical and chemical cleaning of the raw gut are followed by sterilization, usually with ionizing radiation, and storage in hermetically sealed packages. Modern manufacturing processes also ensure tensile strength, more controlled absorption, and more predictable results.

Absorption occurs by digestion of the gut by tissue enzymes. The absorption rate of surgical gut is influenced by the type of body tissue it contacts and, to some extent, by the patient's general physical condition. Studies also show that surgical gut is absorbed faster in serous or mucous membranes than in muscular tissues. When fine chromic gut is properly buried in successive layers of the gastrointestinal tract, it retains its strength long enough for primary union to take place.

Degradation	Tissue Reactivity	Handling	Knot Security	Contraindications
Proteolytic	Moderate	Fair	Poor	Not used where extended approximation of tissue under stress is required. Not used in patients with known allergies or sensitivities to collagen or chromium
Proteolytic	Moderate	Fair	Fair	Not used where extended approximation of tissue under stress is required. Not used in patients with known allergies or sensitivities to collagen or chromium
Hydrolytic	Minimal	Excellent	Good	Not used where extended approximation of tissue under stress is required or where wound support beyond 7 days is required
Hydrolytic	Minimal	Excellent	Excellent	Not used where extended approximation of tissue is required. Not for use in cardiovascular surgery, neurologic surgery, microsurgery, or ophthalmic surgery
Hydrolytic	Minimal	Excellent	Good	Not used where extended approximation of tissue is required. Undyed not indicated for use in fascia
Hydrolytic	Minimal	Good	Good	Not used where extended approximation of tissue is required. Not for use in cardiovascular or neural tissues
Hydrolytic	Minimal	Excellent	Excellent	Not used where extended approximation of tissue is required. Not for use in cardiovascular or neural tissues
Hydrolytic	Minimal	Good	Good	Not used where extended approximation of tissue is required. Not for use in cardiovascular or neural tissues
Hydrolytic	Minimal	Excellent	Excellent	Not used where extended approximation of tissue is required. Not for use in cardiovascular or neural tissues
Hydrolytic	Minimal	Good	Good	Not used where extended approximation of tissue is required. Undyed not indicated for use in fascia
Hydrolytic	Slight	Good	Good	Not used where extended approximation of tissue is required. Not used with prosthetic devices, such as heart valves or synthetic grafts
Hydrolytic	Minimal	Good	Good	Not used where extended approximation of tissue is required. Not for use in cardiovascular surgery, neurologic surgery, microsurgery, or ophthalmic surgery

TABLE 6-4

Comparison of Nonabsorbable Sutures

Ethicon	Syneture (U.S. Surgical)	Package Color	Configuration	Tensile Strength	Absorption Rate
Perma-Hand (silk)	Sofsilk	Light blue	Braided; Sofsilk is available with wax coating	Progressive degradation with gradual loss over time	Hydrolysis leads to gradual encapsulation by fibrous connective tissue
Ethilon (nylon)		Light green	Monofilament	Progressive degradation with gradual loss over time	Hydrolysis leads to gradual encapsulation by fibrous connective tissue
Nurolon (nylon)	Dermalon, Surgilon, Monosof (nylon)	Light green	Braided; Dermalon, Surgilon, Monosof silicone coated	Progressive degradation with gradual loss over time	Hydrolysis leads to gradual encapsulation by fibrous connective tissue
Mersilene (polyester)	Surgidac (polyester)	Turquoise, orange (Surgidac)	Braided or monofilament	No significant loss in vivo	Gradual encapsulation by fibrous connective tissue
Ethibond (polyester)	Ti-Cron (polyester)	Orange, orange stripe (Ti-Cron)	Braided; uncoated or coated with silicone	No significant loss in vivo	Gradual encapsulation by fibrous connective tissue
Prolene, Pronova (polypropylene)	Surgipro, Surgipro II (polypropylene)	Deep blue	Monofilament	Not subject to degradation or weakness by hydrolysis	Nonabsorbable
	Novofil (polybutester)	Blue green	Monofilament	Not subject to degradation or weakness by hydrolysis	Nonabsorbable
Stainless steel	Stainless steel	Mustard	Monofilament, twisted, or braided	Indefinite	Nonabsorbable

Modified from *Ethicon wound closure manual,* Sommerville, NJ, 2004, Ethicon, available at www.jnjgateway.com. Accessed July 12, 2009; *Syneture nonabsorbable suture,* available at www.syneture.com/syneture/pagebuilder.aspx?topicID=319&;xsl=xsl/absorptionPage.xsl. Accessed July 12, 2009.

Surgical gut suture is wet-packaged in an alcohol solution to provide maximal pliability and should be used immediately after removal from the packet. When a gut suture is removed from its packet and is not used at once, the alcohol evaporates, which causes the strand to lose its pliability. If required, the strand's pliability may be restored just before use by immersing it in sterile water or normal saline solution, preferably at body temperature, for only a few seconds. This immersion is recommended only for eye sutures; in other areas, tissue fluids moisten the gut sufficiently as it passes through the tissue when the surgeon sews. Excessive moisture reduces tensile strength.

COLLAGEN SUTURES. Collagen sutures are derived from the tendons of cattle. They are chemically treated to remove noncollagenous material, purified, and processed into strands that have physical properties superior to those of surgical gut. Collagen suture is used most often as a fine suture material for the eye.

SYNTHETIC ABSORBABLE SUTURES. To produce synthetic absorbable sutures, specific polymers are extruded into suture strands. The base material for synthetic absorbable sutures is a combination of lactic acid and glycolic acid polymers (Vicryl, Dexon, and Polysorb). The molecular structure of these products has a tensile strength sufficient for approximation of tissues for 2 to 3 weeks, followed by rapid absorption.

Other synthetic polymers (PDS, Maxon, and Monocryl) provide wound support for longer periods (3 months). They are used when prolonged support for wound healing is desired, as with fascial closure or for elderly or oncology patients. They combine the desirable qualities of extended wound support and eventual absorbability.

A new synthetic absorbable suture has recently been approved by the Food and Drug Administration (FDA). Recombinant DNA technology is used to produce poly-4-hydroxybutyrate (TephaFLEX) suture. This suture has a high degree of flexibility and maneuverability, but may have limitations for use in patients who are allergic to the cells or the growth medium used for its production. The suture is not indicated for use in cardiovascular or neurologic tissues or for microsurgery or ophthalmic surgery (FDA, 2007).

Synthetic absorbable sutures are absorbed by slow hydrolysis in the presence of tissue fluids. Hydrolysis is the chemical process whereby the polymer reacts with water to cause an alteration of breakdown of the molecular structure. These sutures are degraded in tissue by this process at a more predictable rate than surgical gut (or collagen) and with less tissue

Degradation	Tissue Reactivity	Handling	Knot Security	Contraindications
Progressive	Acute inflammatory reaction	Good	Good	Not used in patients with known sensitivities or allergies to silk. Not used in contaminated or potentially contaminated wounds. Not used where permanent retention of tensile strength required
Progressive	Minimal	Poor	Poor	Not used where permanent retention of tensile strength required
Progressive	Minimal	Fair; Syneture products coated for better handling	Fair; Syneture products coated for increased knot security	Not used where permanent retention of tensile strength required
None	Minimal	Good	Good	None known
None	Minimal	Good	Good	None known
None	Minimal	Poor	Poor	None known
None	Minimal	Fair	Poor	Not used in patients with known sensitivities or allergies to its components. Not used in microsurgery or neurologic surgery
None	Minimal	Poor	Good	Not used in patients with known sensitivities or allergies to steel or its principal metallic components, chromium and nickel

reaction. These sutures are dry-packaged in sizes 10-0 to #3. They should not be dipped in solutions because moisture reduces their tensile strength. Some polymers have additional coatings to reduce drag in tissue.

Nonabsorbable Sutures. Nonabsorbable sutures are strands of material that effectively resist enzymatic digestion in living animal tissue. The USP classifies nonabsorbable surgical suture as follows:

- Class I suture is composed of silk or synthetic fibers of monofilament, with a twisted or braided construction.
- Class II suture is composed of cotton or linen fibers or coated natural or synthetic fibers, in which the coating significantly affects thickness but does not contribute significantly to strength.
- Class III suture is composed of monofilament or multifilament metal wire.

The strand of suture material may be uncoated or coated with a substance to reduce capillarity and friction when passing through the tissue. Several products are used for coating, including silicone, polytef (Teflon), and various polymers. Fibers may be uncolored, naturally colored, or impregnated with a suitable dye.

Nonabsorbable suture material is encapsulated or walled off by the tissues around it during the process of wound healing. Skin sutures, for which nonabsorbable materials are often the choice, are removed before healing is complete. The most common nonabsorbable suture materials are silk, nylon, polyester fiber, polypropylene, and stainless-steel wire (Table 6-4).

SILK. Silk is prepared from thread spun by the silkworm larva while making its cocoon. Top-grade raw silk is (1) processed to remove natural waxes and gum, (2) manufactured into threads, and (3) colored with a vegetable dye. The strands of silk are twisted or braided to form the suture, which gives it high tensile strength and better handling qualities. Silk handles well, is soft, and forms secure knots.

Because of the capillarity of untreated silk, body fluid may transmit infection along the length of the suture strand. For this reason, surgical silk is treated to eliminate its capillarity properties (able to resist the absorption of body fluids and moisture). It is available in sizes 9-0 to #5, in sterile packets or precut lengths, and with or without attached needles. Silk should be kept dry. Wet silk loses 20% of its original strength. Silk is not a true nonabsorbable material. When buried in tissue, it loses its tensile strength after about 1 year and may disappear after several years.

COTTON. Surgical cotton sutures are made from individual cotton fibers that are combed, aligned, and twisted to form a finished strand. Because new types of fibers have been introduced, cotton suture is rarely used. Some companies no longer manufacture it.

Umbilical tape, although not used for suturing, is produced by suture manufacturers and packaged in the same way as suture. It consists of long woven ribbons of cotton, 1/16 to 1/8 inch wide, and is used for retraction or suspension of small structures and vessels. (Other soft, pliant products, such as vessel loops, are available and more commonly used for this purpose.)

NYLON. Surgical nylon (Dermalon, Ethilon, Surgilon, Nurolon, Bralon, Monosof) is a synthetic polyamide material. It is available in two forms: multifilament (braided) and monofilament strands. Multifilament nylon is relatively inert in tissues and has a high tensile strength. It is used in conditions similar to those in which silk and cotton are used. Monofilament nylon is a smooth material that is particularly well suited for closing skin edges and for tension sutures. Because of its poor knot security, the surgeon usually ties three knots in small sutures and a double square knot in large sutures. It is used frequently in ophthalmology and microsurgery because it can be manufactured in fine sizes. Size 11-0 nylon is one of the smallest suture materials available.

POLYESTER FIBER. Surgical polyester fiber (Ti-Cron, Dacron, Mersilene, Tevdek, Polydek, Ethibond, Surgidac) is available in two forms: a nontreated polyester fiber suture and a polyester fiber suture that has been specifically coated or impregnated with a lubricant to allow smooth passage through the tissue. Polyester fiber is available in fine filaments that can be braided into various suture sizes to provide good handling properties.

Polybutester (Novafil) is a special type of polyester suture that possesses many of the advantages of polyester and polypropylene. Because it is a monofilament, it induces little tissue reaction.

Polyester material has many advantages over other braided, nonabsorbable sutures. It has greater tensile strength, minimal tissue reaction, and maximal visibility and does not absorb tissue fluids. It is used frequently as a general-closure fascia suture and in cardiovascular surgery for valve replacements, graft-to-tissue anastomoses, and revascularization procedures.

POLYPROPYLENE. Polypropylene is a clear or pigmented polymer. This monofilament suture material (Prolene, Surgilene, Surgipro, Dermalene) is used for cardiovascular, general, and plastic surgery. Because polypropylene is a monofilament and is extremely inert in tissue, it may be used in the presence of infection. It has high tensile strength and causes minimal tissue reaction. Sizes range from 10-0 to #2.

STAINLESS STEEL. Surgical stainless steel is formulated to be compatible with stainless-steel implants and prostheses. This formula, 316L (L for "low carbon"), ensures absence of toxic elements, optimal strength, flexibility, and uniform size. Monofilament and multifilament surgical stainless-steel sutures are known for their strength, inert properties, and low tissue reaction. Stainless steel–suturing technique is very exacting, however. Steel can pull or tear out of tissue, and necrosis can result from a suture that is too tight. Barbs on the end of steel can traumatize surrounding tissue or tear gloves. Torn or cut gloves fail to provide an adequate and effective barrier for the patient or the surgeon and assistant and can remain undetected. Kinks in the wire can render it practically useless. For this reason, packaging has played an important part in the development of surgical stainless-steel sutures. Surgical stainless steel is available in packets on spools or in packages of straight, precut, sterile lengths, with or without attached needles. This packaging affords protection to the strands and delivery in straight, unkinked lengths.

TABLE 6-5

Steel Suture Comparison

Size (USP)	B&S Gauge	Size (USP)	B&S Gauge
6-0	40	0	26
6-0	38	1	25
5-0	35	2	24
4-0	34	3	23
4-0	32	4	22
000	30	5	20
00	28	7	18

B&S, Brown and Sharp; *USP,* United States Pharmacopeia.

Before surgical stainless steel was available from suture manufacturers, it was purchased by weight with the Brown and Sharp (B&S) scale for diameter variations. Today the B&S gauge, along with USP size classifications, is used to distinguish diameter ranges. Table 6-5 compares steel suture sizes.

BARBED SUTURE. Barbed suture is a lesser known suture type, marketed as the Quill Self-Retaining System. This is a self-anchoring suture that does not require knots or slack management for wound closure. A polydioxanone suture, it is available in 0 and 2-0 sizes on both straight and curved needles, and it is absorbed in 26 weeks. Murtha and colleagues (2006) report comparable results with conventional would closure techniques in patients undergoing cesarean section. This suture, also used in cosmetic surgery, avoids the drawbacks inherent to suture knots in some patients.

SURGICAL NEEDLES

Surgical needles vary in shape, size, point design, and wire diameter (Figure 6-2). The appropriate needle is selected depending on the type and location of tissue being sutured. Surgical needles are made from stainless steel or carbon steel. Various metal alloys used in manufacturing surgical needles determine their basic characteristics. They must be strong, ductile, and able to withstand the stress imposed by tough tissue. Stainless steel is the most popular, not only because it provides these physical characteristics but also because it is noncorrosive. The three basic parts of a surgical needle are the *eye,* the *body,* and the *point* or *tip*.

Eye

The eye of the surgical needle falls into the following three general categories:

1. Eyed needles, in which the needle must be threaded with the suture strand, and two strands of suture must be pulled through the tissue (Figure 6-3, *A*)
2. Spring, or French, eyed needles, in which the suture is placed or snapped through the spring (Figure 6-3, *B*)
3. Eyeless needles, a needle-suture combination in which a needle is swaged (permanently attached) onto one or both ends of the suture material (Figure 6-3, *C*)

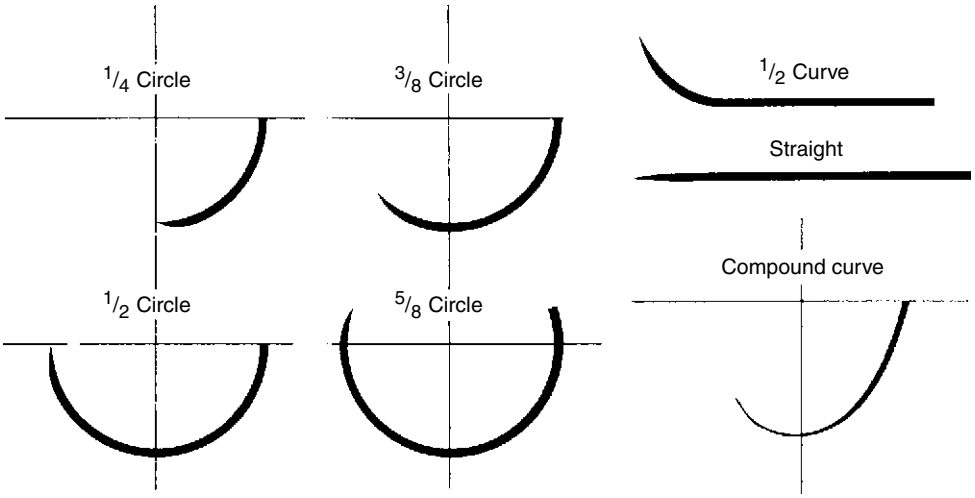


FIGURE 6-2 Surgical needles vary in shape, size, type of point and body, and how the suture is attached.

The swaged needle is the most universally used needle type, eliminating threading eyed needles before and during surgery. A single strand of suture material is drawn through the tissue, and tissue damage is minimized (atraumatic). The swaged needle may need to be cut off with suture scissors or swaged for controlled release of the suture (semiswaged). With semiswaged suture, the needle remains attached until the surgeon releases it with a straight tug of the needle holder.

Body

The body, or shaft, of the needle may be round, triangular, or flattened. Surgical needles also may be straight or curved; the curve is described as part of an imaginary circle (see Figure 6-2). As the radius of the imaginary circle increases, the size of the needle also increases. The body of a round needle gradually tapers to a point.

Point

Choice of needle point relates to the density of the tissue to be penetrated. Delicate tissue, such as bowel or kidney, requires a taper or blunted point, whereas skin, which is dense in structure, requires a cutting edge. Taper points tend to tear tissue less than cutting needles do and leave a smaller hole in the tissue. Recently introduced blunt protect-point needles are being recommended as an alternative to taper point needles. Interest in blunt needles has evolved because of the risk of bloodborne exposure from percutaneous injuries (PIs). Approximately 77% of sharps injuries result from suture needle sticks (Berguer and Heller, 2005). Such injuries have been reported to occur in an estimated 1% to 15% of surgical procedures—mostly associated with suturing. Some studies have been conducted to evaluate the effectiveness of blunt needles in preventing PIs and to assess their clinical acceptability by surgeons. The use of blunt needles represents a key strategy to reduce risk to the surgical team (Risk Reduction Strategies). Blunt needles are associated with a statistically significant reduction in PIs and can be substituted for conventional curved needles in a variety of surgical procedures. Table 6-6 illustrates the type of points available for various tissues. Interestingly, recent research has been conducted to evaluate the relationship between glove perforations and the risk of surgical site infections (Research Highlight).

RISK REDUCTION STRATEGIES

Using Blunt Needles to Avoid Needle-Stick Injuries

Analysis of percutaneous injuries shows that essentially most injury rates have decreased in many device categories. Suture needles have failed to show a major decline in sharps injury rates, however. Of the top six devices responsible for 80% of all injuries, suture needles ranked second, accounting for 19% of needle sticks. A safer alternative to sharp-tip suture needles is the blunt-tip suture needle. These needles are sharp enough to pierce internal tissue, but not sharp enough to penetrate the skin. They are now available in a range of bluntness. In the past, a challenge for perioperative nurses was their inability to persuade a surgeon to use a safer device, such as a blunt-tip needle, because the surgeon chose which devices to use. In 2007 the American College of Surgeons (ACS) replaced the 2005 *Statement on Blunt Suture Needles* with a more comprehensive document entitled *Statement on Sharps Safety*. This document outlines a comprehensive strategy that includes the use of blunt needles, implementation of a neutral zone, use of engineering controls, and implementation of workplace practices such as wearing double gloves.

Modified from Cowles L: The point of the matter, *Adv Nurs* 6(17):43-44, 2004; Perry J, Jagger J: Sharps safety update—are we there yet? *Nursing 2005* 35(6):17, 2007; American College of Surgeons: *Statement on sharps safety,* available at www.facs.org/fellows_info/statements/st-58.html. Accessed July 8, 2009.

Triangular needles have cutting edges along three sides. The cutting action may be conventional or reverse. The cutting edge of the conventional cutting needle is directed along the inner curve of the needle, facing the wound edge when suturing is performed.

The reverse cutting needle is preferred for cutaneous suturing. When it transects the skin lateral to the wound, the outside cutting edge is pointed away from the wound edge, and the inside flat edge is parallel to the edge of the wound. This cutting action reduces the tendency for suture to tear through tissue.

For certain types of delicate surgery, needles with exceptionally sharp points and cutting edges are used. Microsurgery, ophthalmic surgery, and plastic surgery require needles of this type; special honing wheels provide needles of precision-point

RESEARCH HIGHLIGHT

Surgical Glove Perforation and the Risk of Surgical Site Infection

There is an ongoing debate among perioperative personnel about the risk of infection in patients when gloves of operative personnel have been perforated during the course of a surgical procedure. The literature is weak in providing evidence to determine best practices. The hypothesis of this study was, "Clinically apparent surgical gloves perforation increases the risk of surgical site infection (SSI)." Conducted over a 12-month period in a university-based facility with a surgical case volume of 28,000 surgical interventions annually, a consecutive series of 4147 surgical procedures were included. Initial observations were gathered in the OR and follow-up data were gathered through direct chart review, from physician feedback, and with follow-up phone calls. A total of 188 SSIs were detected in the 4147 procedures studied. Asepsis was compromised by glove leakage in 677 (16.3%) of the cases. The study also considered SSIs in procedures that lasted >2 hours without glove perforation. Analysis revealed that the risk of SSIs was higher in those cases in which the patient did not receive antibiotic prophylaxis. The authors contend that the risk of developing SSIs is significantly higher in surgical procedures in which gloves are perforated and no antimicrobial prophylaxis is administered. This was the first study to explore the correlation of these two variables on the risk of SSIs. Other considerations noted in the study were the role of double-gloving, the type of glove worn (latex vs. other), and the duration that the gloves were worn. The authors report some limitations in the study; however, they conclude that the clinical consequences of glove perforation in terms of SSIs have been neglected. They also acknowledge that there is opportunity for greater research in this area. Perioperative nurses have long recognized the importance of the role of vigilance of aseptic practices during a surgical procedure. As members of the team, they need to aggressively declare breeches in technique as well as accurately classify those surgical procedures in which glove perforations occur so that, based on each patient's unique situation, a decision can be made about the risks and benefits of antimicrobial administration in patients who have increased risk.

Modified from Misteli H et al: Surgical glove perforation and the risk of surgical site infection, *Arch Surg* 144(6):553-558, 2009.

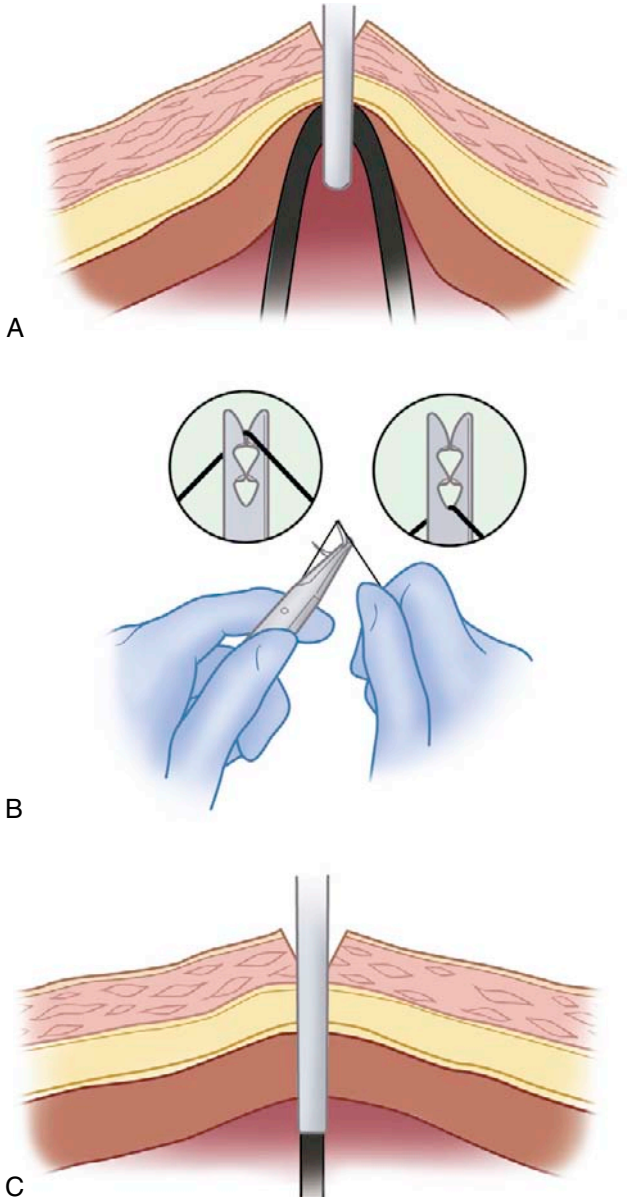


FIGURE 6-3 Types of needles. **A**, Eyed needle. Greater tissue trauma is caused by the double suture strand threaded through eyed needles. **B**, Spring eye. Holding suture strand taut with left hand, bring strand down over top and spring into eye. **C**, Atraumatic (eyeless) needle causes minimal tissue trauma by eliminating the double suture strand.

quality for surgery in these specialties. In some instances, the application of a microthin layer of plastic to the needle surface provides for easier penetration and reduces drag of the needle through tissue.

Most surgical services departments have instituted standardization programs to control the variety of needle-suture combinations available for surgical procedures.

PACKAGING, STORAGE, AND SELECTION OF SUTURES

Types of Packaging

For packaging, the suture material is sealed in a primary inner packet, which may or may not contain fluid; placed inside a dry, outer, peel-back packet; and sterilized. This method permits easy dispensing onto the sterile field. Various forms of foil, plastic, and special paper are used for the inner and outer packets.

Each primary suture packet is self-contained, and its sterility for each patient is ensured as long as the integrity of the packet is maintained. Some suture packets have expiration dates that relate to stability and sterility. Packages should be stored in moisture-proof and dust-proof containers in units of one size and type.

Suture packets may contain single or multiple strands, with or without a needle attached to the strand. The needle may be swaged to the suture and may need to be cut off for removal, or it may be designed to separate easily from the suture with a quick tug of the needle holder (Controlled Release, D-Tach, Pop-off). Some sutures may be double-armed, with a needle at each end of the strand.

TABLE 6-6

Atraumatic Needles

Needle Type	Description of Body	Use
Taper point	Round shaft, straight or curved, taper point, no cutting edge	Soft tissue closure, such as gastrointestinal, fascial, vascular, and most soft tissues below skin surface
Penetrating point	Taper body with finely sharpened point; optimal penetration with less tissue wound	Ligaments, tendons, and calcified, fibrous, and cuticular tissue; mostly used for vascular, thoracic, plastic, obstetrics/gynecology, and orthopedic surgery; excellent penetration through synthetic grafts and scar tissue during repeat surgeries
Blunt point	Taper body with rounded point, no cutting edge	Friable tissue, fascia, liver, intestine, kidney, muscle, uterine cervix (note recommendations regarding use of blunt needles, p. 181)
Protect-point	Taper body with blunted point, no cutting edge	Primarily in fascia and mass closure to minimize potential of needle sticks
Reverse cutting	Triangular point with cutting edge on outer curvature	Skin closure; retention sutures; subcutaneous, ligamentous, or fibrous tissues
Cutting taper	Reverse-cutting tip with taper shaft	In microsurgery for excellent penetration through tough tissue, such as vasovasostomy, tuboplasty
Hand-honed reverse cutting	Same as reverse cutting but hand-honed for added sharpness	Primarily in plastic surgery for delicate work and where good cosmetic result is priority
Spatula side cutting	Two cutting edges in horizontal plane	Ophthalmic surgery for muscle and retinal repair; also for delicate eyelid or plastic surgery; cutting edges "ride" along scleral layers
Regular cutting	Triangular point with cutting edge on inner curvature	General skin closure, subcutaneous tissue; sometimes for ophthalmic surgery, plastic, or reconstructive surgery
Lancet, inverted lancet	Spatula needle with cutting edge (lancet) or outer (inverted lancet) curvature	Ophthalmic surgery and microsurgery

Modified from *Ethicon wound closure manual,* Sommerville, NJ, 2004, Ethicon, available at www.jnjgateway.com. Accessed July 12, 2009.

Color Codes. Color-coded packaging based on suture fiber is used by most companies to make identification quicker and easier. Each individual packet is color-coded, as is the dispenser box. Although most color codes are universal across companies, there are some exceptions. Ethibond, a coated polyester, is coded orange, whereas most polyesters are coded in shades of green. Dexon, a glycolic acid polymer, is gold, whereas Vicryl, a comparable polymer, is violet.

Selection of Suture

The choice of suture material, size, needle, and type depends on the procedure, the tissue being sutured and type of reapproximation required by the general condition of the patient, and the surgeon's preferences. A surgical services committee or project team may be responsible for establishing standard suture uses for various operations. Current guides published by suture manufacturers should be consulted. These guides list the specific suture materials recommended for various wounds and are based on current clinical practice and research. Although the perioperative nurse is not responsible for choosing the suture material used, he or she must be knowledgeable of the suture properties to ensure the best possible outcome for the surgical patient.

SUTURING TECHNIQUES/WOUND CLOSURES

Surgeons may use suture or other devices to accomplish wound closure. The *primary suture line* refers to sutures that obliterate dead space, prevent serum from accumulating in the wound, and hold the wound edges in approximation until healing takes place (Figure 6-4). The *secondary suture line* refers to sutures that supplement the primary suture line. They are placed on each side of the primary suture line, passing through several layers of tissue at once. A secondary suture line helps eliminate tension on the primary sutures and reduces the risk of evisceration or dehiscence. Retention sutures are a type of secondary suture line.

An *interrupted suture* is inserted into tissues or vessels in such a way that each stitch is placed and tied individually. This type of suture is widely used and generally considered the strongest and most secure (Figure 6-5, *A*). Various techniques used for the insertion of interrupted sutures in the tissue are designed to alter the angle of pull and the relationship of the wound's edges to each other. Such maneuvers cause the edges of the wound to invert or to evert and aid in wound healing because fewer sutures are used. The interrupted technique may be used for anastomotic repairs (e.g., bowel anastomosis), in fascial closure, or on the skin.

A *continuous suture* consists of a series of stitches, of which only the first and last are tied (Figure 6-5, *B*). With this type of suture, a break at any point may mean a disruption of the entire suture line. It is used to close tissue layers where there is little tension but tight closure is required, such as the peritoneum, to prevent the intestinal loops from protruding, or on blood vessels to prevent leakage.

Retention (or *stay*) sutures are placed at a distance from the primary suture line to provide a secondary suture line (Figure 6-5, *C*), relieve undue strain, and help obliterate dead space.

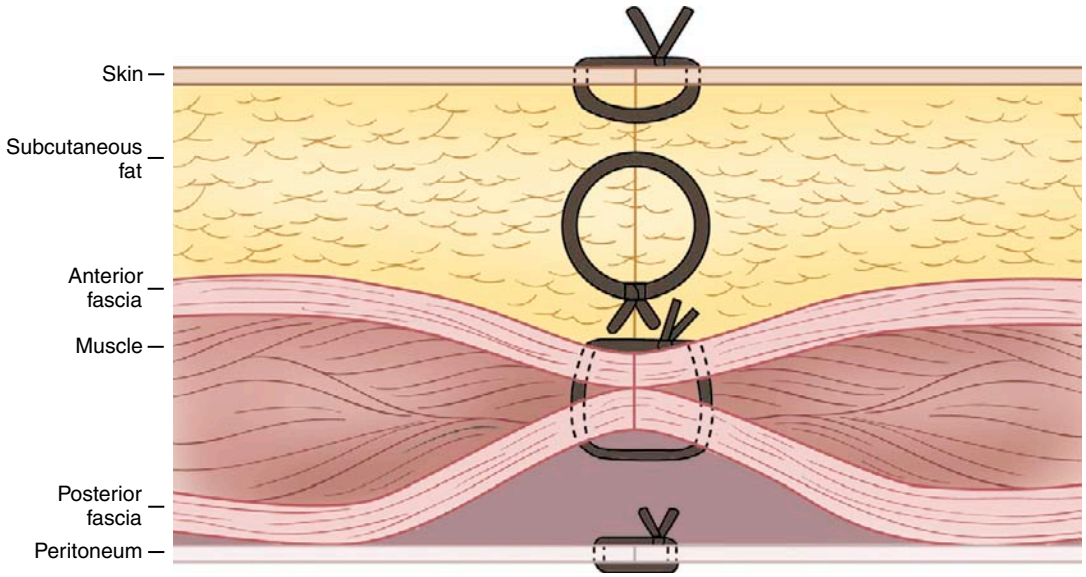


FIGURE 6-4 Primary suture line on the abdominal wall, midline incision.

These sutures are placed in such a way that they include most if not all layers of the wound. A simple interrupted or figure-of-eight stitch is used. Usually heavy, nonabsorbable suture materials, such as silk, nylon, polyester fiber, or wire, are used to close long, vertical abdominal wounds and lacerated or infected wounds. To prevent the suture from cutting into the skin surface, a small piece of rubber tubing (bumper, bolster, bootie) or other type of device (bridge, button) is passed over or through the exposed portion of the suture. The bridge device allows the surgeon to adjust tension over the wound postoperatively.

Subcuticular sutures, sometimes referred to as *buried,* are sutures placed completely under the epidermal layer of the skin (Figure 6-5, *D*). This technique is often used to achieve a cosmetic closure.

A *purse-string suture* is a continuous circular suture placed to surround an opening in a structure and cause it to close (Figure 6-5, *E*). This type of suture may be placed around the appendix before its removal, or it may be used in an organ such as the cecum, gallbladder, or urinary bladder before it is opened so that a drainage tube can be inserted; then the purse-string suture is tightened around the tube.

The Nursing Interventions Classification (NIC) lists suturing as a nursing intervention, defined as "approximating edges of a wound using sterile suture material and a needle" (Bulechek et al, 2008). The NIC was developed to classify nursing interventions so that the work of nursing could be documented and nursing knowledge improved through the evaluation of patient outcomes. In perioperative nursing practice, the act of suturing is considered part of the education and subsequent role of the registered nurse first assistant (AORN, 2009a).

Knot-Tying Techniques

The successful use of the many varieties of suture materials depends, in final analysis, on the skill with which the surgeon or first assistant ties the knot. The completed knot should be firm to prevent slipping and should be small, with ends cut short, to minimize the bulk of suture material in the wound. The suture may be weakened by inappropriate handling. One should avoid excessive tension, sawing, friction between the strands, and inadvertent crushing with clamps or hemostats.

Endoscopic Suturing/Knot Tying

Suturing through an endoscope is a learned skill, not an innate talent. The ports must be placed and used to maximize the precision and efficiency of the suturing motions. An array of needles and suture materials is available for endoscopic suturing so that the surgeon is not disadvantaged by a lack of choice. Research and development of technique, instrumentation, needles, and suture materials are ongoing as the types of procedures done endoscopically increase and methods are perfected. Knot tying is one of the most challenging aspects of endoscopic surgery. Preformed ligature loops are used in ligating the appendix or blood vessels. Extracorporeal knots are tied outside the abdomen and slid into the abdomen using a knot pusher. They can be tied rapidly and securely; the square knot is normally used as the locking loop knot. Intracorporeal knotting is done completely within the abdominal cavity whenever fine sutures are being placed in tissues for reconstruction purposes. All suturing and knot-tying techniques performed through the endoscope require excellent hand-eye coordination, practice, and the ability to perform these techniques while the operative site is being viewed on a television monitor.

Skin Staples

Skin staples are one of the most frequently chosen methods of skin closure. They can be used on many types of surgical incisions. The staple appliers are easy to use. They reduce operating time and tissue trauma, allowing uniform tension along the suture line and less distortion from the stress of individual suture points. When properly applied (Figure 6-6), they provide excellent cosmetic results. Some staplers use bioabsorbable staples that are placed under the skin and then absorbed similar to suture. Others use stainless-steel staples. With these, the length of time the staples stay in place depends on the part

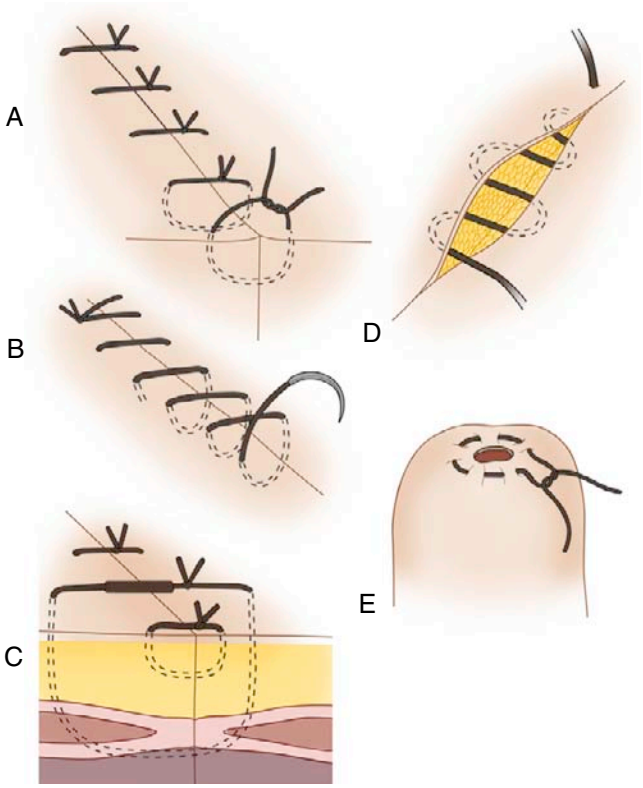


FIGURE 6-5 Types of stitches. **A**, Interrupted. Each stitch is made with a separate piece of suture material, which is tied separately. **B**, Continuous or "running." A stitch is made with one uninterrupted length of suture material. **C**, Retention. Stitches are used to reinforce the primary suture line; heavy, strong suture material is used. **D**, Subcuticular. Stitch is placed completely under the epidermal layer of the skin. **E**, Purse-string. A stitch runs parallel to the edge and encircles a circular wound.

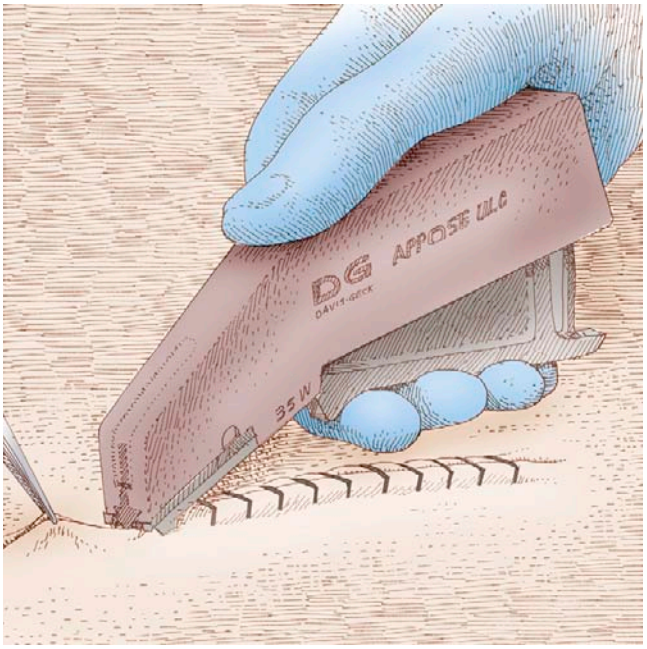


FIGURE 6-6 Application of skin staples. The stapler is lightly positioned over everted skin edges. It is not necessary to press the staple, or stapler anvil, into the skin to get a proper "bite" (just "kiss" the skin). Center the staples over the incision line, using the locating arrow or guideline, and place staples approximately ¼ inch apart.

of the body affected; they are usually removed within 5 to 7 days. An extractor is required for their removal.

Most staplers employ a similar anvil-type mechanism for forming the staple, but the application device varies from company to company. Device choice usually is determined by the weight, handling characteristics, ease of application, and unobstructed view of the site during application. Staplers are packaged in various assortments of numbers and types of staples, depending on the length of the incision and the type of tissue encountered.

Wound Closure Strips

Wounds that are subjected to minimal static and dynamic tension are easily approximated with skin tape. The selection of surgical tape for skin closure is based on the tape's adhesive ability, tensile strength, and porosity. The tape must provide a firm tape-to-skin bond to keep the wound edges closely adhered. The tensile strength must be sufficient to maintain wound approximation. A tape that is too occlusive limits moisture or vapor transmission; fluid may accumulate under the tape and lead to maceration and bacterial growth. Microporous tapes prevent this problem. The surgeon must apply the tape to dry skin; an adhesive adjunct (e.g., tincture of benzoin or Mastisol liquid adhesive) may be applied in a thin film to the skin at the wound edges before tape application. If an alcohol-based adhesive adjunct is used, care must be taken to prevent inadvertent surgical fires (e.g., electrocautery unit must be shut off before the agent is delivered to the field by the perioperative nurse). Edema at the surgical site may cause taped wound edges to invert; supplemental skin sutures may be used to enhance closure. Tapes may be cut to accommodate smaller incisions. Tapes are applied perpendicularly to the wound edge, first on one side and then the other, so that the edges can be pulled together (Figure 6-7).

Surgical Adhesives

Tissue adhesives may be applied topically to intact skin at the wound edges to hold surfaces together. Care must be taken to avoid any contact with the open wound; adhesive in the wound creates a barrier to wound healing. When used in areas that are not subject to stress (e.g., areas that penetrate the fascia) or movement (e.g., on the hands or joints, where there is repetitive movement), tissue adhesives provide for fast closure and less pain for the patient (Neumayer and Vargo, 2008).

HEMOSTASIS

Hemostasis is an ongoing process during surgery. In addition to the damaging physiologic effects of blood loss for the patient, bleeding from cut vessels obscures visualization of the operative site for the surgeon and must be controlled. Hemostasis may be accomplished from direct pressure applied with a surgical sponge (Box 6-2) or by the use of suture materials, electrosurgical devices, lasers, and chemical agents. Before wound closure, the surgeon carefully checks the operative site to ensure that all active bleeding has been stopped.

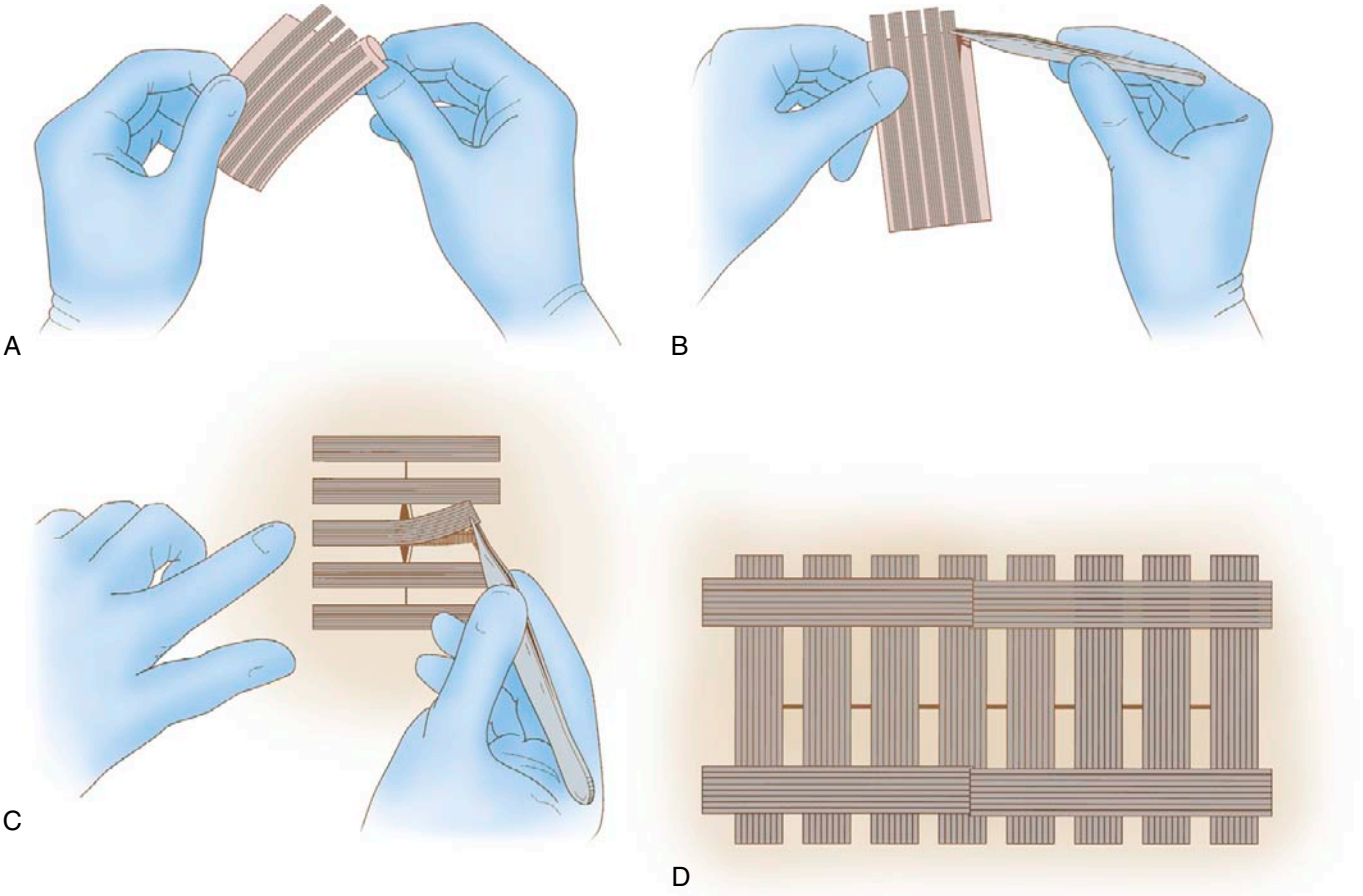


FIGURE 6-7 Application of skin tapes. **A**, Perforated tab is bent and removed. **B**, Tape is peeled from the card. **C**, Tape is applied to wound. **D**, Additional tape is placed parallel to wound to limit shear stress on the skin.

Methods of Ligating Vessels

A ligature is a strand of suture material used to encircle and obstruct the lumen of a vessel to affect hemostasis, block a structure, or prevent leakage of materials. Ties may be on a reel (i.e., a spool or disk containing a long length of suture) that the surgeon may use to ligate several superficial vessels, or they may be free ties (i.e., precut lengths of suture) handed to the surgeon one at a time, usually for bleeders in deeper tissues.

Following are several techniques used to secure a ligature in deep tissues:

- A hemostat is placed on the end of the structure; the ligature is then placed around the vessel. The knot is tied and tightened with the surgeon's fingers or with the aid of forceps.
- A slipknot is made, and its loop is placed over the involved structure by means of a forceps or clamp.
- In deeper cavities, ties are often placed on clamps with the long end extending from the tip. These are sometimes called *ties on a pass* or *bow ties*. The extending long end is held tightly against the rings by the surgeon (creating the bow), who then passes the tip of the clamp under the vessel or duct to be ligated. The first assistant grasps the extending tie with a forceps, the surgeon releases it, and the tie is pulled under and up to the wound surface and tied.
- A forceps or a clamp is applied to the structure, and transfixion sutures are applied and tied. A *suture ligature, stick tie,* or *transfixion ligature* is a strand of suture material threaded or swaged on a needle. This is usually placed through the vessel and around it to prevent the ligature from slipping off the end.

When two ligatures are used to ligate a large vessel, usually a free ligature is placed on the vessel and a suture ligature is placed distal to the first ligature. To ligate a blood vessel situated in deep tissues, the strand must be of sufficient strength and length to allow the surgeon to tighten the first knot. See the discussion of preparation of ligatures and suture ligatures in Perioperative Nursing Considerations later in this chapter.

Ligating Clips

Ligating clips are small, V-shaped, staplelike devices that are placed around the lumen of a vessel or structure to close it. They may be made of one of several metals, such as stainless steel, tantalum, or titanium. Stainless-steel clips are the most economical to use. Although more expensive, titanium clips are used frequently in specific surgical procedures because the starburst reflection on postoperative radiographs is less with titanium than with other metals. Absorbable clips made of synthetic absorbable suture material also are available.

BOX 6-2

Surgical Sponges

Surgical sponges are used to affect hemostasis via direct pressure, absorb intraoperative blood loss and drainage, act as aids to blunt dissection, pack the viscera from the field, and keep areas of the wound moist. Surgeons may also use sponges as a filter between a suction tip and delicate tissue. A variety of surgical sponges are available commercially packed in increments of 5 or 10. Any sponge used during a surgical procedure must contain an x-ray–detectable element to facilitate location of the item if a count discrepancy occurs.

The following is a list of the types of surgical sponges:

- *Radiopaque 4 × 4's:* Commonly referred to as a Ray-Tec or 4 × 4, this sponge is composed of loosely woven gauze folded into a 4-inch square. A radiopaque thread, which may change to a darker color when exposed to fluid, is integrated into the sponge. This type of sponge is useful for superficial small incisions, and may be folded into thirds and mounted onto a sponge stick for use in deeper incisions.
- *Laparotomy sponges:* Also referred to as "laps," "lap pads," or "tapes," these sponges are either square or oblong and have a loop of colored twill tape with a radiopaque marker sewn to one corner. Used for major surgical procedures with large incisions, laparotomy sponges are presented to the surgeon either moist or dry.
- *Dissectors:* Dissecting sponges have the radiopaque element incorporated into the weave of the material and are generally composed of very tightly rolled cloth tape. They may be referred to as "peanuts," "pushers," or "kitners." Dissecting sponges are *always* presented to the surgeon mounted on a clamp because of their small size.
- *Round sponges:* Often known as "tonsil" or "cherry" sponges, round sponges are gauze-covered cotton balls with strings attached. The radiopaque element is woven into the gauze covering. These sponges are often used in the oropharynx and are presented on the tip of a clamp or sponge stick.
- *Flat neurosurgical patties:* Flat sponges are composed of soft compressed cotton or rayon with an embedded radiopaque element and string attached. Often used in neurosurgical procedures, these sponges are available in a multitude of sizes and widths. They may be used as a filter for a suction tip to prevent damage to the underlying tissue, or as a vehicle for the application of topical anesthetic to the nasal mucosa.

Ligating clips are available in several sizes. These clips are available in individual sizes that must be loaded by the scrub person or as preloaded, disposable, prepackaged units. (NOTE: The scrub person may be a surgical technologist or registered nurse. He or she is referred to in this chapter as "scrub person.") There are multiple sizes and lengths of clips that can be used in both open and endoscopic procedures. Ligating clips afford a rapid and secure method of achieving hemostasis when arteries, veins, nerves, and other small structures are ligated. Since the introduction of minimally invasive endoscopic surgery, the need for ligating clips that can be applied through a trocar has emerged. These clips are changing frequently and no one standard has emerged. Regardless of the type of clip, the surgeon applies them similarly. The surgeon often follows the application of a clip with a request for scissors (Figure 6-8).

Metal cushing or Frazier clips are made of small-diameter pieces of stainless steel or silver wire and are heat sterilized.

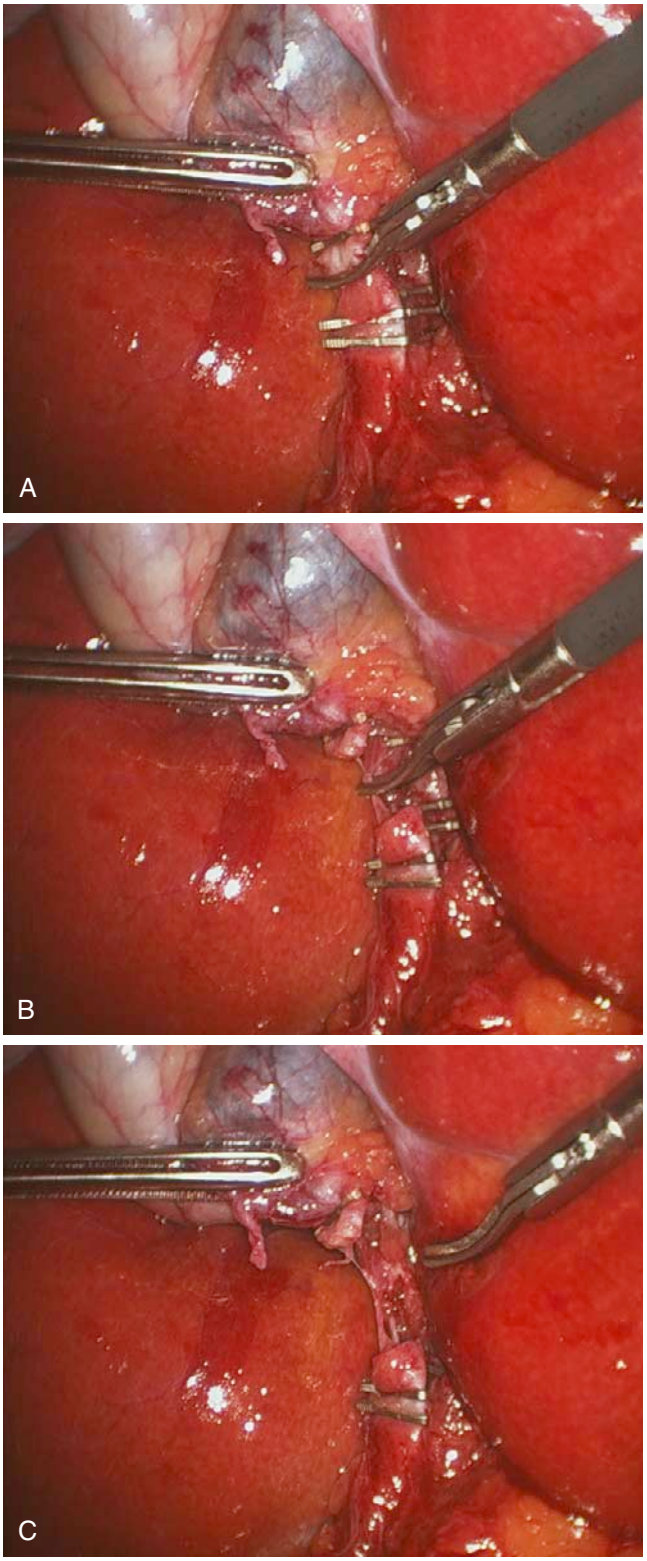


FIGURE 6-8 Laparoscopic instrumentation. **A**, Endo Clip being applied to proximal end of gallbladder duct. **B**, Gallbladder duct being cut with Endo Scissor. **C**, View of severed duct with artery behind it.

They must be hand-loaded onto special rack dispensers. Frazier clips are applied to the ends of severed nerves and blood vessels by means of a forceps designed for this purpose. Formerly widely used in neurosurgery and orthopedic procedures, the use of these clips has diminished since the introduction of prepared ligating clips.

PERIOPERATIVE NURSING CONSIDERATIONS

General Considerations

In the preparation and use of sutures in surgery, every precaution must be taken to keep the sutures sterile, to prevent prolonged exposure and unnecessary handling, and to avoid waste. Before perioperative personnel prepare any suture materials, they should review the sutures listed on the physician's preference card or in the computerized intraoperative record. Care should be taken to ensure fiscal responsibility by minimizing the number of sutures on the field when the initial count is performed. The perioperative nurse should have an adequate supply of sutures available for immediate dispensing to the sterile instrument table as needed throughout the procedure.

Customized suture kits that contain a designated number and variety of sutures for particular procedures, surgeons, or both are available for use when suture preferences are consistently the same. These kits may be more economical than individually packaged sutures because of reduced packaging costs, decreased gathering and dispensing times, and less capital outlay for inventory.

Opening Primary Packets

The scrub person tears the foil packet across the notch near the hermetically sealed edge and removes the suture. Some sutures may be packaged for delivery to the field in their inner folders, ready to load, with no foil wrapper.

Handling Suture Materials

To remove suture strands to be used for ties when they are not on a reel or disk, the user pulls the loose end out with one hand while grasping the folder with the other hand. To straighten a long suture, the free end is grasped (using the thumb and forefinger of the free hand) and the kinks, caused by package memory, are removed by gentle pulling with the free ends secured, one in each hand, and then the arms are slowly abducted to straighten the strands (Figure 6-9).

The scrub person should never remove kinks from suture by running gloved fingers over the strand because this action causes fraying. The tensile strength of a gut suture should not be tested before it is handed to the surgeon. Sudden pulls or jerks may damage the suture so that it will break when in use.

To remove a suture-needle combination from the package, the scrub person grasps the needle with a needle holder and gently pulls (Figure 6-10). To straighten the suture in a suture-needle combination, the scrub person grasps the suture 1 to 2 inches distal to the needle and pulls gently on the other end of the strand with the other hand to remove kinks. The jaws of the needle holder grasp the flattened surface of the needle to prevent breakage and bending. To facilitate suturing, the needle is secured about ⅛ inch distal from the tip of the needle holder (Figure 6-11). The holder is placed on the needle about one third of the distance distal from the eye or swaged end.

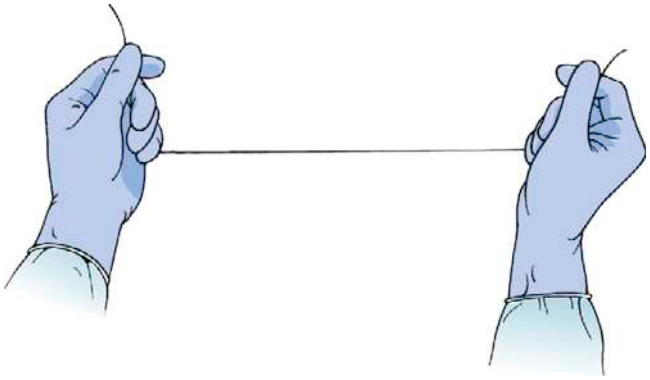


FIGURE 6-9 Straightening suture material.

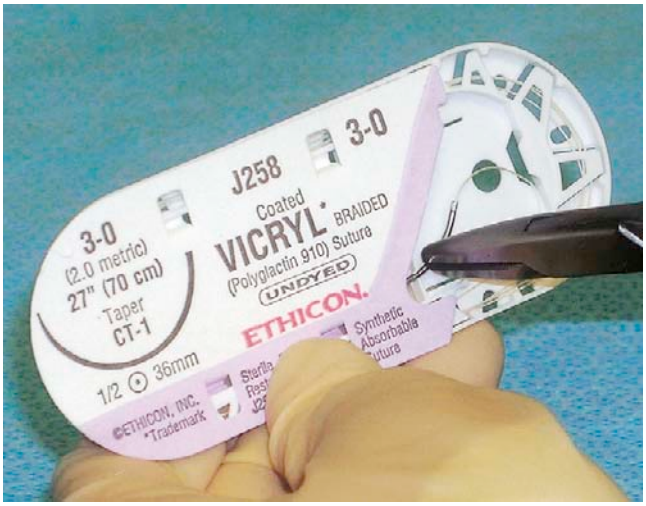


FIGURE 6-10 Loading a suture directly from packet.

FIGURE 6-11 Loading a needle holder. Clamp needle holder approximately one third the distance from the swage or eye to point of needle.

A suture or free ligature should not be too long or too short. A long suture is difficult to handle and increases the possibility of contamination because it may be dragged across the sterile field or fall below it. A short suture makes tying difficult; if threaded on a needle, it may slip out of the eye. The depth and distance to the site of tying or suturing guide the scrub person in preparing ties or sutures of the correct length.

For general surgery, a continuous suture threaded on a needle is usually about 24 inches long, and its short end is 3 to 4 inches long (half-lengths). An interrupted suture is 12 to 14 inches long, with 2 or 3 inches threaded through the needle

(quarter-lengths). To ligate a vessel in the epidermal and subcutaneous layers, the ligature may be quarter-lengths. Vessels or structures deep in the wound are ligated with a suture or ligature that is 24 to 30 inches long (third-lengths to half-lengths). Sutures also are provided in 12- to 60-inch precut lengths by the manufacturer. Also supplied are the more commonly used 54-inch lengths on reels or disks and labyrinth packs, where precut strands may be removed one at a time from the package rather than all at once.

Threading Surgical Needles

Free needles, which are packaged separately from the suture, must be threaded by the scrub person for the surgeon. A curved needle is threaded from within its curvature so that the short end falls away from the outside curvature (Figure 6-12). This practice helps to prevent accidental pullout. The scrub person pulls the suture about 4 inches through the eye of the needle to prevent the suture from being pulled out of the eye during suturing.

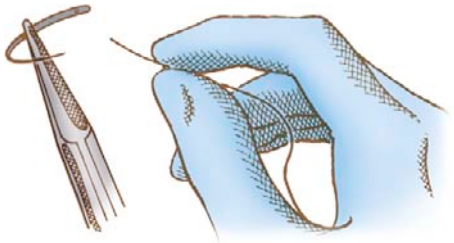


FIGURE 6-12 Eyed needle is threaded from inside curvature. Take care to avoid pricking glove on sharp needle point.

Counting Needles

One of the patient outcomes identified in the Perioperative Nursing Data Set (PNDS) is that "the patient is free from signs and symptoms of injury due to extraneous objects" (Peterson, 2007). One of the many perioperative nursing activities undertaken to achieve this patient outcome is the performance of counts to ensure that the patient is free from injury related to retained sponges, sharps, or instruments (Patient Safety). Institutions vary in their policies regarding needle and sharps counts during operative procedures, but most follow established procedures based on the Association of periOperative Registered Nurses (AORN) *Recommended Practices for Sponge, Sharp and Instrument Counts* (AORN, 2009b). Initial counts before the start of the procedure provide the basis for subsequent counts.

The documentation of counts should include the items on the instrument table at the beginning of the procedure as well as those added during the procedure. The count should be performed audibly and with each sharp visualized by both the scrub person and the perioperative nurse. The number of needles should be recorded.

During the procedure, the scrub person should be aware of the location of sharps on the sterile field. Needles should be accounted for by the scrub person as they are placed in the neutral zone on a one-for-one exchange basis when possible. Subsequent counts should be performed by the scrub person and perioperative nurse before closure of a body cavity or deep, large incision; after closure of a body cavity; and at skin closure. Additional counts should be an element of the hand-off process when either the scrub person or the perioperative nurse is permanently relieved by other personnel. In situations in which personnel may be relieved on a temporary basis, the verbal hand-off should include a discussion about counted items. In all situations it is imperative that two individuals be involved in the count—one counting and the other witnessing that the count is correct. All sharps are retained in the OR during the surgical procedure. Many institutions have printed forms to keep track of routinely counted items (Figure 6-13). Others use erasable count boards visible to all personnel. Recording the count is the responsibility of the perioperative nurse. Depending on institutional policy and practices, the count sheet may become part of the patient's record. To facilitate counting, needles are counted according to the number indicated on the package; the scrub person verifies this number with the perioperative nurse when the package is opened. Used needles should be kept on a needle pad or counter on the scrub person's table. Broken or missing needles must be reported to the surgeon and accounted for in their entirety. Each institution should have established policies for dealing with incorrect counts. Unintentional retention of objects during surgery has been identified as a "Never Event"; institutions need to adopt a comprehensive strategy to manage the complexity of this issue. Strategies include several elements, such as emphasizing forced communication, standard processes, and checklists (Figure 6-14). In general, the surgeon is immediately notified of an incorrect count; a recount is initiated. Sterile team members and the perioperative nurse initiate a search of the sterile and unsterile fields. If the missing item is not revealed after a recount and search, the surgeon is asked to explore the wound. If the missing item is still not found, agency policy may dictate that an x-ray film be taken. Documentation of these activities should be completed according to institutional policy and procedure.

Sharps No-Touch Technique

Because sharp instruments used in surgery are a frequent cause of injury, recommendations for eliminating hand-to-hand passing have been established and numerous engineering controls, such as safety scalpels and blunt suture needles, have been developed (Evidence for Practice, p. 193).

Based on Occupational Safety and Health Administration (OSHA) regulations and the Standard Precautions of the Centers for Disease Control and Prevention (CDC), institutions should have written policies regarding the handling of sharp instruments and needles at the surgical field. In a no-touch technique, sharps are placed in a predesignated basin, tray collection device, or safe "neutral" zone on the field, from which the surgeon can retrieve the sharps. After use, the item is placed back in the neutral zone, and the scrub person retrieves it. This technique eliminates hand-to-hand passing of sharps between the surgeon and the scrub person, such that no two individuals touch the same sharp at the same time, reducing the chance of accidental needle punctures and cuts. All sharps should be accounted for and properly disposed before the room is prepared for the next patient.

The Needlestick Safety and Prevention Act was signed into law November 6, 2000, and changes to OSHA's Bloodborne Pathogens Standards mandated by this Act took effect in April 2001. In fact, OSHA has also reported that the OR is a more

PATIENT SAFETY

Prevention of Unintentionally Retained Objects

Counts are performed to account for items and to ensure that the patient is not injured as a result of a retained foreign body. Implementation of accurate count procedures and clear communication between the members of the surgical team help to promote an optimal perioperative patient outcome. Many institutions have developed strategies to reduce the risk to the patient of negative outcomes resulting from inadvertent retention of foreign bodies, including worksheets (Figure 6-13), checklists (Figure 6-14), guidelines, and policies.* The following are examples of policy statements:

- *Purpose:* Counts are performed to account for items and to ensure that the patient is not injured as a result of a retained foreign body. Implementation of accurate count procedures and clear communication between members of the surgical team help promote an optimal perioperative patient outcome.†
- Sponge, instrument, needle, and miscellaneous item counts should be performed for all procedures in which the possibility exists that a foreign body could be retained. The counting procedure must be followed unless an exception exists or the surgeon or anesthesiologist determines that the patient is medically unstable and there is no time to perform counts. In this circumstance, an x-ray will be ordered by the surgeon to be taken before the patient leaves the OR at a time when the patient is deemed medically stable.‡
- Active communication between all members of the surgical team must be employed in the count process, which includes verbal notification of the status of all counts when executed.
- To ensure patient safety, distractions must be avoided during the count process.
- An exploration of the operative site should be performed by the surgeon before the closure.
- An x-ray must be taken in the OR before the emergence from anesthesia in all cases in which a count is deemed incorrect, unless the surgeon or anesthesiologist determines that the patient is medically unstable and there is no time to perform counts.

EXCEPTIONS TO COUNTS ARE PERMITTED IN THE FOLLOWING LIMITED CIRCUMSTANCES:

- *Emergent procedures:* A count may be deferred in a procedure that is performed emergently in a medically unstable patient for whom there is no time to perform counts (e.g., cardiac bring-back, abdominal aortic aneurysm [AAA], multiple trauma, converting from laparoscopy to laparotomy).
- *Hips and shoulder arthroplasties (total and partial)*
  1. An instrument count may be deferred when an x-ray is taken immediately post-procedure in the PACU.
  2. Sponges, sharps, and miscellaneous items must be counted according to policy.
- *Total knee*
  1. An instrument count is not required for total knee arthroplasties.
  2. An x-ray is not required.
- *Medical implant procedures:* Instrument counts may be deferred during procedures in which there are numerous items of hardware (such as spinal surgery) and an x-ray is taken before the conclusion of the procedure. Sponges, sharps, and miscellaneous items must be counted according to policy.
- *Needles:* When it is identified that the missing needle is 9.5 mm or smaller, an x-ray does not have to be obtained for an incorrect count.
- *Complex, multi-setup procedures*
  1. Counting instruments detracts from, and may be detrimental to, the care of the patient during highly complex procedures that require more than one setup and/or excessive instrumentation.
  2. Certain procedures may be predetermined to meet these criteria (e.g., deep inferior epigastric perforator (DIEP) flaps, transverse rectus abdominus myocutaneose (TRAM) flaps, abdominoplasty).
  3. In circumstances as described in III.5.a above, the circulating nurse and the surgeon may collaborate during the briefing before the beginning of the procedure to set the framework for the day.
  4. A determination may be made that the instrument count be deferred and replaced with an x-ray at closure.
- Any other exception to this policy needs to be approved by the Chief of Surgery (or designee) or the Chief of Anesthesia (or designee) before the patient's emergence from anesthesia.
- If a count is not completed under one of the permitted exceptions and a possibility exists that a sponge/sharp/instrument/miscellaneous item could be retained, *an x-ray of the entire operative area must be taken before the patient leaves the OR,* if the patient's condition permits. If the patient is medically unstable, an x-ray will be ordered by the surgeon before the patient leaves the OR and taken in the ICU when the patient is deemed medically stable by the surgeon.
- The **ONLY** exception to getting an **x-ray** under this policy is if a count is incorrect **solely** on the basis that a sponge, instrument, or miscellaneous item is intentionally retained with the patient, thereby making the count technically incorrect. The retained items(s) must be documented in the intraoperative documentation record and the surgical procedure note.

†Documentation of this process will be done utilizing *Part A of the Count Safety Checklist* (see Figure 6-14).
‡The information will be communicated by the circulating nurse to subsequent circulating nurses during all hand-off reports.
*Sponges, sharps, and miscellaneous items must be counted according to policy.
Policy statements used with permission Beth Israel Deaconess Medical Center, Boston, Mass.

hazardous work environment than a construction site (Taylor, 2006). Considerations for the perioperative healthcare team include the following:

- Blunt needles, stapling devices, adhesive strips (skin tapes), and tissue adhesives are used whenever clinically feasible to reduce the use of sharp suture needles.
- Scalpel blades with safety features are used.
- Alternative cutting methods are used when appropriate.
- Manual tissue retraction is avoided by using mechanical (self-retaining) retraction devices.
- All equipment that is unnecessarily sharp is eliminated.
- Double-gloving is employed.
- Eye protection and face shields are used by all healthcare team members.
- Appropriate use and disposal of all sharps is mandated (Box 6-3).

Patient Name: _____ Date: _____

Needles

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200

Blades

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40

Hypos

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Lap Sponges

5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200

Raytext Sponges

10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
210	220	230	240	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390	400

Clip Houses

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40

Miscellaneous Items

ESU Tips	ESU Scratch Pad							

FIGURE 6-13 Example of a count sheet.

1. Embed forced, "structured" communication between members of the team when resolving counts
   - ✓ Mandating Attending-to-Attending communication in "real-time"
   - ✓ Mandating a scripted discussion that all cavities that could harbor a retained object have been searched
   - ✓ Clarify "Hand-off" content — No staff changes during resolution process
   - ✓ Create clear expectations of how to elevate discrepancies
2. Standardize the mechanism to respond to incorrect counts
   - ✓ Count process including documentation
   - ✓ Response to incorrect counts in a structured manner prescribing roles of all team members
   - ✓ Embed response by radiology to include concurrent visualization of all x-rays by entire team, inclusion of a "like-object" with the film
   - ✓ Document the steps of the room search
   - ✓ Create pathway for managing intentionally retained objects
   - ✓ Create a pathway for managing intentionally not retrieved objects
3. Establish clear resolution process for the resolution of incorrect counts
   - ✓ Count Safety Checklist forces a standard approach to resolution
   - ✓ Implement a "No Hand-off Zone" during incorrct count resolution
   - ✓ Develop a digital library to enhance radiology recognition

FIGURE 6-14 Management of incorrect counts. (Adapted from Beth Israel Deaconess Medical Center Count Safety Checklist.© Used with permission.)

EVIDENCE FOR PRACTICE

Preventing Sharps Injuries

The Exposure Prevention Information Network (EPINet) is a voluntary surveillance system used to track needle-stick injuries. During the period from 1993 to 2001, 29% of OR injuries occurred between steps in the procedure, such as when passing sharp devices. Another 29% of injuries occurred after the device was used, but before it was disposed—that is, while disassembling the device. Suture needles caused 34% of injuries to perioperative nurses, whereas scalpels were responsible for 19% of injuries.

Although 2002 data revealed that the number of injuries from reusable scalpels had declined, the proportion of injuries to perioperative nurses from suture needles increased. Perioperative nurses should use the following best practices for handling sharps:

- Double-glove; inspect gloves for punctures frequently.
- Use standardized sterile field setups.
- Keep all sharps on instrument tables or trays with the points away from staff members.
- Use a neutral zone or hands-free method for passing sharps. Establish the neutral zone before the initial surgical incision (a magnetic pad or basin may be used to create the neutral zone; if a basin is used, it should be placed on the field and not held by the scrub person).
- Dedicate the neutral zone for sharps only (these include suture and hypodermic needles, scalpels, and other sharp instruments). Include identification of the neutral zone during hand-off communications to relief scrub persons.
- Only one sharp at a time should be in the neutral zone.
- Avoid handling suture needles manually whenever possible. Instead, use a needle holder, forceps, or suturing assist device.
- Do not hold a sharp and any other instrument simultaneously.
- Announce the transfer of a sharp before placing it in the neutral zone. After the announcement, orient the sharp in the correct position in the neutral zone. The scrub person and surgeon or assistants should communicate about the best placement of sharps in the neutral zone.
- Do not use fingers to touch tissue being cut or sutured.
- Know where all sharps are located throughout the procedure.
- Confine and contain all sharps in a disposable, puncture-resistant needle container.
- Pass sharp, long laparoscopic instruments handle first, keeping the tip down.
- At the conclusion of the procedure, verify that the container holding sharps is securely closed.

Modified from AORN guidance statement: Sharps injury prevention in the perioperative setting. In *Perioperative standards and recommended practices*, Denver, 2009, The Association; Perry J, Jagger J: Exposure safety—pass with care in the OR, *Nursing 2005* 35(2):70, 2005.

BOX 6-3

Sharps Disposal Containers

- Durable, closable, leakproof, and puncture resistant
- Appropriate size for user and type of sharps
- Lids allow sharps to enter by gravity without need for additional manipulation
- Within horizontal reach of healthcare team members (close to the point of use) who dispose of sharps
- Container, level of fullness (full line), proper warning labels (biohazard labels), and color coding (orange, orange-red) must remain visible to healthcare team members
- Self-closing lids to prevent overfill if container is not "see-through" to observe fill line
- Ease of assembly and operation, including one-handed disposal

Modified from AORN guidance statement: Sharps injury prevention in the perioperative setting. In *Perioperative standards and recommended practices,* Denver, 2009, The Association; Davis MS: *Advanced precautions for today's O.R.,* ed 2, Atlanta, 2001, Sweinbinder.

The risk of transmission after a needle-stick or sharps injury is estimated to be 6 to 30 out of every 100 people for hepatitis B virus (HBV), 3 to 10 out of every 1000 people for hepatitis C virus (HCV), and 1 out of every 300 people for human immunodeficiency virus (HIV). If an occupational exposure or injury occurs that could result in a bloodborne pathogen exposure, the injured person should do the following (Kenny, 2005):

- Immediately flood the exposed area with water.
- Clean the wound with an antimicrobial skin disinfectant or soap and water.
- Alert the nurse manager or other appropriate person.
- Identify the source patient.
- Immediately report to employee health department (or the appropriate institutional department).

An immediate evaluation and risk assessment are done. A postexposure treatment plan is initiated with counseling, education, and follow-up testing 1 year after exposure.

All OR personnel should work collaboratively to select the least dangerous device that would accomplish the intended function (e.g., cutting, providing hemostasis, retracting, suturing) efficiently and effectively. By doing so, perioperative personnel may significantly reduce the rates of injuries in the OR and exposures to blood and bloodborne pathogens.

INSTRUMENTS

Historical Perspective

The history of surgical instruments dates back to 2500 BC. The first instruments were sharpened flints and fine animal teeth. Ancient Greek, Egyptian, and Hindu instruments are amazing in their resemblance to contemporary instruments.

To be equipped for the practice of surgery in the late 1700s, the surgeon had to employ various skilled artisans, such as coppersmiths; steelworkers; needle grinders; turners of wood, bone, and ivory; and silk and hemp spinners. The surgeon had to explain the mechanisms of the instruments and supervise their manufacture. The resulting instruments were crude, expensive, and time-consuming to make. Each artisan used hand labor exclusively and devoted time to making only one type of instrument, thus gaining proficiency in the manufacture of a certain kind of instrument. For example, a cutter would keep a small supply of surgical knives. Thus began physicians' supply houses and surgical instrument making.

In the mid-1800s, physicians' principal tools were their eyes and ears. Official records show that amputation, the trademark of the Civil War, was the result in three of four operations. Surgeons were scarce, and medical instruments were almost nonexistent. Kitchen knives and penknives, carpenter saws, and table forks did the job. After the Civil War, the advent of the administration of ether and chloroform brought a demand for new ideas and methods in surgery and instruments. The division of general surgery into specialties occurred in the late 1800s and early 1900s. Delicate instruments were seen as more useful than the force of crude and heavy instruments. So that instruments could withstand repeated sterilization, handles of wood, ivory, and rubber were discontinued.

The development of stainless steel in Germany ensured a better material for surgical instruments and other equipment. Today, surgeons and perioperative nurses assist manufacturers in research, design, and development of new and better instrumentation. Most instrument companies design an instrument to a physician's specifications. Advancement in endoscopic surgery continually requires the development of instrumentation specifically designed for this type of surgery.

Throughout the history of surgery, the tools of the surgeon and the manual aspects of the surgical technique have influenced the evolution of practice. Along with innovative wound closure materials and tools in recent decades, there have been unprecedented developments of new and improved instrumentation. The benefits of minimally invasive surgery are well documented, especially in surgical procedures that typically required lengthy hospital stays, required long and sometimes difficult postoperative recovery or rehabilitation, and exposed the patient to increased risk of surgical infection.

Composition of Surgical Instruments

Successful management of instrumentation requires a continual partnership between surgeons, perioperative nurses, surgical technologists, and central processing personnel, each of whom shares responsibility for the use, handling, and care of surgical instruments. A basic knowledge of how these instruments are manufactured can help in their selection and maintenance. Surgical instruments are expensive and represent a major investment for every institution.

Instruments used today are made in the United States, Germany, France, and Pakistan. The United States does not have an agency that reviews or sets standards for surgical instruments. The quality is set by the individual manufacturer. A reputable company endorses its product. An instrument that receives proper care should last 10 years or more.

Most instruments are manufactured from stainless steel. Stainless steel is a compound of iron, carbon, and chromium, which means that stainless steel can have varying qualities. These qualities are designated by grading the steel into series by the American Iron and Steel Institute (AISI). The 400 series stainless steel has some noncorrosive characteristics and good tensile strength. It resists rust, produces a fine point, and retains a keen edge. Handheld ringed instruments, such as scissors and clamps, should be 400 series stainless steel.

For ringed instruments, the raw steel is converted into instrument blanks by a machinist making an impression of the piece in a stainless-steel blank. These blanks are die-forged into specific pieces—male and female halves. The excess metal is trimmed away, and the instrument parts are ready for the final steps.

The two halves are milled to prepare the box lock fittings, jaw serrations, and ratchets, and the jaws and shanks are properly aligned. After this is completed, the halves are assembled by hand. A hole is drilled through the box lock, and a pin or rivet is inserted through the hole. Final grinding and hardening, accomplished by heat-treating, permit the object to attain proper size, weight, spring temper, and balance.

The last part of the process is called *passivation*. The instruments are submerged into nitric acid to remove any residue of carbon steel. The nitric acid also produces a surface coating of chromium oxide. Chromium oxide is important because it produces a resistance to corrosion in the stainless-steel instrument. The instrument is then polished.

There are three types of instrument finishes. The first is the bright, highly polished mirror finish, which tends to reflect light and may interfere with the vision of the surgeon. The second is the satin or dull finish, which tends to eliminate glare and lessen eyestrain for the surgeon. The third finish is ebonized, which produces a black finish. Ebonized instruments are used during laser surgery to prevent deflection of the laser beam.

The final inspection and testing are for hardness, proper jaw closure, and smooth lock-and-ratchet action. The instrument is then ready for sale.

Instrument Categories

Although there is no standard nomenclature for specific instruments, there are four main categories: *cutting instruments* (also called *dissectors*), *clamps, retractors,* and *accessory* or *ancillary* instruments.

Cutting Instruments (Dissectors). Dissectors, which may be sharp or blunt, are instruments used to cut or separate tissue. The largest categories of sharp dissecting instruments are scalpels and scissors. Scalpels are probably the oldest of all surgical instruments (Figure 6-15). Most scalpels are handles (knife handle) with one end suited to the attachment of disposable blades (Figure 6-16). Safety scalpels have been modified to provide an engineering control in sharps injury prevention strategies. During an operation, the blades may be conveniently changed by the scrub person as often as necessary. The blades are available prepackaged and sterile and are passed onto the sterile field as needed by the perioperative nurse. Careful handling of blades during the procedure and disposal of blades at the end of a procedure are important in the implementation of Standard Precautions.

Scissors are designed in various shapes and sizes for different purposes in cutting body tissues and surgical materials. The basic design consists of two blades, each having a chisel-shaped edge with the bevel consistent with the structure or material it has to cut. Scissor tips may be blunt or sharp, and the blades may be straight or curved. Conventional scissors require two movements in use: one to open and another to close the jaws. Other scissors may have a spring action in the body design that holds the jaws in an open position. A single movement pressing the spring together closes the jaws to cut. Scissors designed for delicate plastic and eye surgery are often of the latter type. A basic instrument set usually includes a curved Mayo scissors for dissection of heavy tissues, a Metzenbaum scissors for dissection of delicate tissues, and a straight scissors for cutting suture. For surgery in deep areas of the body, scissors with long handles and short blades are used for better control and easier use.

Other sharp dissectors include drills, saws, osteotomes, rongeurs, and other instruments such as adenotomes and dermatomes. Some instruments in the dissecting category are produced in sharp or blunt form, such as curettes and periosteal elevators. Instruments or devices used for blunt dissection include gauze dissectors (e.g., peanuts, pushers, kitners), a sponge on a stick, the back of a knife handle, and the surgeon's finger or hand.

Clamps. Clamps are instruments specifically designed for holding tissue or other materials, and most have an easily recognizable design. They have finger rings, for ease of holding;

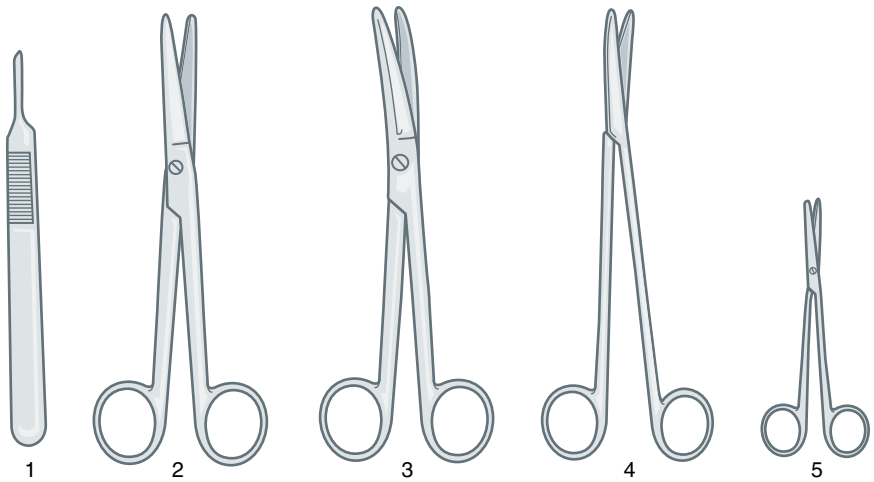


FIGURE 6-15 Basic cutting instruments. *1,* Knife handle; *2,* Mayo scissors, straight; *3,* Mayo scissors, curved; *4,* Metzenbaum scissors, curved; *5,* suture scissors, straight.

shanks, whose length is appropriate to the wound depth; ratchets on the shanks near the rings, which allow for the distal tip to be locked on the tissue or object grasped; a joint, usually a box lock (described later), which joins the two halves of the instrument and allows opening and closing of the instrument; and a jaw, which is the working portion of the instrument and defines its use (Figure 6-17). Clamps are divided into the following categories.

Hemostats are used to close the severed ends of a vessel with a minimal amount of tissue damage (Figure 6-18). They prevent the excessive loss of blood in the course of dissection. The jaws have deep transverse cuts so that the bleeding vessels may be compressed with sufficient force to stop bleeding. The serrations must be cleanly cut and perfectly meshed to prevent the tissue from slipping free from the jaws of the clamp.

Occluding clamps usually have vertical serrations or special jaws that have finely meshed, multiple rows of longitudinally arranged teeth to prevent leakage and to minimize trauma when clamping bowel, vessels, or ducts that are to be reanastomosed.

Graspers and *holders* are used for tissue retraction and generally have jaws of specific design based on their use (Figure 6-19).

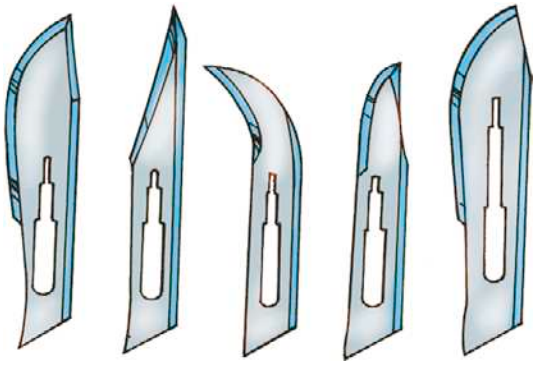


FIGURE 6-16 Scalpel/knife blades. From left to right: blade sizes 10, 11, 12, 15, and 20, respectively (actual size).

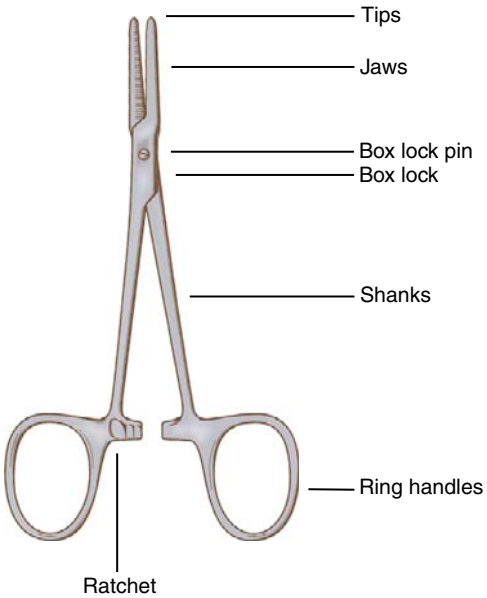


FIGURE 6-17 Anatomy of a clamp.

The Kocher (also referred to as an Ochsner) clamp has transverse serrations and large teeth (1 × 2) at its tip to grasp tightly on tough, slippery tissue such as fascia. The Allis clamp has multiple, interdigitating short teeth on the tip, minimizing crushing or damaging tissue. The Babcock clamp has broad, flared ends with smooth tips, and it atraumatically grips or encloses delicate structures, such as bowel, ureters, or fallopian tubes. Other holding forceps have handles like clamps with specialized tips or jaws, which may be triangular, straight, angular, or T-shaped.

Nonclamp graspers and holders are known as *forceps* or *pickups* because they are used to lift and hold tissue (see Figure 6-19). Often, while the surgeon is cutting with scissors or sewing with a needle, forceps are used in the other hand. Forceps are held like a pencil. The most common kinds are the various two-arm spring forceps. Forceps resemble tweezers, vary in length and thickness, and are available with and without teeth. Nontoothed forceps create minimal damage and hold delicate, thin tissues. Toothed forceps hold thick or slippery tissues that need extra grip. Toothed forceps ("rat tooth") have interdigitating teeth that hold tissue without slipping; these are used to hold skin or dense tissue. Adson tissue forceps have small, serrated teeth on the edge of the tips; these are designed for light, careful handling of tissue and are commonly used during skin closure.

Grasper and holder clamps may hold objects as well. Sponge-holding forceps with ring-shaped jaws (see Figure 6-19) are available in 7- and 9-inch lengths. They can be used to grasp or handle tissue but are commonly used as sponge holders. A gauze sponge is folded and placed in the jaws and is used to retract tissue, to absorb blood in the field, and occasionally to perform blunt dissection.

Needle holders (Figure 6-20), because they must grasp metal rather than soft tissues, are subject to greater damage. As a result, needle holders must be repaired and replaced regularly. For maximal usage, needle holders must retain a firm grip on the needle. Many types of jaws have been designed to meet this need. The so-called *diamond jaw* needle holder has a tungsten carbide insert designed to prevent rotation of the needle. In needle holders of standard design, a longitudinal groove or pit in the jaw releases tension, prevents flattening of the needle, and holds the needle firmly. Needle holders may have a ratchet similar to that of a hemostat, or they may have a spring action that may or may not lock.

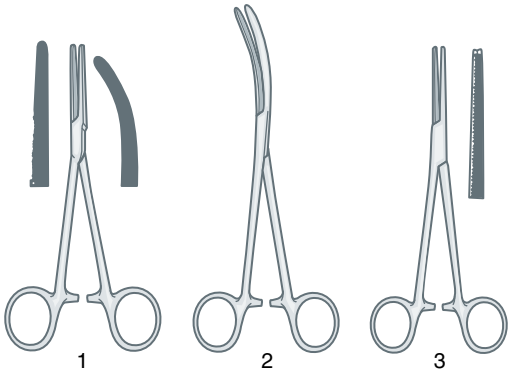


FIGURE 6-18 Basic clamping instruments. *1,* Crile hemostatic forceps; *2,* Rochester-Péan forceps; *3,* Ochsner or Kocher hemostatic forceps.

Towel clamps also are considered holding instruments. Of the two basic types, one is a non-penetrating towel clamp used for holding draping materials in place. The other has sharp tips used to penetrate drapes and tissues, and it is damaging to both. The use of sharp towel clamps to secure drapes is highly discouraged because they penetrate the sterile field.

INSPECTION AND CARE. The apposition of the instrument's tips is necessary for its functioning and must be periodically checked. When a hemostat is held up to the light and the handles are fully closed, no light should be visible between the jaws. These instruments, if used for purposes other than those for which they are intended, can be damaged and need

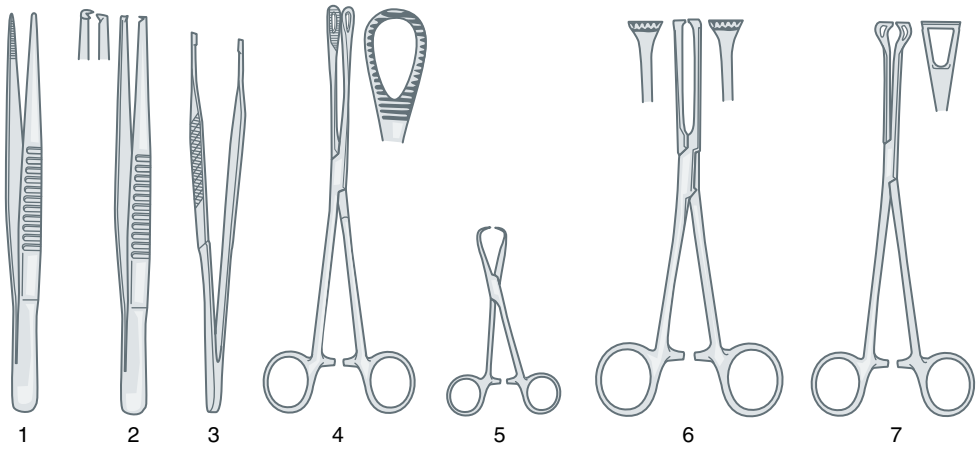


FIGURE 6-19 Basic holding instruments. *1,* Tissue forceps, smooth; *2,* tissue forceps with teeth; *3,* Adson tissue forceps; *4,* Sponge-holding forceps; *5,* towel clamp; *6,* Allis forceps; *7,* Babcock intestinal forceps.

FIGURE 6-20 **A**, Needle holders. **B**, Fine. **C**, Regular. **D**, Heavy.

to be repaired. The instrument's joint also must be checked. Instruments made up of two halves have one of three types of joints.

- The most common joint is the box lock, where one arm has been passed through a slot in the other arm and is riveted or pinned. This joint is needed where accurate approximation of the tips is necessary, and it is basic to most ringed instruments.
- The second type is the screw joint. The two halves are aligned and placed on top of each other, connected only by a screw. The joint must be checked and tightened periodically because the screw may become loose. Screw-joint instruments are easy to make and comparatively inexpensive.
- The final and least common type is the semibox, or aseptic, joint. It has the advantage that the two halves can be separated for easy cleaning.

All types of joints must be cleaned regularly. Protein deposits or rust collecting at the site must be removed to ensure proper functioning.

Retractors. Retractors are used to hold back the wound edges, structures, or tissues to provide exposure of the operative site. A surgeon needs the best exposure possible that inflicts a minimal degree of trauma to the surrounding tissue. Retractors are self-retaining (Figure 6-21) or manually held in place by a member of the surgical team. The two types of self-retaining retractors are (1) retractors with frames to which various blades may be attached, and (2) retractors with two blades held apart with a ratchet. An example of the latter is a Weitlaner retractor. Other very large self-retaining retractors, such as the Omni or Bookwalter, are equipped with multiple blades and attachments of varying lengths and sizes. With handheld retractors, the handles may be notched, hook-shaped, or ring-shaped to give the holder a firm

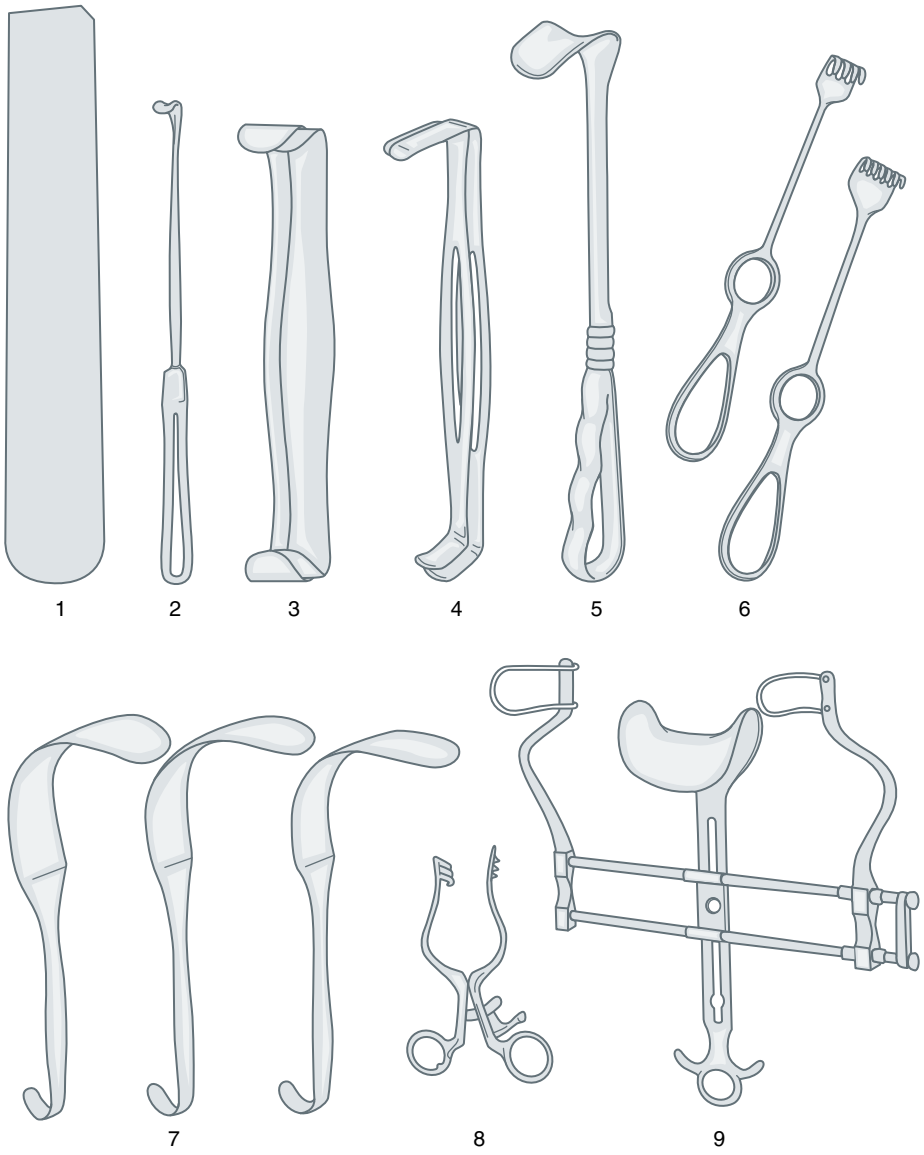


FIGURE 6-21 Basic retractors. *1,* Malleable retractor; *2,* vein retractor; *3,* Parker retractor; *4,* Army-Navy retractor; *5,* Richardson retractor; *6,* Volkmann rake retractors; *7,* Deaver retractors; *8,* Weitlaner retractor; *9,* Balfour retractor with blades.

grip without tiring. The blade is usually at a right angle to the shaft and may be a smooth blade, rake, or hook. A malleable (ribbon) retractor is a flat metal ribbon that may be shaped at the field.

Accessory and Ancillary Instruments. Accessory and ancillary instruments are designed to enhance the use of basic instrumentation or to facilitate the procedure (Figure 6-22). These include suction tips and tubing; irrigators-aspirators; electrosurgical devices; and special-use devices, such as probes, dilators, mallets, and screwdrivers.

Many miscellaneous instruments or specialty items are particular to a certain specialty but generally fall into one of the categories just mentioned. Microsurgical instruments are delicate and expensive. They are extremely fine and should be handled separately from other instruments. Instruments used in specialty surgery are discussed in each of the chapters under Surgical Interventions.

When nursing team members can analyze the planned surgical procedure and approach and identify each instrument and its specific function, they are able to select instrument sets without omitting necessary items and without including items that will not be used. This intelligent, planned approach ensures economy of time and motion, protects instruments from misuse, and prevents unnecessary handling. During the operation, the informed scrub person who anticipates instrument needs becomes a more valuable member of the surgical team.

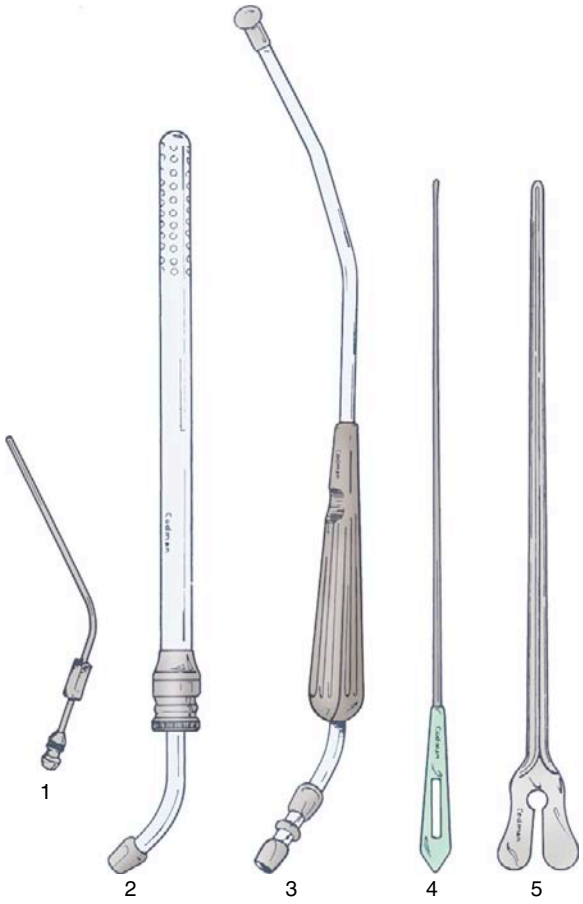


FIGURE 6-22 Accessory items. *1,* Frazier suction; *2,* Poole suction; *3,* Yankauer suction; *4,* Silver probe; *5,* Grooved director.

Endoscopic Instrumentation

Laparoscopy has introduced new equipment and instrumentation to the surgical suite (see Chapter 7 for a full discussion of laparoscopic equipment). In addition to insufflation equipment, an optical system, and a documentation system, perioperative personnel must be familiar with the instrumentation used by the surgeon when performing a surgical procedure through the endoscope. Basic instrumentation, which may be disposable or reusable, includes trocars, forceps or graspers, clip appliers, stapling devices, scissors, needle holders, and aspiration-irrigation systems.

Verres needles and trocars provide access to the peritoneal cavity. A retractable safety shield protects abdominal structures from being inadvertently punctured during insertion. Forceps or graspers are available in 3-mm, 5-mm, and 10-mm sizes. Atraumatic graspers provide appropriate retraction and little risk to tissues. Bipolar coagulation forceps are used to control bleeding. The forceps are available with different tips, including ring, paddle, dolphin nose, claw, spoon, DeBakey, Allis, Pollack, Pennington, Glassman, Maryland, Reddick-Saye, Duval, and Babcock. Some dissectors are available with coagulation capability. Scissors also come with different tips: hook, straight and microtipped, serrated, and curved. Also, several disposable instruments coagulate and cut the tissue. One such instrument is the Harmonic Scalpel (discussed in Chapter 7).

Needle holders have a hinged-jaw tip to allow easy positioning of the needle before intracorporeal suturing and using the sliding sheath. The sliding sheath holds the needle in a distal notch and inner spring-loading mechanism. To aid with extracorporeal knot tying, the surgeon may use a knot pusher (e.g., a Clarke-Reich) to deliver tied knots into the abdomen. A slide and cinch pusher (Gazayerli) also is used to deliver and secure the preformed knot. Intraabdominal stapling devices have been modified to fit and function through the endoscope.

Stapling Instruments

Instrumentation for internal stapling, first introduced in 1908, has been refined and is now widely used (Figure 6-23). Various instruments to suture tissue mechanically are used for ligation and division, resection, anastomoses, and skin and fascia closure. In general, these instruments may be classified as follows (Neumayer and Vargo, 2008):

- Ligating and dividing staplers (LDSs)
- Gastrointestinal anastomosis (GIA) staplers (Figure 6-24)
- Thoracoabdominal (TA) staplers
- End-to-end anastomosis (EEA) staplers
- Laparoscopic hernia mesh staplers
- Open hernia mesh staplers
- Endo-GIA devices

Employed in many surgical specialties, the mechanical application of these instruments reduces tissue manipulation and handling. The edema and inflammation that usually accompany anastomoses are minimized because the noncrushing B shape of the staples allows nutrients to pass through the staple line to the cut edge of the tissue.

Mechanical staplers (both nondisposable and disposable) use cartridges of tiny stainless-steel staples or absorbable, nonmetallic staples that are commercially preloaded, prepackaged, and presterilized. The staples are essentially nonreactive; metal

staples remain permanently in the tissue. The staplers may fire individually or lay down multiple rows in a straight or circular pattern. Devices to cut or anastomose bowel and other structures are available for open-wound use or through endoscopic cannulae. The use of staplers significantly decreases operating time and may shorten postoperative stays.

Selecting and Preparing Instruments for Patient Use

Designated OR or central supply personnel arrange the various instruments into trays or sets. The trays are named according to their functions. Tray/set names and instrument composition will vary by institution, but three basic OR instrument sets are the minor/plastic, the basic laparotomy, and the dilation and curettage (D&C). A minor (or plastic surgery) set includes instruments needed for simple superficial incision, excision, and suturing. A basic laparotomy set includes instruments to open and close the abdominal cavity and repair any gross defects in the major body musculature. A D&C set, in addition to its use for dilation and curettage, is often used as the basic instrumentation for vaginal surgery.

According to each procedure's needs, more individualized instruments or specialty sets, such as an intestinal set or a vascular set, may be added. In the same way, basic instrument sets may be selected for opening other body cavities, such as the skull, chest, and pelvis.

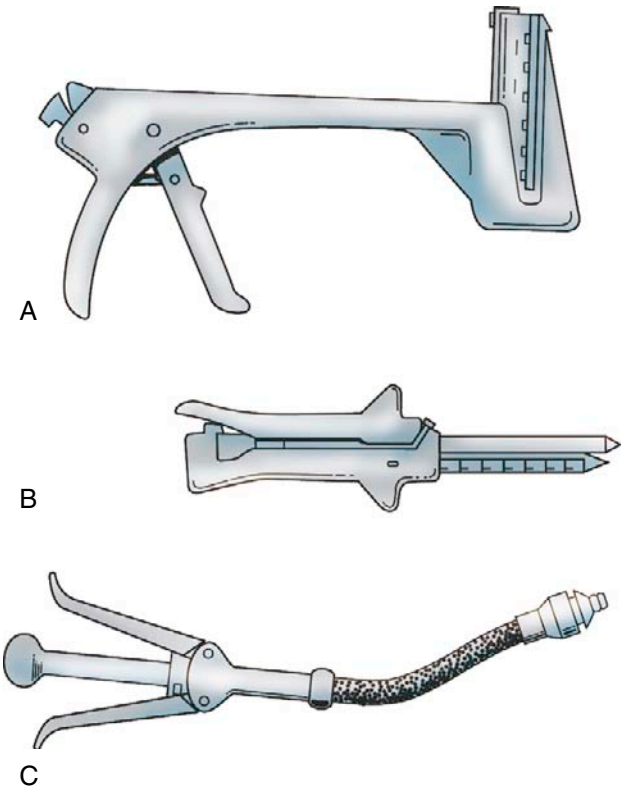


FIGURE 6-23 Internal staplers. **A**, Terminal end stapler, designed for closing the end of a hollow organ, such as the stomach, with a double staggered line of staples. **B**, Internal anastomosis stapler, designed to connect hollow organ segments to fashion a larger pouch or reservoir. **C**, End-to-end stapler, designed to staple two hollow, tubelike organs, such as bowel, to create a continuous circuit.

Instruments are selected according to the size of the patient's body structures and the nature of the organs involved. Proper selection requires a general understanding of surgical procedures and approaches and knowledge of anatomy, possible pathologic conditions, and the design and purpose of instruments.

Basic Table Setups

In most ORs, the instruments are set up on Mayo stands and back tables in a planned, standardized, organized, functional manner to maintain continuity when the original scrub person is replaced by another. Care is taken on all sterile fields to ensure that all solutions, syringes, and medication cups are clearly labeled to guarantee patient and staff safety. Each facility should create tools as a part of a comprehensive orientation process to ensure standardization of setups.

A proficient scrub person must know the instrument inventory of the department; the instruments routinely needed for each type of operation; the individual surgeon's preferences; and the correct use and handling, method of preparation, and postoperative care of the instruments. A file of preference cards or computerized data/preference sheets usually lists the procedures each physician performs, the physician's glove size, the preferred skin prep solution, specific draping instructions, and instruments required for the procedure.

Before an operative procedure, the scrub person may assist the perioperative nurse in gathering the needed supplies, equipment, and sutures. The scrub person scrubs; dons gown and gloves (see Chapter 3); and begins to set up the sterile tables with drapes, instruments, supplies, and sutures. Instruments are arranged with those most frequently used on the Mayo stand. When the patient is on the OR bed and is draped, the Mayo stand, set up for instrument use at the immediate operative site, is brought across the lower part of the patient's legs (Figure 6-25).

One or two back tables, according to the number of instruments and supplies, also are set up. The scrub person prepares the sutures and ligatures and places the knife blades on the handles. Other supplies needed are suction tubing and tips, electrosurgical cord and tip, drains, basins, gowns, gloves, drapes, sponges, and needles, all of which are sterile and set up on the back table according to standardized institutional policy

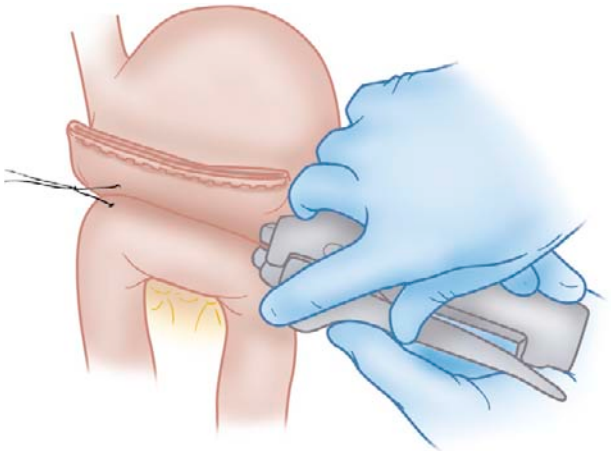


FIGURE 6-24 Using the GIA stapler to staple and join stomach and jejunum. At the same time, the blade in the GIA cuts between double staple lines, creating a stoma for a gastrojejunostomy.

FIGURE 6-25 Mayo stand, with instruments required for start of surgical procedure, is moved into place across the lower part of the draped patient.

(Figure 6-26). During the "Final Time-out" before incision, the scrub person has the responsibility to articulate instrument and equipment readiness to the team to enhance a safe, seamless procedure.

The scrub person must be attentive to the sterile field to anticipate the surgeon's needs. Instruments should be passed in a positive and decisive manner. Each instrument is placed or slapped firmly into the surgeon's palm in such a manner that it is ready for immediate use with no wasted motion. When a curved instrument is passed to the surgeon, the curve should be pointing in the direction of intended use; there should be no need for readjustment. It is necessary to know if a surgeon or assistant is left-handed or right-handed to pass instruments efficiently and in the correct position.

Often the surgeon or assistant uses hand signals for the type of instrument desired, to eliminate unnecessary talking. Scrub persons should become familiar with the basic signals for knife, scissors, suture, forceps, and clamp.

Care and Handling of Instruments

An instrument should be used only for the purpose for which it is designed. Proper use and reasonable care prolong its life and protect its quality. Scissors and clamps, which are most frequently misused, can be forced out of alignment, cracked, or broken when used improperly. Tissue scissors should not be used to cut suture or gauze dressings. Hemostatic clamps should not be used as towel clamps or to clamp suction tubing.

Instruments must be handled gently. Bouncing, dropping, and setting heavy equipment on top of them must be avoided. During the procedure, the scrub person should wipe the used instruments with a damp sponge or place them in a basin of sterile distilled water to prevent blood from drying on the surfaces and in the box locks. Saline solution should never be used on instruments because the salt content is corrosive and accelerates rusting or deterioration of the metal. As time allows during the procedure, the scrub person should rinse and dry the used instruments and replace them on the back table to facilitate closing counts.

At the end of a procedure, during the table breakdown process, the scrub person must handle the instruments in a logical organized fashion, either individually or in small groups. Sharp and delicate instruments should be set aside for individual handling and cleaning to avoid damage and accidental injury. Surgeon-specific instrumentation should be isolated to prevent loss or damage in the cleaning and reassembly process. Standard Precautions should be applied as dictated by institutional policy. All instruments set up for the procedure should be terminally sterilized or disinfected before reassembly. Instruments must be completely clean to ensure effective sterilization.

Each instrument should be inspected before and after each use to detect imperfections. An instrument should function perfectly to prevent needlessly endangering a patient's safety and increasing operative time because of instrument failure.

Forceps, clamps, and other hinged instruments must be inspected for alignment of jaws and teeth. Instrument jaws and teeth should meet perfectly so that blood flow is occluded without damaging the vein or artery. Ratchets should hold firmly yet release easily. Instrument joints should work smoothly.

The edges of scissors should be tested for sharpness by cutting smoothly through four layers of gauze. All instruments

FIGURE 6-26 **A,** Back table setup. **B,** Labeled medications and sharps on table setup.

should be checked for worn spots, chips, dents, cracks, or sharp edges.

Damaged instruments should be set aside and sent for repair or replacement. An instrument repair service should be selected carefully and used for regular maintenance, such as sharpening and realignment.

With today's focus on cost containment, perioperative nurses must assess the care and handling of instrumentation carefully. Instrument sets can be monitored for use, and instruments that are used infrequently can be removed and packaged separately to prevent continued wear from unnecessary resterilization.

Instrument Counts

Instrument counts are standard practice. Establishing standardized instrument sets with the minimal numbers and types of instruments in them facilitates instrument counts and reduces the amount of time and space required for a setup. Initial counts should be carried out concurrently by the perioperative nurse and scrub person before the procedure, with each person simultaneously viewing the instrument and audibly counting it. This is the baseline count. To facilitate the baseline count, the scrub person needs to be in the OR or other invasive procedure room in a timely manner to complete the instrument setup. Items added

during the procedure are counted and immediately recorded. Subsequent counts should be taken before closure of a cavity or large, deep incision; when the scrub person or perioperative nurse is relieved by other personnel; and at the completion of the procedure. The method of counting should be consistent for every procedure, beginning at the surgical site and immediate surrounding area and moving to the Mayo stand, the back table, and then to items discarded from the field. Rushing at the end of a surgical procedure can result in incorrect or incomplete counts. When the scrub person and perioperative nurse are rushed, it may be necessary to call for a "pause for the count," enabling counts to be carried out in an orderly manner. Many institutions have implemented engineering controls to assist in the prevention of the unintentional retention of instruments and other surgical items. These controls do come at some expense. The literature is beginning to demonstrate models for predicting the cost-effectiveness of this new technology (Research Highlight).

Instruments that break during the procedure or are disassembled (e.g., certain retractor systems) must be accounted for in their entirety. The nurse documents all counts on the appropriate record.

RESEARCH HIGHLIGHT

Prevention of Retained Surgical Sponges: A Decision-Analytic Model Predicting Relative Cost-Effectiveness

In a very tight economy, it becomes increasingly difficult for perioperative leaders to prepare a business proposal for safety when considering the introduction of new technology. This study provides decision makers with critical quantitative data about new options available to assist in the prevention of unintentionally retained surgical sponges (RSS). An empirically calibrated decision-analytic model comparing standard counting against alternative strategies—universal or selective x-ray, bar-coded sponges (BCS), and radiofrequency-tagged (RF) sponges—was developed and tested. The study used standard decision trees to model the predicted incidence of RSS and the incremental costs for each prevention strategy. The base case was established by estimating model probabilities on a per-operation basis for an average inpatient population. Estimates of the likelihood of discrepancies and reconciliation were derived from field observations. The following treatment strategies were employed: no sponge tracking, standard counting protocol, universal radiography without counting, universal radiography added to standard counting, selective mandatory radiography for high-risk operations, BCS system, RF-tagged sponge system, and RFID system. Cost estimates were determined and cost-effectiveness and sensitivity analyses were completed. It was determined that standard counting protocols already detected >80% of RSS; however, sponges were still unintentionally retained in 12 of 100,000 operations. Through decision-analytic modeling, the authors illustrated that in order for a sponge-tracking strategy to be cost-effective, it must be able to nearly eliminate RSS while controlling the costs. The BCS strategy was found to be the most cost-effective adjunct of the methods reviewed.

Modified from Regenbogen SE et al: Prevention of retained surgical sponges: a decision-analytic model predicting relative cost effectiveness, *Surgery* 145(5):527-535, 2009.

Patient Safety

In 2002 the AORN initiated its *Patient Safety First Program* and has continued to assist perioperative nurses in maintaining a safe environment for surgical patients. Retained foreign bodies after surgery are a complication with serious potential consequences for the people involved. Several steps are taken to ensure that needles, sponges, and instruments are not retained in the patient, as follows:

- Identification and counting of instrumentation in instrument sets before sterilization
- Initial counting of all items at table setup, before the surgical procedure (baseline count)
- Counting of items added during the procedure
- Counting of items as the wound closure is initiated
- Final counting of items as wound closure is completed

Despite these efforts, items still may be retained in the patient after surgery. The Agency for Healthcare Research and Quality (AHRQ) has established quality indicators based on literature review, expert input, and empiric evaluation. Patient Safety Indicators (PSIs) constitute a set of measures that can be used to screen for problems that patients experience. One of these is "Foreign body left during procedure" (Elixhauser et al, 2005). In 2005 the American College of Surgeons issued a patient safety statement regarding the prevention of retained foreign bodies after surgery. Paramount to preventing retained foreign bodies are good communication, consistent practices, and wound exploration before closure of the surgical site (ACS, 2005).

Storing Instruments

Instruments should be stored in a manner that keeps them safe and supports the maintenance of the container's integrity. Cabinet shelving should be adjustable and properly spaced for storage of various sizes and types of instruments. Most institutions store instruments in presterilized trays or containers. Attached labels and diagrams in cabinets assist personnel. An inventory of all instruments should be taken at periodic intervals.

REFERENCES

American College of Surgeons (ACS): Patient safety statement on preventing retained foreign bodies after surgery, 2005, available at www.facs.org/news/patientsafetystatements.html. Accessed July 12, 2009.

Association of periOperative Registered Nurses (AORN): Official statement on RN first assistants. In *Perioperative standards and recommended practices,* Denver, 2009a, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for sponge, sharp and instrument counts. In *Perioperative standards and recommended practices,* Denver, CO, 2009b, The Association.

Berguer R, Heller PJ: Strategies for preventing sharps injuries in the operating room, *Surg Clin North Am* 85:1299–1305, 2005.

Bulechek GM et al: *Nursing interventions classification (NIC)*, ed 5, St Louis, 2008, Mosby.

Elixhauser A et al: Using the AHRQ quality indicators to improve health care quality, *Jt Comm J Qual Patient Saf* 31(9):533–538, 2005.

Food and Drug Administration (FDA): FDA Clears First of Its Kind Suture Made Using DNA Technology, available at www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/2007/ucm108843.htm. Accessed July 12, 2009.

Kenny P: Safe needles save lives, *The PA Nurse* 60(3):12, 2005.
Mosby's medical dictionary, ed 8, St Louis, 2008, Mosby.
Murtha AP et al: Evaluation of a novel technique for wound closure using barbed suture, *Plast Reconstr Surg* 117:1769–1780, 2006.
Neumayer L, Vargo D: Principles of preoperative and operative surgery. In Townsend CM et al, editors: *Sabiston textbook of surgery*, ed 18, Philadelphia, 2008, Saunders.
Petersen C: Perioperative nursing data set, Denver, 2007, Association of periOperative Registered Nurses.
Taylor DL: Bloodborne pathogen exposure in the OR—what research has taught us and where we need to go, *AORN J* 83:833–846, 2006.

CHAPTER 7

Surgical Modalities

KAY A. BALL

Surgery continues to evolve as less invasive procedures and instrumentation are adopted. Modalities have been developed that enhance and advance surgical procedures. This chapter provides information about the evolution of some widely used surgical modalities, including laparoscopy (sometimes referred to as endoscopy), video technology, and energies used during surgical intervention.

MINIMALLY INVASIVE SURGERY OVERVIEW

In the late 1980s, the "laparoscopy revolution" began in the United States (History box). General surgeons developed techniques to perform procedures using the laparoscope, eliminating the need for a large incision. As surgeons and perioperative nurses accessed evolving knowledge and information, the surgical industry worked to accommodate a rapid change from open surgical procedures to newer techniques of minimally invasive surgery (MIS). Perioperative nurses and surgical technologists experienced a marked opportunity to acquire new competencies. Since the 1990s, equipment, instrumentation, surgical skills, and perioperative nursing knowledge have markedly expanded as MIS has become a safe approach for many surgical interventions. Ongoing changes in surgery that aim to incorporate MIS procedures continue to present complex challenges for the surgical team while offering patients potentially shorter hospital stays (Sajid et al, 2009), reduced postoperative pain, lower rates of surgical site infections (Poon et al, 2009), and faster recuperation (Schmock, 2009) (Table 7-1). A keen understanding of the goals of endoscopic MIS, clinical competence, and preoperative patient assessment establish the basis for the perioperative plan of care.

Endoscopes

An endoscope is a tube inserted into a natural body orifice or through a small incision to access internal organs or structures. Endoscopes are flexible, rigid, or semirigid. Flexible endoscopes include angioscopes, bronchoscopes, choledochoscopes, colonoscopes (Figure 7-1), cystonephroscopes, hysteroscopes, mediastinoscopes, ureteroscopes, and ureteropyeloscopes. Rigid endoscopes include cystoscopes, laparoscopes, sinuscopes, arthroscopes, bronchoscopes, laryngoscopes, and hysteroscopes (Figure 7-2). Some endoscopes are manufactured in flexible and rigid forms. A semirigid endoscope, such as the deflectable tip video laparoscope, allows movement through a deflectable tip to provide a complete field of view from different angles (Figure 7-3).

Endoscopes are diagnostic or operative. *Diagnostic* scopes are for observation only and have no operating channels. The system is sealed at both ends. A diagnostic scope can be used, however, when multiple access sites are planned for the introduction of other instrumentation to perform a surgical procedure. *Operative* endoscopes are channeled to irrigate, suction, insert, and connect accessory instrumentation (Figure 7-4). For example, when a potassium titanyl phosphate (KTP) laser is used, the laser fiber is inserted into the operating port of the laparoscope. Advanced laparoscopic techniques may include the use of a flexible endoscope to check for anastomotic leaks, identify bleeding sites, or detect other problems before, during, or immediately after the laparoscopic procedure.

Endoscopes are available in various diameters and lengths, depending on access to the area being visualized and the requirements of the procedure. Optical capability through a rigid scope is controlled by a lens system and can be direct (0-degree angle) or angled (e.g., 30, 70, 120 degrees) (Figure 7-5). Some rigid endoscopes integrate a distally mounted camera chip inside the scope with a rotation dial for proper orientation of the target site. Because flexible scopes are able to be angulated, they allow for a more panoramic view.

There are two types of flexible endoscopes: fiberoptic endoscopes and videoscopes. Fiberoptic endoscopes have an eyepiece with a lens for visualization; the image is carried through the endoscope via a bundle of tiny glass fibers. Videoscopes have, at their distal end, a video chip that provides an image that is directly viewed on a monitor; a videoscope does not have an eyepiece for direct viewing.

Flexible endoscopes have four distinct components:

1. Control body (e.g., angulation knobs, air-water channels, biopsy port, eyepiece for fiberoptic endoscopes)
2. Insertion tube (e.g., flexible tube containing channels for suction, biopsy, irrigation, air and water, image bundles for the fiberscope, light bundles)
3. Bending section at distal tip (e.g., bending rubber, lenses, air-water nozzle, C-cover, charge-coupled device [CCD] chip for videoscopes)
4. Light-guide connector unit (e.g., suction, air-water channel)

Flexible endoscopes also have three different systems that include some of the various components within the endoscope:

1. Mechanical system (provides ports to introduce accessories to perform treatments and procedures)
2. Angulation system (allows the endoscope's distal tip to be moved in different directions)
3. Illumination system (provides light to view internal structures)

Rigid endoscopes also have four distinct components:

1. Eyepiece (e.g., ocular lenses; rigid videoscopes are offered today without an eyepiece)
2. Body (e.g., light-guide connector, valves)

HISTORY

Evolution of Endoscopic Minimally Invasive Surgery

Endoscopy, the examination of body organs or cavities by means of an endoscope, has been used for several centuries. Although primitive, the first use of reflected light for inspection of the vagina and uterine cervix is credited to Abul Kasim (936-1013), an Arabian physician. From this new conquest instrumentation was developed to examine the nasal sinuses and urinary bladder. Of primary concern during this initial era of endoscopy was thermal tissue injury caused by the intense heat emitted by the light sources used. Incandescent lighting was eventually incorporated into the tips of certain endoscopes (e.g., cystoscopes, ureteroscopes) that could be cooled by continuous irrigation. Modifications permitted examination of the nasal sinuses, larynx, bronchus, and sigmoid colon. Procedures were restricted, however, to endoscope placement in external body orifices.

In 1910 Jacobaeus, a Swedish physician, first reported using a cystoscope to examine the peritoneal cavity. He was only able to diagnose conditions because the ability to create a pneumoperitoneum (the introduction of a gas into the peritoneum to increase visualization and operative exposure) was yet to be developed. Numerous complications were associated with these brave attempts to perform this rudimentary form of laparoscopy. During these pioneering procedures, common injuries occurred to bowel and vascular structures—complications that today, although not unknown, are rare.

In an attempt to reduce morbidity, gynecologists introduced the cul-de-sac approach to pelvic endoscopy (culdoscopy). Instead of inserting the scope through the abdomen, they did so through the cul-de-sac. During this era, the importance of introducing air into the abdomen was recognized. Air was introduced through the use of a syringe and needle. Knee-chest and Trendelenburg positions were used to facilitate this procedure.

In 1964 the German surgeon Semm developed an automatic insufflation device. Laparoscopy was still considered to be "blind" surgery and did not gain rapid popularity in North America or Europe. During the 1960s two other developments enhanced the endoscopic revolution. In 1966 the rod-lens system designed by the British optical physicist Hopkins improved brightness and clarity. Fiberoptic (cold) light sources also were introduced that further reduced the risk of visceral and bowel burns.

In the late 1970s to early 1980s, endoscopic surgery transitioned from diagnostic to operative. Semm termed his pioneering work *pelviscopy.* His work led to many technologic advances in instrumentation, equipment, and practice. Diagnostic and operative laparoscopies were becoming techniques of choice for gynecologists throughout the world. Flexible and rigid endoscopic procedures also were increasing for urologists, internists, and otorhinolaryngologists. In the 1970s orthopedic surgeons began to develop their skills in the art of arthroscopy.

In the 1980s the laparoscope was introduced in general surgery. General surgeons were familiar with laparoscopy because many were consulted to assist gynecologists evaluating right lower quadrant pain in young women. That experience enabled surgeons to adopt laparoscopic procedures to diagnose acute appendicitis, presaging its wide use in general surgery today.

Modified from Ball KA: *Endoscopic surgery,* St Louis, 1997, Mosby; White RA, Klein SR: *Endoscopic surgery,* St Louis, 1991, Mosby; Semm K: Advances in pelviscopic surgery, *Prog Clin Biol Res* 112(Pt B):127-129, 1982; Zucker KA: *Surgical laparoscopy,* St Louis, 1991, Quality Medical Publishing.

TABLE 7-1

Advantages of Minimally Invasive Surgery Over Open Surgery

Minimally Invasive	Open
Ambulatory or short hospital stay	Hospital admission
Short postoperative recuperation	4- to 6-wk recuperation
Reduced postoperative pain; reduced need for pain medications	Postoperative pain related to surgical site; more analgesics required
Earlier return to normal lifestyle	Return to normal lifestyle varies with recuperation period

FIGURE 7-1 Flexible colonoscope.

3. Shaft (e.g., rod lenses, spacers)
4. Distal end (e.g., objective lens, negative lens)

Understanding the anatomy of an endoscope can help to assess technical problems that can occur during any endoscopic procedure. Internal components are complex, sophisticated, and sometimes delicate (Figure 7-6) and the endoscope must be treated with care.

Light Sources and Fiberoptic Cables

Endoscopic light is often referred to as *cold light*, meaning that the heat from the light source is not transmitted through the length of the scope. Therefore tissue damage from heat at the distal tip of the endoscope is minimized. When the ends of the fiberoptic cables are disconnected from the scope, however, they may be very hot. The surgical team must use extreme caution to ensure the ends of the cables do not contact the patient's skin and any flammable materials or liquids. If the fiberoptic cable is disconnected from the endoscope during surgery, the scrub person must ensure that the cable end is held away from drapes or placed on a moist towel to prevent burns and fires. Ideally the light should be turned off whenever disconnected from the endoscope. ECRI Institute (formerly, the Emergency Care Research Institute) recommends labeling all fiberoptic light sources to prevent fires from the hot light source energy.

According to ECRI, high-intensity fiberoptic light sources and cables can ignite drapes and other materials. To prevent a fire, all cable connections must be completed before activating the light source. The light source must be placed on standby when the cables are disconnected.

Light sources should have adjustable manual and automatic brightness modes. The automatic mode adjusts brightness according to the video image. If the light source is set in this mode, the circulating nurse need not make adjustments constantly.

When selecting a light source, certain options should be considered. A light source that can adapt to several rigid endoscopic systems is desirable, such as one with a universal light cable adapter, which enhances flexibility and usage (Figure 7-7). If a previously purchased unit does not provide this feature, universal light cables with connectors to an interchangeable light source and endoscope adapters are available (Figure 7-8). A generic cord can be used with most scopes and light sources, but some light cables can only be used with specific sizes of endoscopes. For example, a 2.5-mm cable should be used with a scope less than 4 mm while a 4.5-mm cable can be used with a 10-mm scope. Using the incorrect light cable with an endoscope may overheat or damage the optics. Color-coding different cable sizes helps in their differentiation. Light sources also must have connection capability with different camera units.

Fiberoptic light cables must be handled with extreme care. They consist of hundreds of glass fibers that transmit light (Figure 7-9) and the tiny fibers can be broken easily if kinked or dropped. Cables must be loosely coiled, never bent, when not in use. After multiple uses, fibers can break. Cables must therefore be checked after each use. To do this, hold one end of the cable pointing toward a bright light while the opposite end is observed for light transmission (Figure 7-10). Do not test the cable by looking into the end while it is attached to the light source. The visible light and ultraviolet light produced by the light source may harm the eye if directly viewed for extended periods. "Peppering" on the light cable end indicates broken fibers. When approximately 20% of the fibers are broken, the cable is replaced because adequate light for visualization cannot be transmitted through fractured fibers.

Bulbs within the light source usually are easy to replace. Extra bulbs are stored in lamp-assembly drawers, which are readily accessible. The bulb itself must not be touched because (1) it may be very hot and (2) the oils on an individual's hands and fingers can adhere to the bulb, causing the bulb to burn out more quickly. Nonmetal handles usually are built into the light source for bulb removal and replacement.

Three popular types of light sources are available today: xenon, metal halide, and halogen. Advantages and disadvantages are associated with each. Xenon bulbs are more expensive, but last longer. Xenon light is better for smaller diameter endoscopes (≤2 mm) because the light can be focused to a smaller spot size. Xenon light also is a preferred light for video or picture taking. Metal halide bulbs have a shorter life span (about 250 hours) and are less expensive. These bulbs are easier than others to handle and replace, and do not require large fans for cooling. Halogen light sources are used for office and some hospital applications. They do not, however, offer the light intensity required for many endoscopic and video applications. Personal preference and conditions for use are two key factors in choosing an appropriate light source for endoscopy. A light source that incorporates a lamp-life status–testing mode is desirable so that bulb replacement can be anticipated.

Given that light sources produce different colors of light whenever a camera is used, *white balancing* must be performed during each procedure. White balancing adjusts the camera to all other optical components (endocoupler, light cable, laparoscope). This method enables the camera to reference white so that it can identify all primary colors properly. White balancing should be performed only when the scope and light cable are connected, the light source is turned on, and the lens is held close to a white gauze or white drape (for white color referencing).

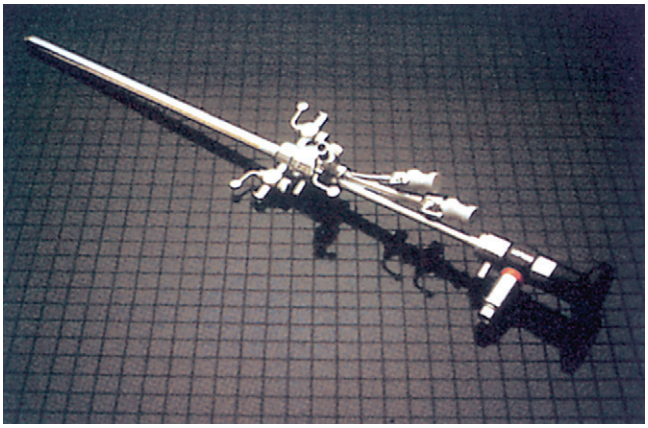


FIGURE 7-2 Rigid endoscope.

Endoscopic MIS Instrumentation

Endoscopic MIS instrumentation has been designed to correspond with the surgical site and the technique used while functioning as an extension of the surgeon's hand. The length and working end of the instrument must be adequate to perform surgery at the target site. The hand control is ergonomically designed for the operator's maximum comfort and reduced fatigue. Graspers and other instrumentation used by the assistant in surgery often are built for a shorter hand span because many women function in this role.

Rights were not granted to include this figure in electronic media.
Please refer to the printed publication.

FIGURE 7-3 Semirigid ureteroscope.

FIGURE 7-4 Operative laparoscope.

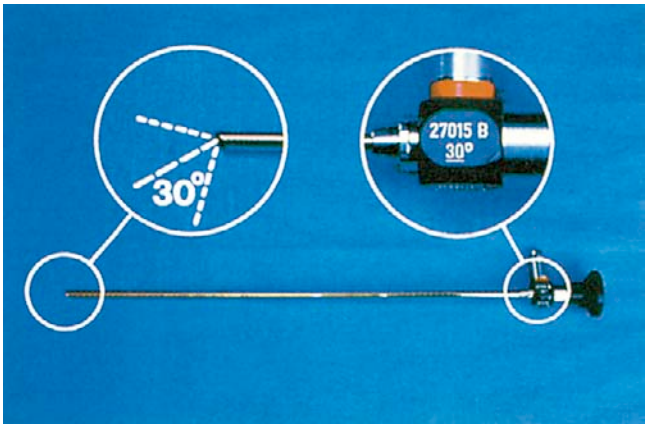


FIGURE 7-5 The lenses inside the endoscope determine the angle of view.

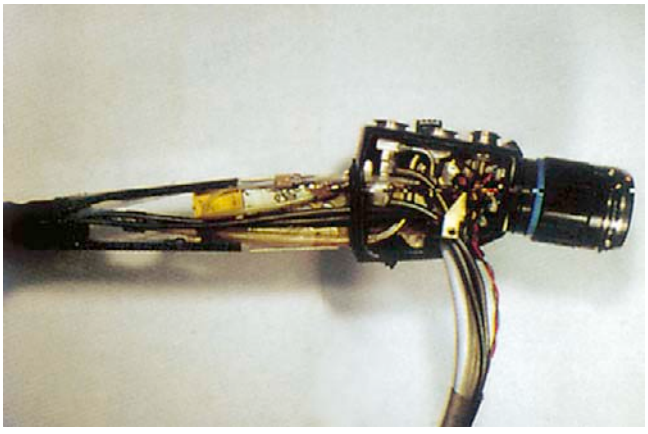


FIGURE 7-6 Dissected flexible endoscope, showing the complexity of the internal structure and design.

FIGURE 7-7 Light source with universal light cable adapter.

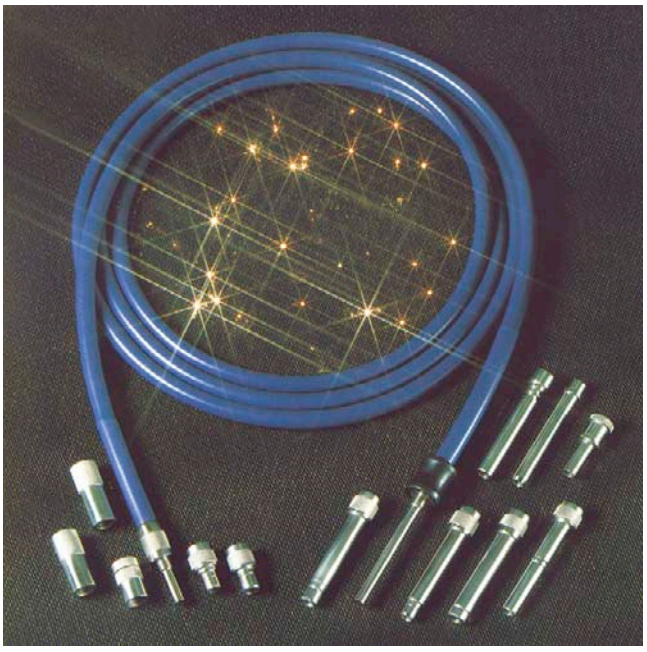


FIGURE 7-8 Universal light cable with interchangeable light source connectors and endoscope adapters.

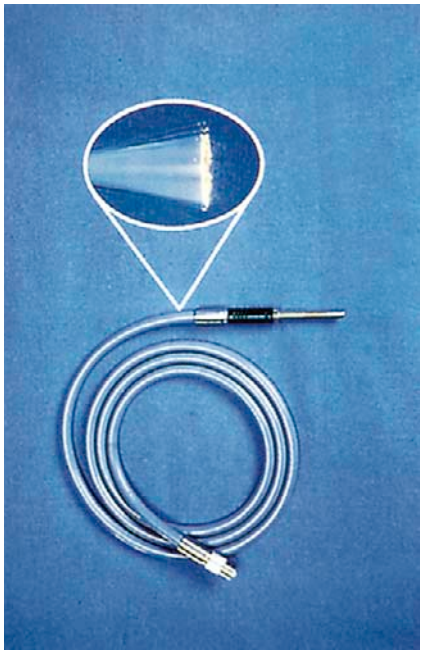


FIGURE 7-9 Inside the light cable are hundreds of glass fibers that transmit light.

FIGURE 7-10 The light cable can be checked for broken fibers by holding one end toward a bright light while looking at the other end.

FIGURE 7-11 Disposable endoscopic instruments are designed to meet procedural needs during endoscopic surgery.

As endoscopic MIS approaches differ from the traditional open equivalents, modifications of existing instruments have been made. Some basic patterns have been used for years and continue to be popular, whereas others have been designed to accommodate newer MIS approaches. The full effect of this new era in surgery was realized in the 1990s and some instrument designs are in their sixth and seventh generations. As surgery becomes evermore sophisticated, so do the instruments required for successful, less invasive techniques (Figure 7-11).

Trocar System. When a natural orifice does not exist for diagnostic or operative procedures, one or several orifices can be created. To do so, a trocar system is necessary, and consists of an obturator and a sleeve (also known as a cannula or sheath). The trocar system provides a mechanism to insert and remove instruments while MIS is performed. The obturator and sleeve are inserted to access the operative site. When the port of entry has been made, the obturator is removed, and the sleeve is left in place. More complex laparoscopic procedures usually require a greater number of trocar systems and puncture sites. The Research Highlight box describes a magnetically controlled system that has the potential to reduce the number of entry points for laparoscopic instruments.

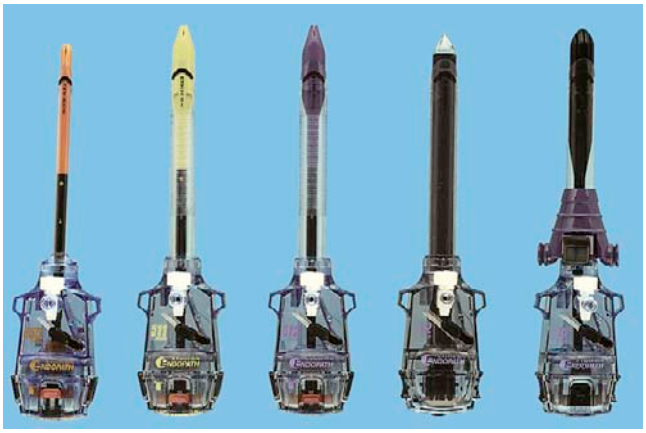


FIGURE 7-12 Disposable trocars and cannulae.

RESEARCH HIGHLIGHT

Trocar-less Instrumentation for Laparoscopy

This study was performed to determine the feasibility of a unique laparoscopic system with instruments that are positioned and locked into place using external magnets placed on the abdomen. The system minimizes the number of trocar sites needed during laparoscopic procedures as only one 12-mm diameter trocar is used. A transabdominal magnetic anchor and guidance platform, designed to integrate instruments, retractors, and a camera, provides movement and stability of the instruments. Results suggest that trocar-less laparoscopy can be performed using magnetically anchored instruments with expanded intracorporeal manipulation capabilities. This decreases the number of trocars and puncture sites needed for laparoscopic surgery, which has the potential to further advance laparoscopic practices.

Modified from Park S et al: Trocar-less instrumentation for laparoscopy: magnetic positioning of intra-abdominal camera and retractor, *Ann Surg* 245(3):379-384, 2007.

If a reusable trocar system is used, the obturator tip must be sharpened routinely. The stopcock and trumpet valves must be inspected before and after each use to ensure proper functioning. Internal gaskets may need occasional replacement. The obturator and sleeve must fit properly and may not always be interchangeable. Component parts must be kept together, but they must be disassembled completely for cleaning and sterilization.

Disposable trocar systems offer several advantages (Figure 7-12). One is that the obturator is always sharp. When multiple ports of the same size are used, the same obturator can be reused on the same patient. Some manufacturers also package one obturator and two or more sleeves of the same size. The same obturator is used to establish multiple access ports. Disposable units also may provide siliconized obturator tips and safety features when entry has been made. Systems are available that both engage a safety shield to advance automatically over the obturator tip (Figure 7-13) and provide retraction of the obturator tip when entry is made.

Many disposable sleeves have gripping devices that can reduce the risk of accidental sleeve removal during repeated advancement and withdrawal of the instruments. Grippers are

FIGURE 7-13 A close-up view of the trocar safety shield in place.

Rights were not granted to include this content in electronic media. Please refer to the printed book.

FIGURE 7-14 Blunt-tipped trocars can be used to minimize injuries during insertion.

incorporated into the sleeve or as separate entities. Grippers can be used with reusable sleeves as long as the fit is appropriate.

Disposable sleeves have a stopcock assembly for insufflation gas, similar to the reusable system. One-way flapper valves in disposables provide leakproof protection and operate automatically for instrument insertion, specimen removal, or rapid desufflation. As instrument diameters vary with design and use, various sizes of obturator and sleeve units may be required for one procedure. Reusable and disposable trocar systems are available in a variety of diameters and lengths. To increase flexibility, converters and reducers are used to adapt the size of the instrument. Converters can be separate or built into the sleeve as a diaphragm seal. Both systems are designed to reduce the chance of CO_2 leaks so that the pneumoperitoneum can be maintained. Radiolucent disposable sleeves offer the ability to visualize tissue and lesions without obstruction. This feature may be crucial during an endoscopic cholangiogram to avoid obstructing the view during fluoroscopy. During other procedures, this design may not be necessary.

Radially expanding dilator systems, consisting of a cannula with blunt obturator and an insufflation/access needle with a radially expandable sleeve, have been shown to cause less traumatic abdominal wall entry. Intraabdominal entry is accomplished using an access needle with a radially expandable sleeve. When insufflation is achieved, the needle is withdrawn, leaving the expandable sleeve in place. While the sleeve and tissue are expanded, a tapered, blunt-tipped dilator is inserted, providing a large working channel for an access port. As a sharp-tipped obturator is not used, the muscles are spread, not cut, and the risk of abdominal wall or vascular damage is minimized. Bladeless obturators, which separate tissue in a sequential fashion rather than cut or stretch tissue, also are available in an optical version that allows the surgeon to visualize all tissue layers being separated.

Occasionally a procedure is scheduled as an *open laparoscopy*. Patients who have had multiple surgeries, patients who have developed adhesions, and pediatric patients can present an added risk and may be candidates for open laparoscopy. A small paraumbilical incision is made and tissues dissected. The peritoneum is opened and a large, blunt-tipped obturator-sleeve assembly is inserted (Figure 7-14). The sleeve is designed to fit snugly against the peritoneum from underneath

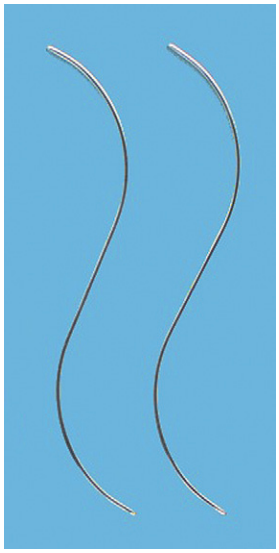


FIGURE 7-15 S-type retractors.

and against the skin from above. Stay sutures are used to close any excess incision. Wafer seals (similar to colostomy wafers) reduce further loss of carbon dioxide (CO_2) gas. Pneumoperitoneum is then created and maintained. If a reusable system is used, stay sutures also are used to stabilize the system. S-type retractors usually are needed for both (Figure 7-15). Sealed system devices have also been developed to introduce not only instrumentation, but the surgeon's hand when direct surgical approaches are necessary during laparoscopy.

When extracorporeal surgery must be performed during laparoscopy (i.e., when tissue undergoing surgery is brought outside the body through a small hole), an even larger diameter port is used. During certain bowel resections, loops of bowel are brought through a larger port to be resected or sutured. When the chest is entered, shorter blunt obturators are used with grippers that provide stabilization while in the pleural cavity. This type of obturator does not have insufflation ports (Figure 7-16). If insufflation is required to assist the anesthesia provider in collapsing the lung, regular obturators with insufflation ports are used.

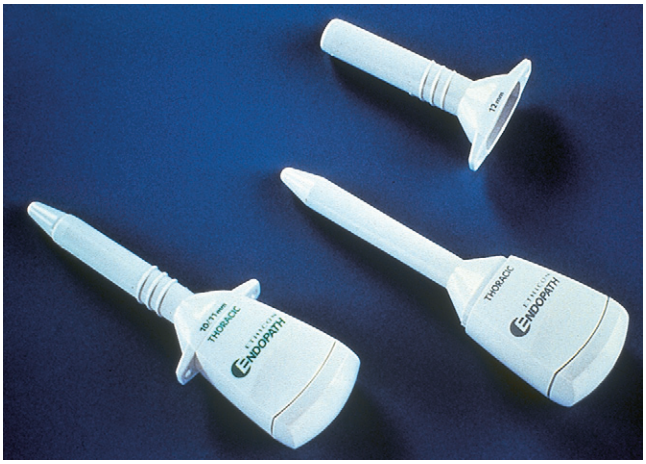


FIGURE 7-16 Thoracic blunt trocar and gripper assembly. Notice absence of stopcock insufflation capability.

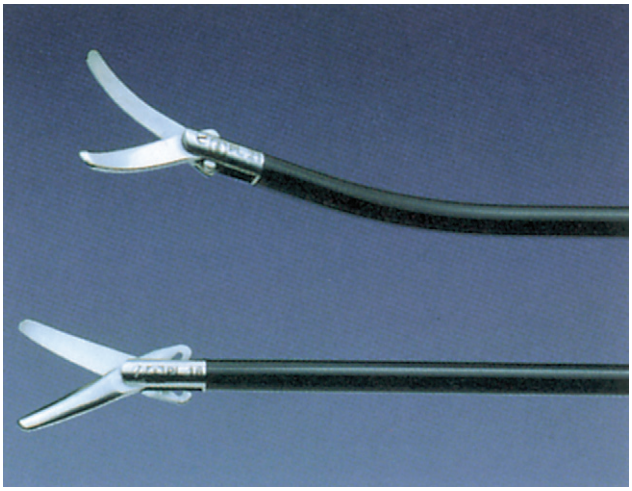


FIGURE 7-17 Straight and curved endoscopic scissors.

Dissecting Instruments. Dissecting instruments are used to cut, divide, or separate tissue. Scissors and dissectors that are similar to their open-procedure counterparts have been designed for use in MIS procedures.

Scissors are available for blunt or sharp dissection. They can be straight or curved (including hook scissors), depending on the location of the target tissue and technique used (Figure 7-17). Scissors usually have a rounded tip when closed so that they also can be used to manipulate tissue without trauma. When open, both jaws of the scissors should be visualized to prevent inadvertent injury. Some scissors are designed to be connected to an electrosurgical energy source so that coagulation can be provided during cutting.

Dissectors are used to separate or divide tissue. Many different tip shapes are available to dissect, spread, divide, grasp, retract, and coagulate structures (Figure 7-18). Other dissecting instruments, such as balloon dissectors, have been developed for blunt dissection or creation of a space so that surgery can be performed. A balloon dissector may be used to create a preperitoneal space during laparoscopic herniorrhaphy (Figure 7-19).

Rights were not granted to include this figure in electronic media.
Please refer to the printed publication.

FIGURE 7-18 Dissector with jaws open to divide and separate tissue.

Rights were not granted to include this figure in electronic media.
Please refer to the printed publication.

FIGURE 7-19 Balloon dissecting instrument.

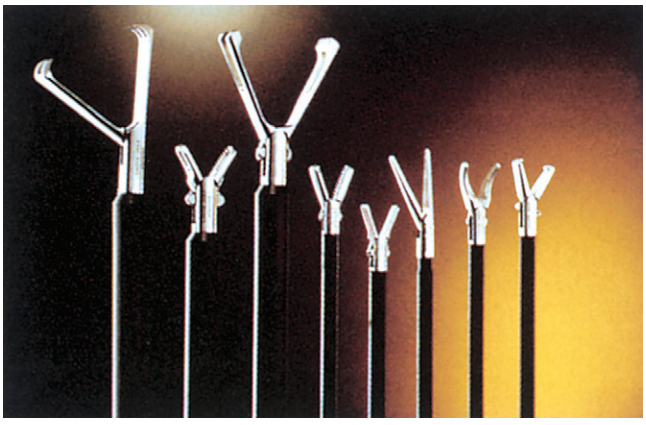


FIGURE 7-20 Endoscopic grasping instruments.

Clamping Instruments. Clamping instruments are used to grasp and hold tissue or other materials. Ratchets are used in the instrument design to allow the distal tip to be locked onto the tissue or whatever is being grasped. Graspers, forceps, and biopsy forceps are classified as clamping instruments.

Graspers and forceps can be (1) traumatic, with sharp teeth, or (2) atraumatic, with a smooth, serrated jaw surface (Figure 7-20). Traumatic graspers and forceps customarily are used to hold tissue that will be excised, whereas the atraumatic

versions are used to gently hold structures, such as the bowel or liver. Some clamping instruments are insulated so that electrosurgical energy can be transmitted to provide coagulation.

Suturing and Stapling Instruments. Suturing or stapling instruments deliver sutures, staples, or clips to join, hold, and secure tissue. Needle holders, clip appliers, and staplers are in this category.

Needle holders have been designed to deliver and place sutures within body cavities during MIS procedures. Tungsten carbide jaw inserts on the needle holders are often used to prevent rotation of the suture needle. These inserts often can be replaced when they become worn. Some needle holders have been designed to transfer the needle from one jaw to the other during suturing (Figure 7-21). Suture passers and curved needle holders also are available.

A clip applier is used to provide hemostasis and tissue security. Its use represents the safest, easiest, and quickest way to occlude small vessels and structures. Reusable appliers exist, but many must be removed from the cannula each time to be reloaded. This process adds time, contributes to loss of pneumoperitoneum (if used), and causes frustration when the clip is dislodged on reinsertion. For this reason, the automatic-feed, reloadable, disposable version is more desirable (Figure 7-22).

Rights were not granted to include this figure in electronic media.
Please refer to the printed publication.

FIGURE 7-21 Endoscopic needle holder that transfers the needle from one prong of the jaw to the other.

Staplers provide cutting and stapling during MIS resections (Figures 7-23 and 7-24). Certain structures can be easily resected intracorporeally (i.e., within the abdominal cavity), such as the ovary or appendix. Others may necessitate extracorporeal resection (outside the body) or reanastomosis; if this is necessary, traditional stapling devices are used.

The evolution of more complex MIS techniques has challenged traditional suturing and ligation methods. As a result, several devices and techniques have been developed for laparoscopic tissue suturing. When surgical clips and staples cannot be used, a laparoscopic suture may be substituted. Conditions that preclude the use of clips include large arteries and edematous or inflamed ducts. Most general surgeons prefer to use nonabsorbable sutures and ligation materials to prevent rapid absorption. Three basic types of laparoscopic suturing materials are *loop ligatures, extracorporeal sutures,* and *intracorporeal sutures.*

LOOP LIGATURES. Preknotted suture loops (loop ligatures) are used to ligate pedicle tissues. The suture loop is packaged with an introducer sleeve, which is inserted through one of the obturator sheaths. The loop is passed over the target tissue or pedicle using a grasping forceps to assist. When the loop is in position, the existing suture knot is pushed down the introducer sleeve until it is cinched tightly around the tissue. The suture is cut with endoscopic scissors (Figure 7-25).

EXTRACORPOREAL SUTURES. Tissue can be approximated intraabdominally when the knot is tied extracorporeally (i.e., outside the body). To accomplish this, endoscopic swaged sutures are used. The suture is grasped proximally to the needle, and both are inserted through one of the obturator sleeves into the abdomen. The needle is held with the grasper or laparoscopic needle holder and driven through the desired tissue. A second grasper or needle holder inserted through a second obturator sleeve is used to assist. The needled end of the suture is pulled through the tissue and out through the sleeve. The needle is removed, and a knot tied extracorporeally. The knot is advanced down the sleeve and onto the tissue. The suture is cut with laparoscopic scissors (Figure 7-26). The three types of knots tied extracorporeally are the *slip knot,* the *fisherman's knot,* and the *surgeon's knot.*

INTRACORPOREAL SUTURES. A suture ligature also can be passed through the obturator sleeve to be tied while it is inside the body. The tissue is approximated in the same fashion but tied intracorporeally (i.e., inside the abdomen) using grasping forceps or laparoscopic needle holders.

Retractors and Accessory Instruments. Retractors are used to hold tissue and expose the operative target site (Figure 7-27). Retractors can be traumatic to some structures, such as the bowel and liver, and must be used with caution. Miniretractors and balloon retractors have been designed for use on delicate

FIGURE 7-22 Disposable endoscopic rotating clip applier.

FIGURE 7-23 Disposable linear cutter with reloading unit.

Rights were not granted to include this figure in electronic media.
Please refer to the printed publication.

FIGURE 7-24 Disposable endoscopic stapling device.

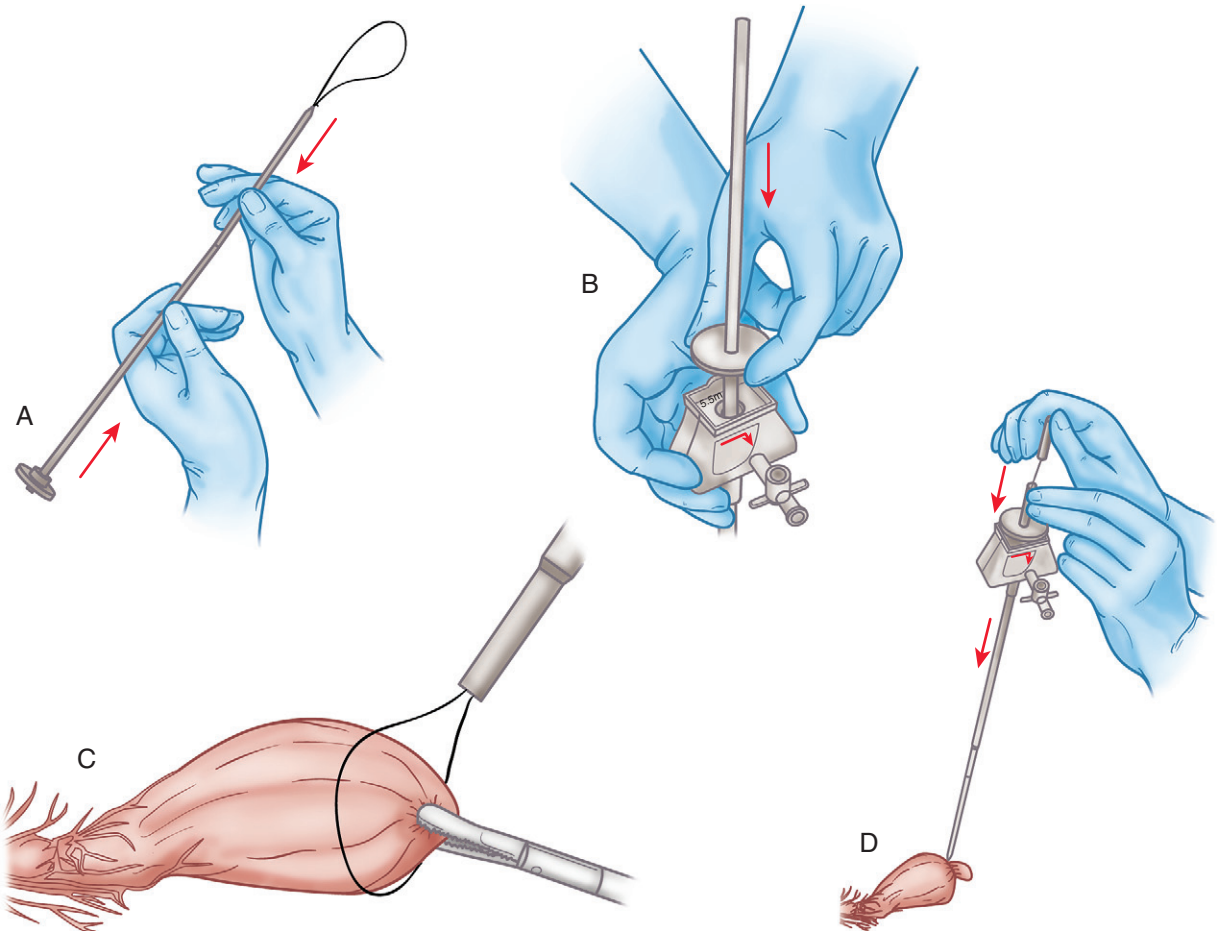


FIGURE 7-25 Surgitie ligating loop. **A**, Back-load loop into introducer completely. **B**, Insert introducer into trocar, all the way down. **C**, Push suture loop through introducer. Grasp desired tissue with grasping forceps (passed through another trocar), and maneuver loop over tissue. **D**, Push down knot by advancing nylon carrier all the way until knot is cinched. Cut suture.

structures. A miniature version of a surgical clamp with blades that splay the incision open beneath the tissue is available. Other accessory instruments have been designed to enhance the use of basic MIS instruments, provide exposure, and facilitate the procedure. Probes used to manipulate tissue should be blunt to minimize tissue trauma. Some probes have centimeter gradations to measure structures within the body. Irrigation-aspirator probes enhance visualization of internal structures, and electrosurgical probes provide hemostasis. Endoscopic specimen bags contain specimens in order to minimize cross-contamination. Special accessory instruments are being designed continually to enhance MIS procedures.

Care and Handling of Endoscopes and Instrumentation. Endoscopes and instruments must be clean and free from all bioburden (contaminating organisms) before sterilization or high-level disinfection. During routine use, bioburden accumulates in channels, ports, crevices, and other movable parts of scopes and instruments. Periodically throughout the procedure, gross blood and bioburden should be removed

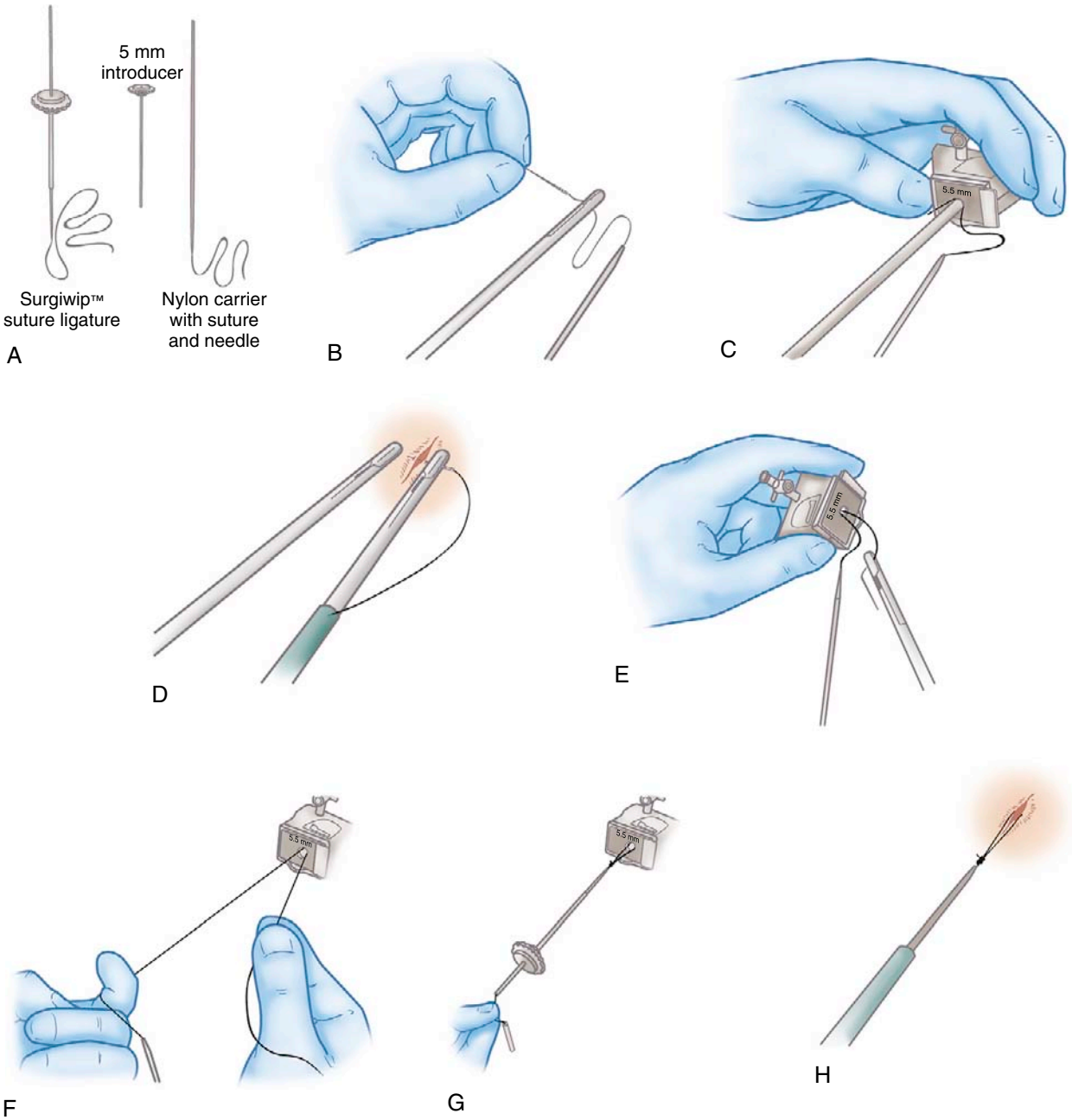


FIGURE 7-26 Surgiwip suture ligature application for approximating tissue intraabdominally by extracorporeal knot-tying (outside body). **A**, Component pieces. **B**, Grasp suture behind swage of needle with tissue grasper or needle holder. **C**, Introduce grasper or needle holder and suture through trocar into abdomen. **D**, Drive needle through tissue to be approximated. Place instrument close to center of needle for control. Pull needle through tissue using second grasper (introduced through another trocar). **E**, Regrasp needle behind swage intracorporeally, and pull it through and out the same trocar. (Allow for slack of suture to avoid tissue tears.) **F**, Remove needle. Tie knot. **G**, After knot is tied, break end of nylon carrier. **H**, Push knot down with nylon carrier and out onto tissue. Cut suture. For additional suturing, repeat steps **B** through **H** until tissue is satisfactorily approximated.

by flushing the channels and wiping the surfaces with sterile water. Saline should never be used routinely to remove gross debris during the procedure because this salt solution can leave mineral deposits on or in the device. Keeping instruments and endoscopes relatively clean during the procedure helps to prevent debris from drying, thus facilitating the cleaning process and protecting the instrument (Making your GI unit more effective, 2009).

After each procedure, all instruments and devices must be decontaminated thoroughly. Immersible equipment is cleaned or flushed with an enzymatic or other appropriate detergent solution; this loosens organic material and makes it easier to remove. Instruments that can withstand cavitation or ultrasonic cleaning (processes whereby high-frequency energy causes microscopic bubbles to assist with debris removal) can be placed in an ultrasonic device. Fiberoptics and endoscopes

Rights were not granted to include this figure in electronic media.
Please refer to the printed publication.

FIGURE 7-27 Endoscopic fan retractor with five fingers.

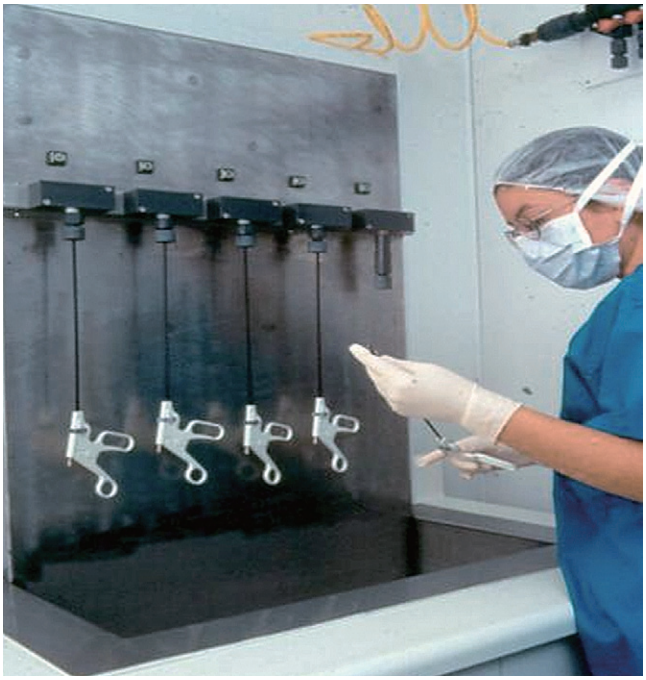


FIGURE 7-28 Commercial endoscopic instrument cleaner used by a reprocessing company.

usually cannot be placed in an ultrasonic machine because the vibratory motion can damage tiny fiberoptic bundles.

Selection of appropriate cleaning solution or detergent is critical. Detergents consist of various formulations that may include pH builders, buffers, surfactants, and chelants that provide the chemical compositions that clean devices. The amount of cleaning power within a solution is determined by the pH of the formulation. The "potential for hydrogen" is the meaning of pH, which represents the degree of acidity (more hydrogen ions present), neutrality (equal hydrogen and hydroxyl ions), and alkalinity (more hydroxyl ions present). A detergent with a very low pH can cause staining and pitting on the surfaces of stainless-steel instruments since they are more susceptible to damage during prolonged exposure of acidic solutions. When detergents are combined with the mechanical or automatic force of a cleaning spray, removal of bioburden is easier.

A low sudsing detergent is recommended so that the detergent can be completely removed. Cleaning solutions with surfactant are less desirable because they are more difficult to rinse. If surfactant is left on the surface, the device may feel sticky or gummy, which could affect the electrical conductivity of the instrument. Careful attention must be paid to the solution used as well as the type of device being cleaned. Certain detergents are not appropriate for cleaning both endoscopes and endoscopic instruments.

Careful rinsing and flushing with copious amounts of water follows the cleaning process. Often deionized or demineralized water is recommended for the final rinse to minimize mineral buildup from tap water. The manufacturer's written recommendations for cleaning and processing always should be followed. After final rinse, instruments must be dried before disinfection or sterilization.

Automatic cleaning devices that flush the ports of instruments provide an economic and effective way to clean reusable channeled instruments (Figure 7-28). Although instruments have flush ports, debris can become lodged distally. Some automatic systems provide a means to flush in a retrograde fashion, forcing debris from the larger proximal port. Sealed instruments also can be tested for seal integrity using this system.

After the device has been thoroughly cleaned, rinsed, and dried, its integrity and functionality must be assessed. Personnel involved with reprocessing MIS devices must be aware of instrument composition, design, and use. Any device with electrosurgical capabilities must be checked to ensure the length of the insulation sheath has not been compromised. Equipment is available that scans these instruments for electrical leakage through breaks in insulation.

Often new MIS accessories are purchased and used without educating the staff responsible for their reprocessing. Staff members cannot understand design and use of a device without proper instruction. The FDA requires that any device purchased as reusable must have written instructions for reprocessing. Staff must understand how the instrument works to ensure that functionality of the device has not changed during reprocessing. Compliance with federal, professional, and regional standards for reprocessing is mandatory.

Instruments and devices that contact sterile tissues and the vascular system must be sterile. Instruments contacting intact mucous membranes can be processed using high-level disinfection (Figure 7-29). This means that sterility is required for all laparoscopy, angioscopy, thoracoscopy, and arthroscopy procedures. High-level (cold-soak) disinfection may be acceptable for colonoscopy, laryngoscopy, bronchoscopy, cystoscopy, and other diagnostic procedures in which surgical devices touch intact mucous membranes. Invasive procedures that access the vascular system (biopsies) are performed during many endoscopy procedures. The adequacy of high-level disinfection must be evaluated for these procedures. Viruses and microorganisms, such as human immunodeficiency virus (HIV), hepatitis B and C viruses, *Mycobacterium* (tuberculosis bacteria), and antibiotic-resistant organisms, are not easily destroyed during high-level disinfection. Even though high-level disinfection has been the accepted primary standard of reprocessing for some endoscopic instrumentation, the concern over viruses and microorganisms has caused debate about the adequacy of using high-level disinfection. Therefore sterilization is quickly becoming the standard for reprocessing endoscopes and endoscopic instruments.

Thermal pasteurization, using a washer/pasteurizer, may be selected for thermal high-level disinfection. An FDA-approved chemical germicide should be selected for chemical high-level disinfection. Glutaraldehyde, used for many years, has hazards for staff that must be considered when this agent is selected for high-level disinfection. The maximum recommended exposure level of glutaraldehyde determined by the Occupational Safety and Health Administration (OSHA) is 0.2 ppm. When solution is being poured after mixing or when devices are being submerged, the level rises to approximately 0.4 ppm, which is double the recommended maximum exposure level. The odor of glutaraldehyde becomes an irritant at 0.3 ppm, causing tearing, nausea, and other effects. Hooded systems to house glutaraldehyde solutions have been designed to remove odor and fumes. When using this or any other chemical germicide, the device must be totally immersed and soaked for the specified contact time, following the manufacturer's recommendations for cleaning protocols, preparing the solution, maintaining contact time, and calculating expiration dates. Other solutions are available for high-level disinfection without the hazards that glutaraldehyde presents.

Institutional policy sets the guidelines from which practitioners work. Insight and coordination are required to provide comparable levels of care when there are too few instruments for the number of scheduled procedures. If sterile instruments are required for a particular procedure, sterile instruments should be used for all patients undergoing that procedure. Sufficient instruments, accessory items, and equipment must be purchased to accommodate patient volume, or other reprocessing measures must be implemented.

When sterile devices and instruments are needed, multiple options provide sterilization today, including steam, ethylene oxide, gas-plasma, and ozone sterilization methods (AORN, 2009). Often, steam cannot be used on delicate endoscopes, but accessory instruments may withstand the heat produced during steam sterilization. Some arthroscopes and laparoscopes have been designed to withstand high temperatures of steam sterilization. For items that cannot withstand high temperatures, options include the following:

- *Ethylene oxide sterilization*—This process has been used for many years to sterilize endoscopes and instruments. Past decisions to eliminate agents that were combined with ethylene oxide to decrease flammability, such as chlorofluorocarbon (CFC) and halogenated CFC (HCFC), have led to the use of 100% ethylene oxide for safe and effective sterilization. Limitations of ethylene oxide sterilization are the prolonged time needed for aeration of ethylene oxide and the installation and monitoring requirements for this type of sterilizer.
- *Plasma sterilization system*—This system uses hydrogen peroxide gas plasma, which sterilizes within 50 to 75 minutes and dissociates into nontoxic by-products. Understanding the advantages and limitations (e.g., lumen restrictions) of this system is important when determining if it would meet the needs of endoscope or instrument sterilization. Generally, flexible endoscopes cannot be sterilized in this system.
- *Ozone sterilizer*—Oxygen is used in a natural process to produce ozone. When oxygen is exposed to an intense electrical field, the oxygen molecule separates into atomic oxygen (O). Atomic oxygen combines with other oxygen molecules (O_2) to create triatomic oxygen (O_3), which is ozone. Ozone reverts quickly back to its oxygen state while producing no toxic residuals. Ozone is a powerful sterilizing agent because it oxidizes organic matter (fungi, bacterial spores, viruses). Key features of ozone sterilization include ease of use, low-temperature sterilization, cost-effectiveness, and compatibility with anodized aluminum containers. The manufacturer's instructions must be followed regarding operation of the sterilizer, instrument and device preparation, and device limitations.

FIGURE 7-29 High level disinfection reprocessor that handles two scopes at one time.

Single-Use Versus Reusable Instrumentation. Many facilities use a combination of reusable and single-use laparoscopic instruments. Advantages of single-use items include sharpness, reliability related to function, guaranteed sterility, and safety. Indirect advantages include no reprocessing, no repair costs, and comparable levels of patient care. Upgraded designs are more easily accepted when the device is labeled for single use. Disadvantages include the need for increased storage space, budgetary implications, and environmental concerns related to disposal of biohazardous waste.

Advantages of reusable instruments include less storage space, reduced costs (except for initial purchase and repair), and minimal waste. With reusable instruments, decontamination and reprocessing systems must be reliable, compatible with the devices being processed, and monitored for effectiveness.

Above all, safe and effective patient outcomes should be the major criteria considered when comparing single-use with reusable instrumentation. Advantages and disadvantages of reusable versus single-use devices must be explored, using a risk-to-benefit analysis, before purchasing decisions can be made. Institutional policy may dictate whether reusable or single-use items are chosen. The choice between single-use and reusable instrumentation and equipment must be evaluated thoroughly in each individual practice setting and justified accordingly.

Reprocessing Single-Use Devices (SUDs). Reprocessing single-use devices is a practice that has grown in acceptance. In the United States, the practice of reprocessing single-use devices is highly regulated by the FDA. The first guidance document was published in 2000, entitled *Enforcement Priorities for Single-use Devices Reprocessed by Third parties and Hospitals* (FDA, 2000). A more recent document to address this practice was published in 2006, entitled *Guidance for Industry and FDA Staff: Medical Device User Fee and Modernization Act of 2002, Validation Data in Premarket Notification Submissions (510(k)s) for Reprocessed Single-use Medical Devices* (FDA, 2006). These documents outline regulatory requirements, enforceable by the FDA, for reprocessing previously used single-use medical devices. The FDA continues to provide prescriptive guidelines to control this industry. In 2006 Dr. Daniel Schultz, addressing the House of Representatives Committee on Governmental Reform, stated that the FDA "will continue to provide, reasonable assurance of safety and effectiveness of reprocessed SUDs for patients."

The FDA defines a "reprocessor" as a third-party reprocessing company or hospital that reprocesses single-use devices. Hospitals rarely pursue the challenges of becoming listed as a reprocessor, given the expense involved with this activity. Reprocessing organizations are considered manufacturers, are subject to the same regulatory requirements as the original device manufacturer, and must comply with the original document guidelines (FDA, 2000):

1. *Registration and listing with the FDA*—Any organization reprocessing single-use devices must register with the FDA and provide a comprehensive list of all single-use medical devices that it reprocesses.
2. *Medical device reporting (MDR)*—Any organization reprocessing single-use devices must comply with the FDA's manufacturer reporting requirements and report not only all patient injuries from device malfunctions or failures but also any event that potentially could have led to patient injury or death.
3. *Device tracking*—The FDA can issue a tracking order for any specific device, if applicable. These devices are typically high-risk, Class III medical devices, such as implants. Reprocessing companies usually refrain from reprocessing Class III devices.
4. *Corrections and removals*—Every reprocessor must have a formal procedure in place to recall or correct affected devices.
5. *Quality System Regulation (QSR)*—Every reprocessor must develop and maintain comprehensive quality system controls that comply with the FDA's requirements for all aspects of their reprocessing operation.
6. *Labeling requirements*—Every reprocessor must provide instructions-for-use documents (IFUs) with reprocessed medical devices and must comply with specific requirements for what appears on the device label. Any reprocessed single-use device must be labeled, "prominently and conspicuously," with the following statement: "Reprocessed device for single use. Reprocessed by (name of manufacturer that reprocessed the device)."
7. *FDA premarket submission of a premarket notification (510[k]) or premarket approval (PMA)*—Every reprocessor is required to register each device to be reprocessed by submitting a 510(k) or PMA. The specific FDA requirements for the regulation of devices are based on the criticality (critical, semicritical, or noncritical) and the risk category/class of the device.

FIGURE 7-30 Single-use device is carefully sharpened during reprocessing at a third-party company.

Reprocessors also repackage and resterilize items with an expired shelf life date or when sterility of the outer packaging has been compromised. Single-use devices that are reprocessed are segregated into two categories for reprocessing: *open/not used* and *open/used* devices. The devices that have been used are grossly decontaminated before they are sent for reprocessing. If devices are not grossly decontaminated, they are collected in approved containers and transported by a licensed biohazardous material hauler using appropriate packaging materials and labeling.

Liability is an important concern for those engaged in reprocessing single-use items. A hospital or surgery center may be liable if reprocessing occurs within the confines of the facility. If a third-party company provides this service, it may likewise be liable and must document liability insurance coverage for this service. Although the original manufacturer of a device warrants a disposable product for one use, a reprocessing company also warrants the reprocessed device for one additional use.

Questions to ask when determining whether to reprocess single-use items include the following:

- Can the disposable device be adequately cleaned?
- Can the device withstand disinfection or sterilization? Can the item be adequately aerated if ethylene oxide sterilization is used?
- Is the device tested and checked for proper form and function after cleaning has been completed?
- Has device integrity been destroyed during reprocessing or is equipment available to test the integrity of the device? How is the integrity of insulation checked on an electrosurgical instrument?
- Can the device be returned to its original intended use (Figure 7-30)?
- Will cost savings be passed on to the patient, if appropriate?
- What is the maximum number of safe reuses, as determined through comprehensive testing? How is the number of reuses indicated on the device?

- Should the patient be informed that a reprocessed device may be used? The FDA does not require informed consent for the use of reprocessed single-use devices. Many providers contend that because reprocessing is so highly regulated and the risk of using a reprocessed device is the same as using the device for the first time, there is no need to seek informed consent.

No matter where reprocessing is performed, appropriate equipment must be available to ensure that the form and function of the device have not been compromised. Customers should inquire about reprocessing and quality assurance practices if dealing with a third-party reprocessor. Usually these companies have appropriate equipment to perform comprehensive device and validation testing. They must register with the FDA and comply with the Quality System Regulations (QSR) (FDA, 2000). Reprocessors should provide documentation of FDA registration, any reports of FDA inspection, such as an Establishment Inspection Report (EIR), FDA warning letters, all-important 510(k) or PMA documentation, and the limited number of uses for each specific device.

The practice of reprocessing single-use devices continues to grow in popularity as significant cost savings are realized by all sizes and types of healthcare facilities. Surgical team members must work closely with their purchasing agent, infection control officer, financial administrator, and others to decide if reprocessing single-use devices is an appropriate option for their facility.

VIDEO TECHNOLOGY

Evolution of Video Technology

A basic standard medical video system includes the scope, light cable, light source, camera head, camera cord, camera-scope coupler, camera control unit, and video monitor. Additional peripheral equipment is necessary for specific surgical procedures and is discussed later. Given the complexity of video technology, a glossary of terms is provided in Box 7-1.

Setting up a video system in surgery begins with the image source—the camera. A camera control unit (CCU) is needed to convert the image signal from the camera into viewable format. The monitor is then connected as the display device that shows the image signal. Options can be added to this setup to record the surgical procedure or to take still images. The image recorder and/or printer is positioned before the display device.

BOX 7-1

Video Glossary

Autoexposure—An electronic circuit built into cameras to eliminate electronically (within the camera) excess light from the picture; sometimes referred to as electronic shutter.
Automatic gain control—Ability to increase or decrease video output levels depending on the average light level of the viewed object.
Blooming—A glaring effect on the monitor caused by excessive light.
Boost—The ability to increase the signal strength of the camera. When used under low light conditions, boost provides increased sensitivity.
CCD—Charge-coupled device.
CCU—Camera control unit.
Chroma—Saturation of a color.
Chromiance—Defines the video camera's ability to handle the color red, the most difficult color to reproduce. The more accurate the color reproduction, the higher the chromiance.
C-mount—Standard thread size and diameter for a standard video camera lens.
Color bars—A test pattern used to adjust controls on the monitor for color, brightness, and contrast.
Color reproduction—Ability of an imaging device to reproduce colors exactly as the human eye perceives them.
Composite video output—Most commonly used video signal; the typical television video signal.
DICOM—Digital Imaging and Communications in Medicine; format for images in healthcare.
DVI—Digital Visual Interface, a popular system for medical imaging.
Electronic shutter—Ability of a camera to freeze image information within fractions of a second (1/60, 1/125, 1/1000, 1/10,000).
Foot-candle—Standard measure of luminance; the amount of light emitted by a standard candle at a distance of 1 foot from the flame; 10 luxes equals 1 foot-candle.
HD-SDI—High-Definition Serial Digital Interface; a popular medical imaging system.
High-definition television (HDTV)—A digital broadcasting system with higher resolution capabilities than traditional television systems, such as standard-definition TV (SDTV). Less bandwidth is needed for transmission because of digital video compression.
Light gain—Another circuit within the camera that amplifies the picture electronically to show a brighter image; sometimes referred to as automatic gain control (AGC), or boost circuit.
Luminance—Intensity or effectiveness of a given light on the eye.
NTSC—National Television Standards Committee; also a designation for a television signal used in the United States.
Orientation—A mark or ridge on the camera head to orient the top portion of the video monitor.
PACS—Picture Archiving Communication System.
Pixel—A signal-sensor element on a solid-state video chip; most solid-state chips used in medical videography have about 400,000 pixels on their surface. Each pixel is light-sensitive and sees its own small part of the total picture.
Resolution—An optical device's ability to separate fine detail; usually expressed in TV lines. Resolution traditionally is measured by aiming the camera at a target chart with squares of fine lines. The maximum resolution of the optical device is determined at the point where it begins to blur the lines together. If a box showing 400 lines per inch is still clear with spaces between the lines, the optical device has at least 400 lines-per-inch resolution.
Sensitivity—The response to low light levels by a video system.
S-Video—Super-Video, used to designate analog video signals.
S-VHS output—Super Video Home System (Japan Victor Co.), a signal from the camera that splits the chroma and luminance, allowing for a richer resolution recording.
White balance—Different light sources produce different temperatures of light and different colors of light. White balancing is an adjustment of the camera for various sources of light.

Video systems use light energy from a source, convert it into electrical energy, and then convert it back into light energy to provide pictures. The camera head contains a sensor, which is light sensitive. The sensor may be a solid-state unit or chip, called a *charge-coupled device (CCD),* which produces the unprocessed video signal, or the sensor may be a high-definition (HD) system.

The CCD is composed of small picture elements called *pixels,* which in the presence of light are conductive and in the absence of light remain nonconductive. Each pixel can sense red, blue, or green light. The picture is transformed into a matrix made up of the conductive and nonconductive pixels. This matrix will scan at an extremely rapid rate that generates the signal frequency.

The National Television Standards Committee (NTSC) sets the standard analog video format in the United States, Canada, Japan, and most of South America and Asia. It was established for broadcast purposes. Even though the NTSC format has been used for more than 50 years, most transmissions in the United States were replaced with the ATSC (Advanced Television Systems Committee) format in 2009, and by August 31, 2011, the ATSC format will also be used in Canada.

The three most commonly used video formats are S-Video, HD-SDI, and DVI. S-Video is short for Super-Video and is a technology used for analog video signals. The information of S-Video is divided into two separate signals, one for color (chroma) and one for luminance (brightness), and carries standard definition video. Standard definition displays 720 lines vertically (side to side) and 480 lines horizontally (from top to bottom). This is usually designated as 720×480 resolution, which produces 345,600 pixels. An S-Video cable is needed to support this transmission.

For medical imaging, the two most widely used systems are HD-SDI (High-Definition Serial Digital Interface) and DVI (digital visual interface). The HD-SDI system was engineered for the highest picture quality (and is most widely used for endoscopic systems) while DVI was engineered for copy-protected distribution.

High-definition (HD) systems that produce ultrasharp images with increased levels of contrast are replacing many standard analog video systems. HD systems are often described as offering picture quality equivalent to what one experiences with the naked eye.

An HD video system refers to a system that has higher resolution (greater numbers of lines of resolution) than with the standard-definition analog systems. The HD visual image is much sharper because gaps between the scan lines are either narrower or invisible to the naked eye. This improvement is most evident with larger screens, but on smaller screens there is no noticeable improvement in picture quality. The number of lines of resolution in the vertical display for HD systems is 1080 or 720 lines. Display resolution for HD is usually 1280 ×720 or 1920×1080 (horizontal × vertical pixels). With this higher number of pixels, as compared to the old standard analog video signal, a much clearer picture results, with higher quality and greater detail.

The vertical lines are also described with a lower-case "i," meaning interlaced, or lower-case "p," meaning progressive (which also describes the picture refreshment rate). An interlaced scanning format divides the 1080 lines of resolution into pairs, with the first 540 alternate lines on one frame and then another 540 lines on a second frame. The progressive scanning method displays all 1080 lines simultaneously on every frame, which then requires a greater bandwidth. Today's highest achievable resolution is 1920×1080p. HD video systems that use 1080i resolution are very appropriate for endoscopy because this procedure targets small areas and uses slow-moving videos.

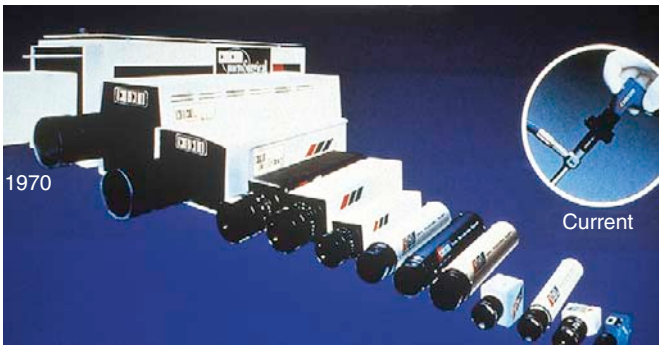


FIGURE 7-31 Evolution of medical video cameras.

Visualization Systems

Endoscopes are used to offer visualization only to the operating physician. The introduction of the teaching arm provided direct visualization not only for the physician, but also for the assistant, perioperative nurse, and other surgical team members. Often, however, images seen through the teaching arm were not identical to the images seen through the primary optics. The inability to interact effectively with the physician or to anticipate surgical needs was frustrating and time-consuming.

In the late 1960s and early 1970s, medical video and still cameras were continually being introduced to the marketplace; this allowed for still photography and video documentation of select surgical procedures. Tube style cameras were large, bulky, and heavy—inadequately meeting the video needs of surgery. Video technology rapidly changed with the introduction of the chip TV camera. Its lightweight, low-profile design triggered the era of video-guided surgery. Cameras that previously weighed several pounds now weigh only a few ounces (Figure 7-31).

Rapid developments in video imaging resulted in higher resolution monitors. Today's integrated video systems provide increased visual capabilities. This leads to enhanced participation by assistants and promotes accurate assessment and planning by perioperative staff. Video technology has evolved to the point of being almost mandatory during MIS procedures. All surgical disciplines have been enhanced by the availability and capability of video systems.

Camera, Cable, and Control Unit. The video camera represents the beginning of the optical-electronic chain of the video system. The camera cable transfers the signal frequency from the camera to a camera control unit (processor), which modifies the signal and then transmits the image to a video monitor, recorder, or hard copy picture, or all three. The camera, being the first in the video chain, is the most important component of the video system. Camera options vary widely according to available technology, specialty, and personal preference.

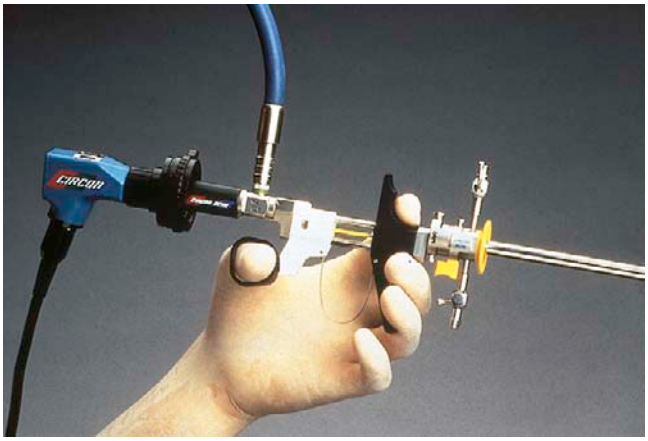


FIGURE 7-32 Microdigital I RGB color video camera with fingertip control.

Cameras have either one or three CCD chips. Three-chip cameras provide enhanced color and image quality, but are larger, can cost three times that of a single-chip camera, and are not as light sensitive. Color and the resulting image are enhanced because each chip is dedicated to one of the primary colors—red, green, or blue. For this reason, three-chip cameras are often used with microscopes when higher magnification requires increased resolution.

Newer single-chip cameras are available with digital processing in their control units, which boosts resolution. In essence, this technology incorporates three-chip quality in a single chip. Although signal processing in the control unit may be digital, the video output from most cameras is still an analog signal.

Digital processing refers to the way information is delivered through the various components of the control unit. This processing format allows for image enhancement and manipulation of the video image. It also allows multiple video signals to be shown on one monitor and has electronic zoom capability. Digital processing also provides the user with freeze-frame capability when using video printers and when using picture-in-picture systems.

Most cameras also feature the ability to adjust to changes in light intensity while in use. This adjustment is done by an automatic shutter (iris), which measures the availability of light and adjusts accordingly. Automatic shutter activation also helps reduce glare from light reflected off instruments and moist viscera. The ability for continuous variable shutter speeds (rather than discrete speeds) allows for instruments to be brought into the field without glare, while still maintaining adequate illumination of background objects. The shutter's response should be rapid, without perceptible stepping of image intensity.

Camera heads have buttons to control certain functions, such as white balancing, light-sensitivity boosting (ability to provide a brighter picture when the image requires more light, especially when a scope less than 3 mm is used during sinusoscopy), starting and stopping the recorder, and taking hard copy prints. The surgeon controls these functions at the camera head instead of requesting the circulating nurse to do so each time at the recording device or with a remote; therefore the surgeon also has the ability to capture events exactly as and when they occur (Figure 7-32).

FIGURE 7-33 Camera control unit.

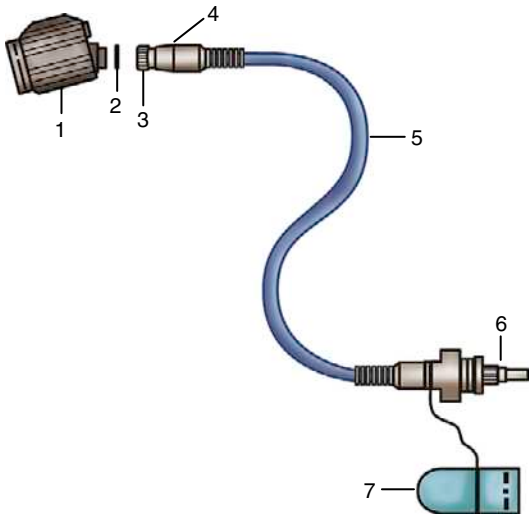


FIGURE 7-34 Camera and field-replaceable cable. *1*, Camera head; *2*, O-ring; *3*, knurled ring; *4*, cable connector; *5*, replaceable cable; *6*, camera connector; *7*, soak cap.

White balancing is performed by turning on the light source, holding the camera about 2 inches away from a white surface, and pressing the white balance button, usually found on the camera head or camera control unit. By sensing pure white, the primary colors of red, green, and blue are controlled so that a white image is created without a visible tint or color cast.

All cameras have focusing capability at the camera-coupler interface. Some also have zoom capability, allowing for closer visualization of specific structures or pathologic conditions. A camera cable connects the camera head to the camera control unit (Figure 7-33). Most camera malfunctions are cable-related, not camera-related. For this reason, a system that provides field-replaceable cables is optimum (Figure 7-34). If wires in the cable break, a new cable can be quickly exchanged, reducing downtime from having to ship the camera and cable for repair. Because wires in the flexible cable can break, the cable must be handled with care. Cables should never be twisted, crimped, or kinked. They also must be long enough to allow sufficient space between the sterile field and the visualization system.

Couplers (Adapters). Endocouplers are optical coupling devices used to connect cameras to various endoscopes. They are usually available in 28-mm and 35-mm focal lengths, with different optical magnifications.

The specific coupler required depends on the surgery or diagnostic procedure to be performed and endoscope to be

FIGURE 7-35 This camera adapter provides a direct link from the camera to the monitor when eyepiece viewing is not desired.

FIGURE 7-37 The camera adapter with a beam splitter allows the physician to look through the eyepiece while others view the procedure on the monitor.

FIGURE 7-36 This camera can be directly attached to the endoscope for viewing on the monitor.

FIGURE 7-38 A one-piece design with a camera incorporated into the endoscope provides consistent, superior image quality.

used. When the surgeon will view only on a monitor, a direct-link coupler between the telescope and camera head is required (Figures 7-35 and 7-36). For the surgeon to look directly through the endoscope and have monitor-viewing capability, a beam-splitter coupler is necessary (Figure 7-37). Beam splitters often are used with flexible endoscopes. There are rotating beam splitters designed for the surgeon who operates in a sitting position. Zoom couplers provide variable focal lengths, usually from 22.5 to 50 mm.

A videoscope is a camera-to-scope connection designed without using a coupler (Figure 7-38). As a coupler adds one more link to the chain, coupler connections can cause loss of light and lens fogging. Connecting the camera and scope with a screw-in design instead of a coupler clamp achieves a tighter fit. This design, however, requires that the camera and scope be purchased as a unit; there is no interchangeability between systems. It also does not allow for sterile bagging of the camera because the camera is part of the endoscope.

Lens fogging can be frustrating. It occurs because a cool metal scope is introduced into a warm body. There are several ways to address this phenomenon. Elimination of a coupler has been discussed. Sterile defogging solutions are available to apply to the endoscope and coupler lenses (Figure 7-39). These provide a coating and reduce the incidence of fogging. Other options on the market include O-ring seals at connections, sapphire lenses,

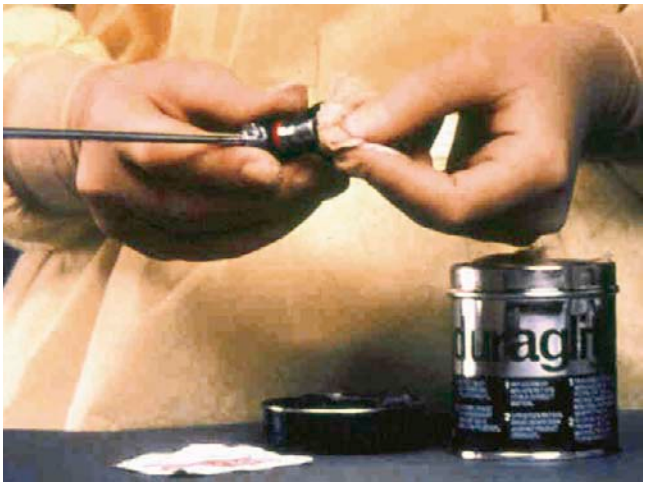


FIGURE 7-39 Sterile defogging solutions are available for endoscopic procedures.

and various water seals. Warming the endoscope before insertion also may reduce fogging. The endoscope can be warmed by wrapping it with lap sponges that have been soaked in warm, sterile water. Also available are scope warmers, such as thermos jugs that warm the scope while maintaining sterility.

Another method is to use a CO_2 insufflator, which warms the gas (if used) before it enters the body. It may be sufficient to change the insufflation site to a secondary port, after the initial pneumoperitoneum has been achieved. The surgeon also may opt to warm the lens of the endoscope by gently touching an intraabdominal structure that requires visualization, obviating the need to withdraw the scope to wipe or defog the outer lens.

An advanced video system has been developed that uses the "chip on a tip" technology. This innovative digital imaging system positions a video chip at the distal tip of the endoscope so that the target is clearly and consistently visualized. The seamless one-piece design eliminates couplers that join together the camera head, telescope, and light cable. The distal end can have either a rigid or flexible tip to access hard-to-reach areas. This unique videoscope minimizes problems encountered by other video systems, such as fogging and faulty connections.

Video Monitor. High-resolution video monitors are the end of the chain in video endoscopy. They have become the "windows of observation" during minimally invasive surgery (MIS). Monitors should match closely the resolution quality of the camera used. A high-resolution monitor that meets or exceeds the horizontal resolution of the camera is required for optimum visualization. By definition, the camera-monitor system will always have the resolution of the least-detailed element. Determining picture quality of monitors is difficult unless the monitors are side by side. Picture-tube design is the component that alters a monitor's picture quality. Monitors must be able to handle the camera/recorder format (standard analog or HD).

Many operative procedures require two video monitors, one placed on each side of the patient so that the primary surgeon and assistant can view the screen simultaneously. The second monitor is called the *slave monitor*. Abdominal and thoracic procedures are performed in this manner. Certain procedures can be performed with only one monitor. Whenever the monitor can be placed comfortably in a position of visibility to both the surgeon and assistant, only one is necessary. This is usually the method of choice for urologists, endoscopists, gynecologists, and otorhinolaryngologists. Most general surgeons require only one monitor whenever they perform surgery with the endoscope directed toward the patient's feet (as in laparoscopic herniorrhaphy).

Monitors should be at least 19 inches (diagonal measurement of screen) for adequate visualization. When the endoscopic revolution began, most institutions purchased 19-inch or 20-inch main monitors and 13-inch slave monitors. Today many institutions purchase mainly 24-inch to 32-inch monitors. This size increases flexibility in usage and provides excellent visibility from most observational angles and distances.

When only one monitor and a composite signal are used, the 75-ohm termination on-off switch must be in the *on* position. When multiple monitors are used, the switch on the last monitor in line to receive the video signal should be in the *on* position, and all others should be in the *off* position to enhance picture quality. Some monitors are self-terminating and do not have termination switches (Figure 7-40), an electronic wiring design known as a "daisy chain."

Recording Systems. Some recording devices allow for archiving the surgical procedure or selected portions of it. The most commonly used is the video printer (Figure 7-41), similar

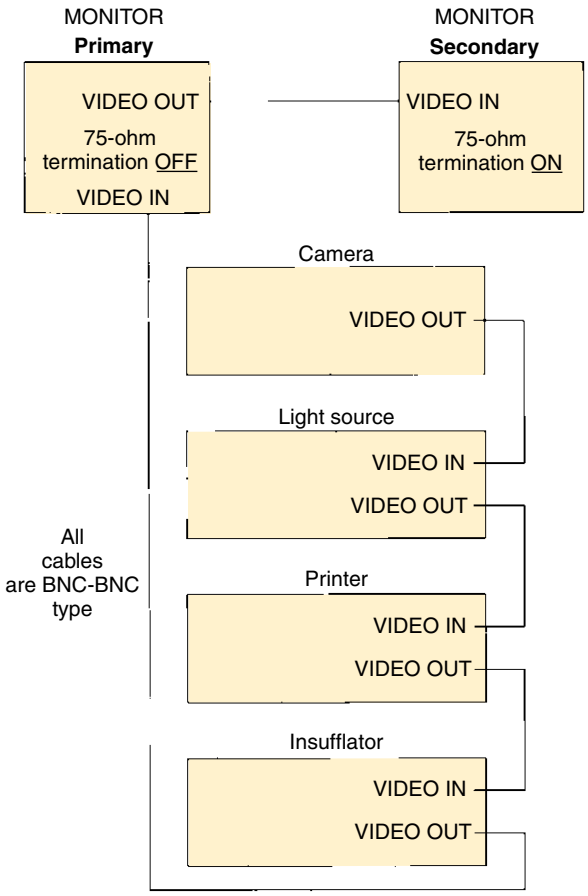


FIGURE 7-40 Basic wiring configuration.

FIGURE 7-41 Video printer producing a picture of the endoscopic image.

to a Polaroid camera in that it takes still pictures instantly. The printer stores the selected image and prints it onto special paper. Many units can be programmed to print 1, 4, 9, or 25 pictures on one piece of 5½ × 8 inch paper in split-screen fashion. Comparisons can then be made as the pathologic condition changes. Information such as patient name, date, time, and operating surgeon usually can be superimposed on top of the print. These prints can be used both for teaching purposes and

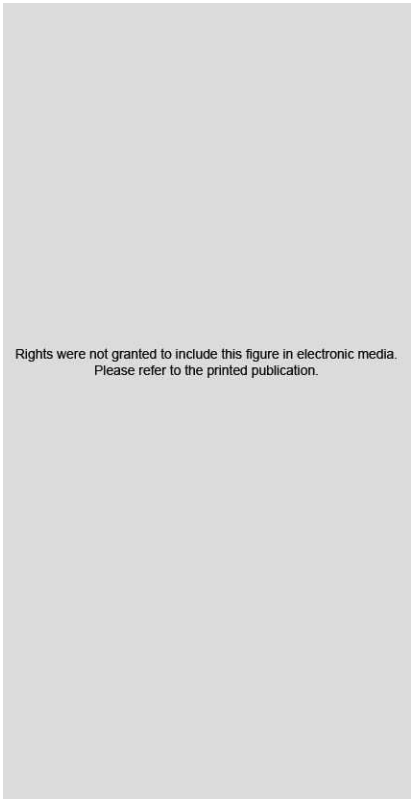


FIGURE 7-42 Video laparoscopy cart.

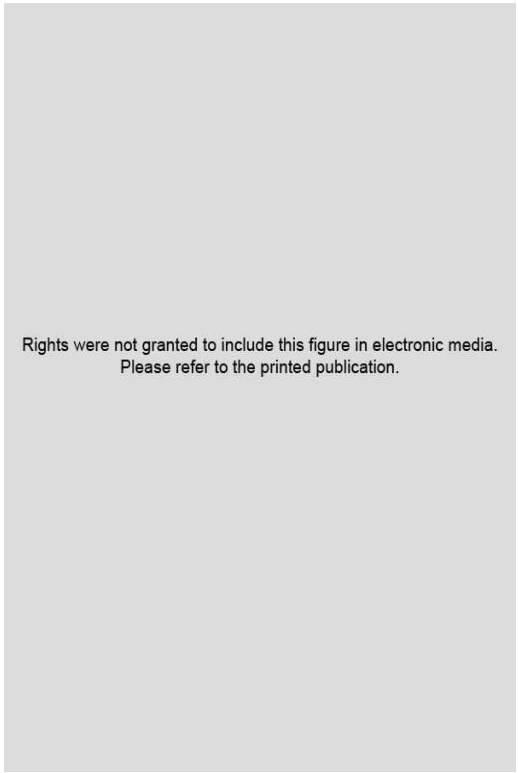


FIGURE 7-43 Video storage cart with swivel monitor arm and lockable door.

as part of the permanent record. Some patients are interested in seeing prints of "before and after" images of their condition.

Video disc recorders store and permit easy access to video information. Video disc recorders have become the documentation format of the future. To use a video disc recorder, one also must use a video printer because the images stored are limited to video. HD recorders with touchscreen monitors are also available; they record on an internal hard drive (usually 250 gigabytes). The images and videos can then be exported via a USB port, burned on a DVD, or sent to the hospital's server. The optical disc standard, known as Blu-ray, can provide digital storage for up to 10 hours of HD, depending on the encoder settings used.

If a picture or video is sent to the hospital's server, HIPAA (Health Insurance Portability and Accountability Act) regulations must be met. The digital images must be saved in a DICOM (Digital Imaging and Communications in Medicine) format as opposed to JPG or MPG formats used in the consumer market. The digital images are exported from the camera to the hospital's server system, called PACS (Picture Archiving Communication System).

Storage Systems. Space, storage capability, security, and required components determine the type and size of video storage carts needed. Purchasing a cart that can house multiple components of the video system is optimum (Figure 7-42). Such carts eliminate the clutter of multiple smaller carts and tables. They also eliminate the number of cord connections to wall outlets because most carts have power strips incorporated in their electrical setup. If a cart has a power strip, an on-off main switch usually is located near its base. The power switch must be in the *on* position for the equipment that is plugged into the strip to work. Given the location of the switch, it can be turned off easily during transport and cleaning. Time and embarrassment can be avoided if this switch position is routinely checked before each use.

Articulating arms can be used as monitor mounts. Surgeon preference and room space determine if this option is necessary or possible. If a surgical or treatment room has been designated for endoscopy, the monitor can be suspended from the ceiling on a swivel mount. The mount should be placed in a location where the monitor can be easily and comfortably viewed and cleaned. Care must be taken to ensure the swivel mount can support the weight of the monitor and other equipment.

Carts have either a locked (Figure 7-43) or an open (Figure 7-44) shelf design. Institutional security determines this configuration. Storage, tampering, and key availability are important issues. A locked drawer may be ideal to store HD recording devices, printing paper, and other valuable video supplies. Carts also should be selected for ease of movement, component accessibility, and cleaning. Carts may also include an optional storage bracket for E-cylinders when insufflation is required. Secondary (slave) monitor carts usually do not contain multiple shelving and cabinet components.

Robotics

Robotic devices to assist with holding and maneuvering a laparoscope free team members to perform other roles and attend to other duties. The robotic arm minimizes shaky video images and reduces miscommunications between surgeon and assistant. The robot's movement is controlled directly by foot pedals, handheld control panels, and voice activation (Figure 7-45).

FIGURE 7-44 Open shelf design video cart.

Advances in laparoscope stabilization and movement facilitate the procedure, promote safety, and sometimes minimize the time to perform the procedure.

The robotic arm chassis houses the power system and the computerized control unit. An electromechanical positioner bar attaches to the surgical bed and connects to the laparoscope with a magnetic coupling device. A sterile drape covers this arm to maintain a sterile field. The robotic arm maintains the laparoscope in proper orientation—the lack of which was a problem experienced with manual scope maneuvering.

Advantages of a robotic device for laparoscope positioning are as follows (Phillips, 2008):

- Minimizes fatigue associated with holding and moving the scope
- Returns scope control to the physician
- Accommodates quick scope movements through a computerized memory
- Shortens the procedure time by minimizing scope-positioning time
- Provides a steady image that enhances video quality
- Ensures consistent scope positioning and movement, not always possible with human assistants
- Frees the surgeon's hands to perform other tasks

In September 2001, an internet news source reported that surgeons at Mount Sinai Hospital in New York used a remote-controlled robot to operate successfully on a patient in France. The American surgeons removed the gallbladder of a 68-year-old French woman at the European Institute for Tele-Surgery in Strasbourg, France, more than 4000 miles from the surgeons. Physicians viewed this as a defining moment in medical history that advanced remote telepresence surgery to a new level (Scheeres, 2001). Research and experimentation continue to determine if robotics can assist with more delicate and precise procedures, such as during laparoscopic surgeries.

FIGURE 7-45 By being able to command the movement of the robotic arm, the surgeon has complete control over laparoscopic positioning.

Computer-assisted surgery (CAS) (also called image-guided surgery, surgical navigation, and three-dimensional [3-D] computer surgery) has also grown rapidly. This surgery is any computer-based surgery that uses high technology, such as 3-D computer imaging and real-time sensing, in planning, implementing, and following up on surgical procedures. CAS provides enhanced visualization and site targeting along with improved diagnostic capabilities.

Videoconferencing

Videoconferencing is a method to reach distant sites through two-way interactive communications using live audio and video signals. Communications between two or more sites may be live, or one site may play a videotape for the other sites connecting to the videoconference. This technology requires basic videoconferencing equipment and a network mode to transmit the communication signal to multiple sites. The higher the network bandwidth used by the participating sites, the better are audio and video motion-handling capabilities, and the resolution of the video signal that can be transmitted to each. A videoconference can be held between two sites or dozens of sites simultaneously. Videoconferencing applications in healthcare include education, remote assessments and consultation, administrative meetings, and product development.

Formal education and continuing education are the foundations of quality healthcare, and providing education to and from distant sites has gained tremendous popularity. Healthcare workers practicing in remote areas do not feel as isolated because educational videoconferencing is now widely available. Distant preceptorships also have been offered as one physician monitors and oversees another physician learning a new surgical technique or using advanced surgical instruments.

Remote consultation to evaluate patients at remote sites has been used as assessment technology has been introduced and accepted. A physician or nurse practitioner (depending on state regulations) can assess heart sounds of a patient located at a distant location through the use of a telemedicine stethoscope. The retina of a diabetic patient can be viewed from afar by use of a special remote-assessment ophthalmoscope. A perioperative nurse practitioner located in a rural area can consult with a specialty physician located in a large urban teaching institution regarding treatment of a patient (Figure 7-46).

FIGURE 7-46 A nurse practitioner can consult with a physician at a remote location about a patient's treatment.

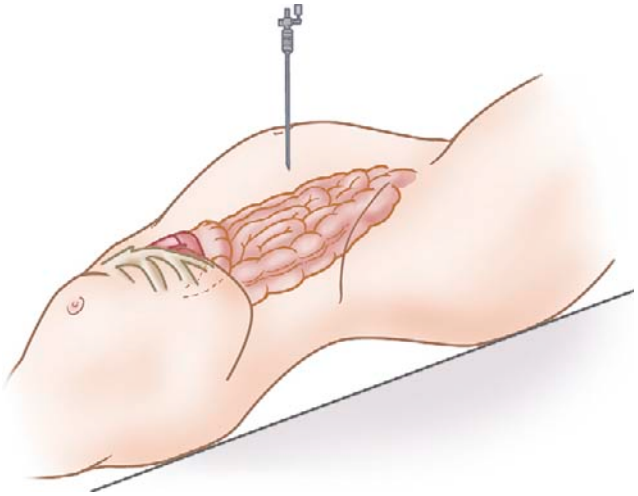


FIGURE 7-47 Verres needle insertion into abdomen.

Videoconferencing can also be conducted for administrative and other meetings to minimize travel expenses and time away from work. Product development also can be enhanced using videoconferencing. A company that manufactures surgical devices can communicate on a regular basis with key customers who are conducting trials of its devices. Device malfunctions and limitations can be assessed easily through real-time audio and video communication.

Some issues remain as videoconferencing becomes accepted. Standardization must be followed so that videoconferencing equipment can communicate and be compatible with each other. Some governmental and professional organization recommendations and mandates have guided manufacturers to meet approved criteria so that global interconnectivity can occur more easily. Confidentiality is another concern as the popularity of this technology increases. Patient information, assessment data, and treatment results are being shared among providers by means of videoconferencing today. Patient confidentiality and privacy must be maintained. HIPAA compliance is vital when transmitting patient records. Private networks, advanced coding systems, and other technology can help address this issue. Practicing across state lines also has become a concern as videoconferencing in healthcare evolves (Cohen, 2009). State boards of nursing, medicine, pharmacy, and other professions are addressing this situation and proposing methods to facilitate licensing so that providers can practice across state boundaries. Finally, reimbursement for remote consultation and assessment is being analyzed by many insurance carriers. Pilot project sites have been established by the Centers for Medicare & Medicaid Services (CMS, formerly the Health Care Financing Administration) to study this question. When reimbursement can be consistently provided, more healthcare providers and facilities will embrace videoconferencing.

PRACTICES AND POTENTIAL RISKS DURING MIS

Insufflation

To help visualize abdominal structures and to enhance safety during laparoscopic procedures, a pneumoperitoneum is created. The surgeon makes a paraumbilical incision and inserts an insufflation (Verres) needle into the abdomen (Figure 7-47). Trendelenburg's position is used to reduce the risk of visceral perforation. Appropriate positioning devices should be used (see Chapter 5). As the surgeon inserts the needle, he or she lifts up the patient's abdomen by grasping and lifting a fold of tissue on either side of the umbilicus. Preoperative patient education should include the possibility of finger-pinched bruising at the site where the abdominal tissue is grasped.

The needle safely enters the peritoneum positioned at a 45-degree angle. Placement is confirmed by negative bowel and blood return on aspiration and by saline instillation that meets no resistance. This is a relatively blind procedure because no scope can be introduced until pneumoperitoneum is established. A new laparoscopic trocar system has been introduced in which the obturator tip, instead of a needle, is inserted with minimal penetration into the peritoneum, then rapid insufflation is provided.

After needle confirmation, insufflation tubing is connected and the process begun. CO_2 gas is used to insufflate because it does not support combustion, can be absorbed at large volumes per minute without serious side effects, and is fairly inexpensive. The peritoneal cavity is filled, first at a low flow rate that is increased to a high flow rate of at least 9 L/min ideally. Flow rate refers only to how quickly a predetermined intraabdominal pressure can be reached. Intraabdominal pressure is the actual measure that must be closely monitored and should be maintained between 14 and 16 mm Hg. High flow rates are important because during the procedure, the insufflation CO_2 gas can escape through smoke evacuation, instrument changes, and other practices. The more quickly the gas can be replaced, the less time is spent waiting for the abdomen to be redistended. Perioperative nurses must demonstrate competence in insufflation, and understand and manage its potential risks.

Insufflator control panels should monitor and display the following variables:

- Rate of flow
- Volume delivered
- Intraabdominal pressure

Selection of an insufflator that accommodates a high flow rate is important. Insufflators delivering 15 to 20 L/min are much more effective than those delivering gas at slower

FIGURE 7-48 A smoke evacuator that can manually remove the insufflation gas using a closed system.

Rights were not granted to include this figure in electronic media.
Please refer to the printed publication.

FIGURE 7-49 Disposable insufflation tubing with two-way filter.

Rights were not granted to include this figure in electronic media.
Please refer to the printed publication.

FIGURE 7-50 Computerized high-flow insufflator with CO_2 warmer.

rates. The insufflator must monitor insufflation pressure continuously, stop the insufflation process when the predetermined set pressure has been reached, and release pressure if there is an inadvertent pressure increase (called "taking a breath"). Intraabdominal pressure can be increased for reasons other than CO_2 insufflation; leaning on the abdomen and additional gas introduction from other sources, such as an argon-beam coagulator or a CO_2 laser with a purge gas system, can inadvertently increase intraabdominal pressure.

Overpressurization can be extremely hazardous to the patient. Excess pressure can force CO_2 to diffuse into the blood, resulting in hypercarbia. End-tidal CO_2 monitoring becomes a crucial assessment parameter to detect increased CO_2 absorption. Excess pressure also increases diaphragmatic pressure, which can cause gastric regurgitation and aspiration of stomach contents. It also can reduce intrathoracic space, resulting in decreased respiratory effort and cardiac output. The phrenic nerve innervates the diaphragm and is responsible for some motor activity associated with respiration. CO_2 gas can irritate this nerve, causing postoperative pain in the shoulder and neck. Excessive pressure could cause tremendous postoperative discomfort and severe nerve damage. The surgeon or assistant should press on the patient's abdomen to release as much residual CO_2 gas as possible before removal of the last trocar sheath when the procedure is completed. Insufflators that automatically vent excess CO_2 gas into the air ensure that many potential complications can be avoided. A special smoke evacuator provides a safe and quick method to manually remove the insufflated gas using a closed system so that no gas escapes into the environment when the surgeon is releasing the insufflated gas (Figure 7-48). This minimizes contaminated air that could possibly be inhaled by the surgical team.

A two-way, single-use disposable filter should be incorporated into the insufflation tubing (Figure 7-49). This hydrophobic filter provides patient protection from harmful gas-tank contamination, such as chromium particles. It also provides protection from the colonization of organisms in the insufflator itself. Without a filter, when the insufflator is turned on, organisms such as *Klebsiella, Pseudomonas,* and *Staphylococcus aureus* can be blown into the patient. This contamination could be deadly for a very ill, elderly, or immunocompromised patient. The manufacturer's written instructions must be followed when implementing CO_2 insufflation. Perioperative nurses should consider the following steps to reduce cross-contamination of the patient and insufflator during CO_2 insufflation:

1. *Before* the procedure, verify that the cylinder is medical-grade CO_2; note the level of gas in the cylinder.
2. Flush insufflator and tubing with CO_2 gas before attaching to patient.
3. Use a disposable hydrophobic filter on insufflation tubing. Discard after procedure.
4. *During* the procedure, monitor level of CO_2 remaining in cylinder; have second cylinder readily available.
5. Keep insufflator elevated above the patient to prevent fluid backflow.
6. At end of procedure, disconnect tubing from insufflator before turning off.

An insufflator capable of warning the team of insufflation problems throughout the procedure is vital. Alarms that sound when there is a deviation from predetermined parameters call attention to the need for immediate intervention, such as an alarm ringing and a monitor blinking "Gas supply low." An alarm sounding when overpressurization occurs from a secondary source (e.g., by leaning on the abdomen) also alerts the team to take corrective action.

Insufflators are also available with CO_2 warming devices (Figure 7-50). Cylinder CO_2 is a liquid, and as it is released, it expands into a gas. During conversion from liquid to gas, energy is lost, and the gas becomes colder. The higher the flow, the colder the gas. Some warming occurs as the gas travels through insufflation tubing. Use of cold CO_2 can cause a decrease in patient temperature, especially with prolonged laparoscopy. Many factors contribute to reduced body temperature during laparoscopic procedures (e.g., cold irrigation,

room temperature, surface exposure, length of the procedure, patient's age and medical history, anesthetic choice); cold CO_2 represents an additional one. The best way to reduce patient heat loss and the risk for hypothermia is to address all variables and intervene wherever possible.

Complications and Anesthetic Considerations During MIS

Although anesthetic technique and delivery are the responsibility of the anesthesia provider, perioperative nurses must anticipate and respond appropriately to associated risks during MIS procedures. Many formerly performed open surgical procedures are now performed as MIS procedures in ambulatory surgery. With this change, anesthetic technique also has changed. Today there is an emphasis on minimal anesthesia during surgery. Short-acting drugs are used so that the patient awakens quickly and experiences far fewer side effects (see Chapter 4).

The three major goals of the anesthesia provider during MIS procedures remain the same: *respiratory stability, appropriate muscle relaxation,* and *hemodynamic stability.* In addition, during many laparoscopic and pelviscopic procedures, it is necessary to control diaphragmatic excursion. Patient monitoring includes an electrocardiogram (ECG) and assessment of end-tidal CO_2, blood pressure, oxygen saturation, and temperature.

When Trendelenburg's position is used, intraabdominal pressure increases, and this can cause respiratory complications, including hypoxia. CO_2 absorption from the peritoneal cavity can aggravate this situation. Reverse Trendelenburg's position, on the other hand, can cause decreased venous return, reduced cardiac output, and hypotension. CO_2 insufflation in this position can also cause an increase in total peripheral resistance, especially if intraabdominal pressure is high and the aorta compressed. The perioperative nurse must be prepared to quickly change the position of the OR bed, decrease the CO_2 flow rate of the insufflator, and assist the anesthesia provider with medications and extra supplies.

CO_2, highly soluble in blood, generally is not hazardous when used during laparoscopic insufflation as it is rapidly absorbed in the splanchnic vascular region. Excessive intraabdominal pressure or any anesthetic technique that reduces splanchnic blood flow, however, could increase the potential for CO_2 gas emboli. That in turn could lead to circulatory collapse. CO_2 also could advance from the heart to pulmonary circulation, causing acute pulmonary hypertension with right-sided heart failure. If these effects are undetected and CO_2 insufflation continues, cardiac arrest and death may occur. If there are signs of CO_2 embolus, and there is not sufficient assistance, it may be necessary to call a rapid response team (Rapid Response Team box).

Intraoperative hypotension can result from excessive bleeding, excessive intraabdominal pressure, and hypoxia. CO_2 insufflation rates may need to be reduced. Extra intravenous fluids may be needed. Likewise, intraoperative hypertension can result from increased intraabdominal pressure, and increased CO_2 gas absorption also may be evident. Increased bleeding may result. The perioperative nurse may need to decrease CO_2 insufflation flow rates. Additional hemostatic agents and endoscopic clips may be required.

Gastric reflux may occur if the patient is obese, a hiatal hernia is present, or excessive pneumoperitoneum occurs. A nasogastric or orogastric tube may be inserted after general anesthesia is induced. Postoperative discomfort is less if an orogastric tube is used. During epidural and regional anesthesia, patients are usually awake, and insertion of a gastric tube may be poorly tolerated. For this reason, the tube is not inserted unless gastric distention occurs. The perioperative nurse must be quick to respond if assistance is required during gastric tube insertion. Intercostal nerve blocks offer surgical pain relief and abdominal muscle relaxation when the patient is awake during surgery. The perioperative nurse's role during intercostal nerve block induction is to remain at the patient's side and help reduce anxiety. Other risks during MIS procedures include hypercarbia, subcutaneous emphysema, and pneumoscrotum.

ENERGIES USED DURING SURGERY

Laser

A healthcare revolution occurred with the birth and evolution of the laser (Box 7-2). Perioperative nurses must be accordingly aware of expanded responsibilities associated with laser applications. The laser has significantly impacted surgery by making possible less invasive procedures, decreasing inpatient hospitalization, diminishing postoperative complications, and saving healthcare dollars.

Laser Biophysics

PRINCIPLES OF LIGHT. *LASER* is an acronym that describes a process in which light energy is produced—*l*ight *a*mplification by stimulated *e*mission of *r*adiation. The term also refers to the device that generates laser energy.

Light is a form of electromagnetic energy that can be graphically illustrated on a continuum known as the electromagnetic spectrum (Figure 7-51). The unit of measurement for this

RAPID RESPONSE TEAM

Most often, the OR has sufficient personnel available to respond to critical situations with patients, such as CO_2 embolus and the risk of cardiac arrest. However, on occasions when there is no additional staff to assist with a suspicion of CO_2 embolus, a Rapid Response Team (RRT) should be called. Signs of CO_2 embolus (pulmonary embolism) include sudden decrease in blood pressure, dysrhythmia, heart murmur, cyanosis, pulmonary edema, and an abrupt increase in end-tidal CO_2 level. If an embolus is suspected, continuous monitoring of heart sounds, blood pressure, and end-tidal CO_2 level assists the anesthesia provider in making a rapid diagnosis. Immediate deflation of pneumoperitoneum is necessary. Treatment may include immediate placement of the patient in a left lateral position and aspiration of the CO_2 gas through a central venous catheter. The perioperative nurse should assist in patient repositioning while maintaining the sterility of the equipment and the surgical field wherever possible. Assistance may be required during central venous catheter placement. Debilitated patients may require preoperative invasive monitoring.

BOX 7-2

History of Laser Technology

During the early 1900s Einstein first described a theory that involved the stimulation of matter to cause the release of energy. In 1957 Gould developed the principle of LASER, derived from the acronym, light amplification by stimulated emission of radiation. In 1958 Schawlow and Townes investigated this concept of stimulated atoms and the creation of photons. They suggested that mirrors be used to amplify the stimulated emission of radiation to multiply photons at an accelerated rate.

In 1960 Maiman developed the first laser for medicine and surgery using a ruby crystal. The ruby laser was used for dermatologic applications and for retinal photocoagulation in patients with diabetic retinopathy, but it was not very efficient. Many other lasers—such as the argon, CO_2, Nd:YAG, KTP, holmium, erbium, excimer, and diode lasers—have been developed and are now used in multiple surgical disciplines. Advancements in laser technology provide surgeons with a precision tool for cutting, coagulating, vaporizing, and welding tissue during surgery.

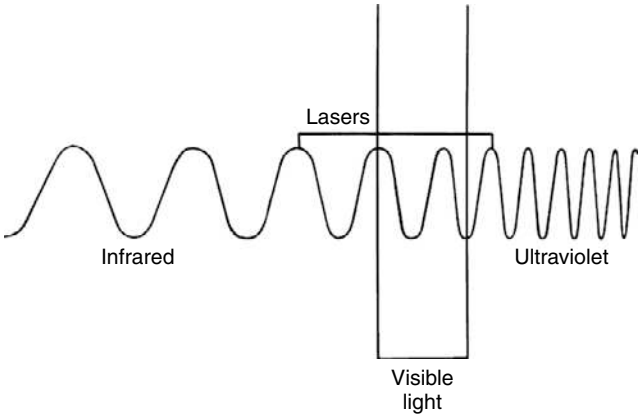


FIGURE 7-51 Electromagnetic spectrum.

continuum is called a wavelength, the distance between two successive peaks of a wave. Wavelength determines color and usually is measured in nanometers (10^{-9} m) or micrometers (1000 nm). Various wavelengths of light extend from the shorter waves in the ultraviolet area to the longer waves in the infrared region (Table 7-2). Visible laser wavelengths occupy only a small portion of this continuum. Radiation used in laser technology in healthcare is nonionizing in that it does not present the hazard of cellular DNA disruption with continual tissue exposure. Pregnant women, for example, can work with lasers because laser energy produces no harmful ionizing radiation.

Briefly, the laser functions in the following way. A negatively charged electron orbits a positively charged nucleus while the atom is in its ground or resting state, its lowest energy level. An outside source of energy (e.g., electricity, flash lamps, other lasers) can excite the atom and cause an electron to jump to a higher, less stable orbit. The electron almost immediately returns to its stable orbit, and the atom resumes its normal resting state. As the unstable electron returns to its ground state, it spontaneously releases a tiny packet of light energy known

TABLE 7-2

Electromagnetic Spectrum Wavelengths

Type of Light	Wavelength (nm)
Ultraviolet (UV)	100-400
Visible	400-750
Near-infrared (NIR)	750-3000
Mid-infrared (MIR)	3000-30,000
Far-infrared (FIR)	30,000 nm-1 mm

as a photon, which travels away from the source in the form of waves. If the photon is close to another similar atom while it is still in the excited state, it interacts with this atom. The photon triggers the excited second atom to return to its resting state, and in this process another photon of laser light is emitted. These two photons of identical energy travel together. The process of stimulated emission has occurred, and laser energy initiated (Figure 7-52). This process repeats itself over and over again, creating more photons of laser energy.

This activity occurs in the resonating chamber of the laser, where the lasing medium is contained. The name of the laser usually is derived from the actual medium that causes the lasing action. The photons generated during the stimulated emission process are reflected back and forth between mirrors at each end of the resonating chamber as the process is amplified, until the number of excited atoms surpasses the number of resting atoms. This is known as population inversion. One of the mirrors in the chamber is partially reflective and, when activated, allows a stream of laser photons to escape the unit. These photons are introduced to the target area by means of a specific delivery system.

CHARACTERISTICS OF LASER LIGHT. Three distinct characteristics distinguish laser light from ordinary light. Laser light is monochromatic, collimated, and coherent.

1. *Monochromatic light* is composed of photons of the same wavelength or color. In contrast, ordinary light consists of many different colors or wavelengths. When white light is passed through a prism, an array of different colors is displayed. White light is the presence of all colors, whereas laser light consists of one color or wavelength.
2. A *collimated* laser beam consists of waves parallel to each other that do not diverge significantly, minimizing any loss of power. When a collimated beam is passed through a lens, the light pattern is changed, allowing the light to be focused into a tiny spot that highly concentrates the energy. In comparison, the light waves from a flashlight are not parallel and lose intensity as they travel away from the source. A lens cannot easily focus these noncollimated waves to concentrate the light into a small area.
3. Laser light is *coherent*—all the waves are orderly and in phase with each other as they travel in the same direction. All peaks and troughs of the waves are opposite each other in time and space. This property provides an additive effect that gives the laser beam power. Ordinary light is incoherent because the waves radiate away from the source without being in phase or in an orderly pattern.

LASER POWER. The power, or energy, of a laser beam is measured in watts. An important factor in laser applications is the concept of power density, or irradiance of the beam. *Power*

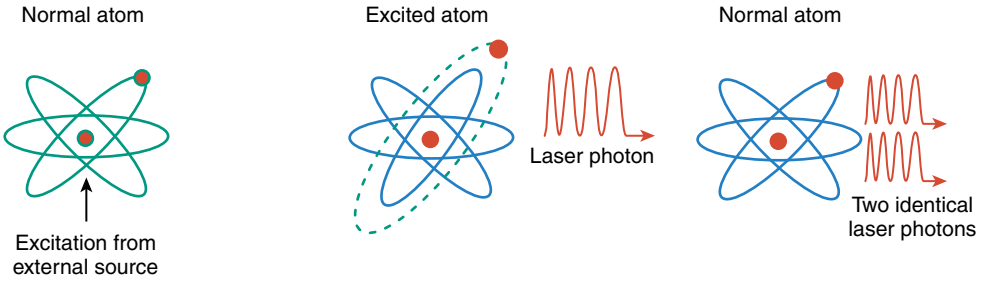


FIGURE 7-52 Laser energy is produced when an external source excites the atom to emit a photon spontaneously. This photon can "stimulate" the emission of two identical photons.

density is the amount of power that is concentrated within an area and is described by the following formula:

$$\text{Power density} = \text{watts/spot size (cm}^2\text{)}$$

The spot size of the laser beam can be controlled when the beam is passed through a special lens that causes the beam to converge. The focal configuration of the lens determines at what distance from the lens the beam would be most intense; this is called the *focal point*. If the beam is defocused into a larger spot size, the laser energy is spread over a greater area, decreasing the intensity or power density of the beam. In contrast, a small spot size of the beam concentrates the laser energy into a smaller area, increasing the intensity or power density of the beam. When power density is increased, the beam has a greater depth of penetration into the tissue.

A *joule* is the unit of measure used to describe total energy used. A joule is expressed by the power multiplied by the time duration of the beam exposure (expressed in the equation joule = watts × time). Often the laser energy used during ophthalmic procedures is expressed in millijoules.

Fluence is a term that expresses the power and duration of exposure of the beam and measures the specific amount of energy delivered to tissue. Fluence is also known as energy density or radiant exposure. The following equation calculates fluence:

$$\text{Fluence} = \text{watts} \times \text{duration time/spot size (cm}^2\text{)}$$

TISSUE INTERACTION. When laser energy is delivered to a target site, four different interactions can occur: reflection, scattering, transmission, or absorption (Figure 7-53). The extent of reaction of the beam on the target depends on laser wavelength, power settings, spot size, length of contact time with target tissue, and tissue characteristics.

Reflection of the laser beam occurs when the direction of the beam is changed after it contacts an area. Specular reflection occurs when the angle of the incoming light is equal to the angle of the reflected light. Laser light can be intentionally reflected in this manner off a reflective mirror to contact hard-to-reach areas. Such reflection also can pose safety problems by inadvertently striking untargeted areas if it is not controlled at all times. The CO_2 laser beam can be reflected off of the surface of a shiny instrument and impact a surgery team member's mask, causing it to ignite. Accordingly, eye and fire safety measures are mandatory when the potential for laser beam reflection is high.

Scattering of laser light occurs when the beam spreads over a large area as tissue causes the beam to disperse. The intensity of the beam decreases as the waves travel in different directions. The Nd:YAG laser beam can backscatter up an endoscope and possibly cause damage to the end of the scope, the optics, or the operator's eye. The noncontact Nd:YAG beam also can scatter through tissue, causing penetration of 3 to 5 mm.

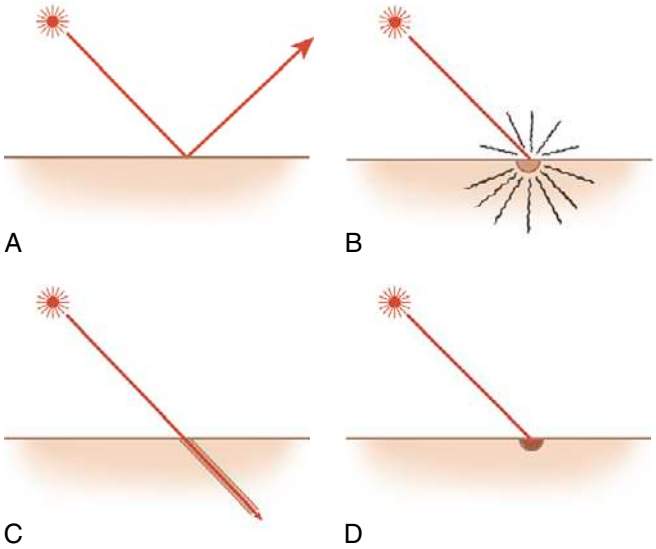


FIGURE 7-53 Laser-tissue interaction. **A**, Reflection. **B**, Scattering. **C**, Transmission. **D**, Absorption.

Transmission of the laser beam occurs when the beam passes through fluids or tissue without thermally affecting the area. The argon beam can be transmitted through clear fluids and structures of the front part of the eye and the vitreous to cause thermal photocoagulation on the retina, while the cornea, lens, and vitreous are unaffected by transmission of this beam.

Absorption of laser light results when tissue is altered from the absorption of the beam. As the amount of energy delivered to tissue (fluence) increases, different tissue effects can be produced. The lowest level of energy produces a photochemical reaction. Then as fluence increases, a photothermal reaction occurs. With the highest level of fluence, a photoacoustic effect occurs. Reactions from the lowest to highest level of energy occur as follows:

- *Photochemical effect*— laser energy is selectively absorbed by tissue containing a light-sensitive dye, leading to a chemical change that produces singlet oxygen, which ultimately causes tissue destruction.
- *Photothermal effect*—laser energy is absorbed by tissue, heating it.
- *Photoacoustic effect*—laser energy is absorbed, creating kinetic energy that produces a snapping sound, disrupting the tissue without significant thermal effect.

TABLE 7-3

Tissue Changes with Temperature Increases

Temperature (°C)	Visual Change	Biologic Change
37-60	No visual change	Warming, welding
60-65	Blanching	Coagulation
65-90	White/gray	Protein denaturization
90-100	Puckering	Drying
>100	Smoke plume	Vaporization, carbonization

From Ball KA: *Lasers: The perioperative challenge,* ed 3, Denver, 2004, AORN.

TABLE 7-4

Description of Laser Color and Wavelength

Laser	Color	Wavelength (nm)
Excimer	Ultraviolet	
ArF		193
KrCl		222
KrF		248
XeCl		308
XeF		351
Helium-cadmium		325
Argon	Blue	488 or 457
Frequency-doubled	Green	514.5 or 528
YAG (KTP)	Green	532
Krypton	Green	531
	Yellow	568
	Red	647
Dye laser	Variable with dyes	400-1000
Gold vapor	Red	628
Helium neon	Red	632
Ruby	Deep red	694
Diode	Visible to near-infrared	532-908
Alexandrite	Near-infrared	760
Nd:YAG	Infrared	1064 or 1318
Holmium:YAG	Infrared	2140
Erbium:YAG	Infrared	2940
Carbon dioxide	Infrared	10,600

From Ball KA: *Lasers: The perioperative challenge,* ed 3, Denver, 2004, AORN.

Consistency, color, and water content of the target tissue often determine the rate of absorption of laser energy. Laser wavelength also affects absorption of the beam. Certain laser light, such as that from the argon laser, is highly absorbed by pigmented tissues. The CO_2 laser, however, is independent of color-selective absorption. CO_2 laser light is absorbed superficially by tissue to a shallow depth of approximately 0.1 to 0.2 mm, whereas the holmium laser beam is absorbed to about 0.4 to 0.6 mm. Argon laser light is readily absorbed by pigmented tissue to a depth of approximately 1 to 2 mm, whereas that of the noncontact Nd:YAG laser beam is more readily absorbed by darkened tissue to a depth of 3 to 5 mm.

Photothermal tissue reaction becomes more pronounced as the temperature of the target area increases during absorption of the laser beam (Table 7-3). As laser energy is absorbed, the water within each cell is heated. As temperature increases, intracellular protein is destroyed and water inside the cell turns to steam. Eventually, the cellular membrane ruptures from increased pressure, spewing cellular debris and plume (smoke) from the tissue. The surrounding tissue also is heated through conduction because it borders the impingement site. The degree of adjacent tissue damage depends on the duration of laser-beam exposure that causes the intended thermal destruction of target tissue.

Laser Systems. New laser systems are being introduced into healthcare regularly. Constant efforts by researchers and physicians to explore the use of different wavelengths frequently change surgical approaches in a variety of specialties. Table 7-4 describes popular lasers used in medicine and surgery today.

LASER SYSTEM COMPONENTS. Five major components of a laser system are the laser head, excitation source, ancillary components, control panel, and delivery system (Ball, 2004). When a laser malfunctions, an organized investigation of each of these parts (Figure 7-54) usually can determine the source of the problem.

The *laser head,* or resonating chamber, is the component in which laser energy is generated and amplified. The laser head contains the active medium or substance that actually produces the photons that generate laser light. The active medium can be a gas (CO_2 or argon), a solid crystal (Nd:YAG), a liquid (tunable dye), or a semiconductor crystal (diode).

The *excitation source* supplies the energy to excite the active medium in the laser head. Different sources include flash lamps, electricity, radio waves, batteries, chemicals, and other laser systems. The CO_2 laser gas mixture is excited by electrical current or radio waves, and the Nd:YAG laser crystal is excited by flash lamps. Diode lasers, such as the gallium arsenide laser, are solid-state lasers that are excited by electrical energy.

Ancillary components are other laser parts needed to help produce laser energy. A cooling system maintains the appropriate temperature of the laser head and keeps the unit from overheating. Usually lasers are air cooled or water cooled. A vacuum pump may be required in a CO_2 free-flowing laser to pull the gas mixture from an external cylinder into the laser head for laser light production. Current sealed-tube CO_2 lasers do not require a vacuum pump because the laser gas mixture is catalyzed to regenerate itself for the lasing action to continue, using the same gas mixture over and over again.

The *control panel* consists of a board that regulates delivery of laser energy. Various power settings, modes, durations, and other parameters can be selected. Most laser panels are computerized, allowing the laser to be controlled quickly and accurately. Wireless control modules can be placed into a sterile plastic bag so that the surgical team can control the laser from the sterile operating field.

The *delivery system* is the device or accessory that conducts laser energy from the laser head to the target area. CO_2 laser energy usually is delivered to tissue through an articulated arm with a series of special mirrors at each joint. The commonly used argon, KTP, Nd:YAG, and holmium lasers deliver energy through a fiber system. Advancements in laser technology are refining delivery systems to make them more adaptable, convenient, and user-friendly. Various lasers are described in the next

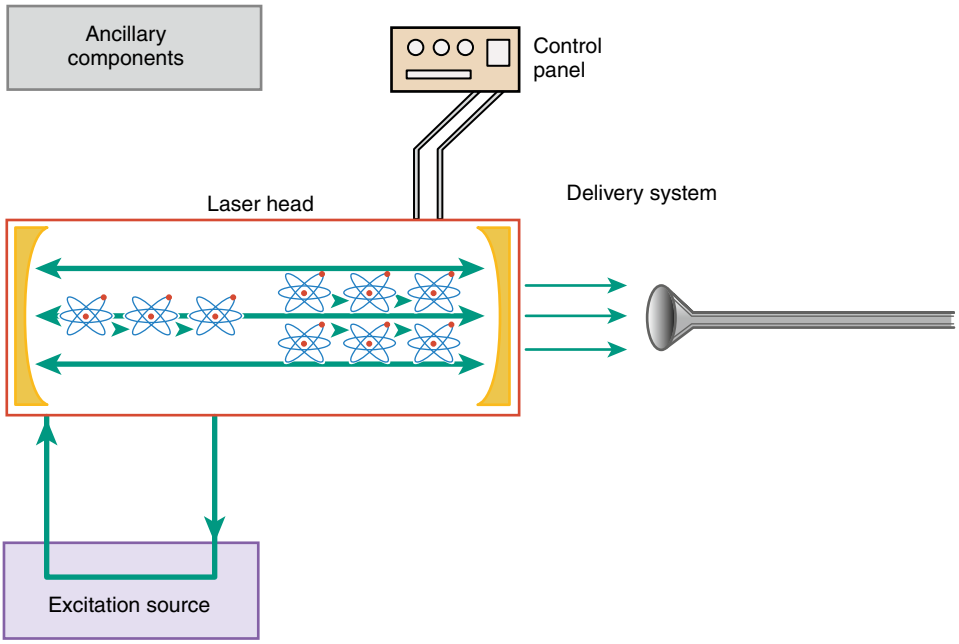


FIGURE 7-54 Parts of a laser system.

section, beginning with lasers in the infrared region with long wavelengths, through visible wavelengths, and finally to short ultraviolet wavelengths.

CO_2 LASER. The CO_2 laser is versatile and widely used. Its wavelength of 10,600 nm is located in the infrared electromagnetic spectrum. As this light is invisible, a visible helium-neon laser beam is transmitted co-axially with the CO_2 laser energy to serve as an aiming beam.

The CO_2 laser is characterized by its superficial tissue interaction (0.1 to 0.2 mm) because the beam is highly absorbed by water. The degree of tissue response is related to the photothermal effect (the amount of heat buildup) from absorption of the CO_2 laser beam. The longer the CO_2 beam is in contact with tissue, as with other laser wavelengths, the more destruction occurs. With the CO_2 beam a greater depth of penetration can be achieved. Tissue reaction is visible and has been described as "what you see is what you get." The CO_2 beam is independent of color selectivity, meaning that lighter tissue absorbs the beam as readily as darker tissue.

There are two types of CO_2 lasers that use electricity or radio waves as the excitation source:

1. *Free-flowing CO_2 laser system*—This is an older system that requires an external cylinder of a special laser gas mixture of CO_2, helium, and nitrogen. The concentrations of these gases must be specific to the particular laser unit so that the laser operates properly. The gas is pulled into the laser head by a vacuum pump, laser energy is generated, and harmless disassociated by-products are discharged from the unit. The laser gas cylinder is replaced when empty.
2. *Sealed-tube CO_2 system*—This system contains a special mixture of CO_2, helium, and nitrogen within a sealed tube. A catalyst is added to the tube to cause regeneration of the mixture so that lasing action can be produced again. The shelf life (functional period) of this tube is usually 1 to 5 years or more. The tube can then be serviced by the manufacturer to replace the special gas and catalyst mixture.

The CO_2 laser beam is delivered to the target site through a hollow tube called an articulated arm. Mirrors are positioned within the arm to reflect the laser energy forward. Care must be taken when moving the laser so that mirrors are not jarred out of alignment.

The articulated arm can be attached to a microscope, a special handpiece, or a scanner for the most precise energy delivery. A lens system within these attachments causes the beam to converge at the focal point. A special coating on the lens maintains the beam's integrity and intensity, and must be carefully maintained, following manufacturer's instructions, so that the coating is not disrupted. The articulated arm is connected to a microscope through the use of a microslad (or micromanipulator). Laser energy is conducted through the articulated arm to a mirror within the microslad that directly reflects the beam to tissue. The position of the beam is controlled by moving a joystick.

As noted previously, the focal length of the lens is the distance from the lens to the focal point where the beam converges and is most concentrated and intense within a small spot. The size of the spot can be changed by focusing or defocusing the lens to allow the spot to become larger or smaller. When the CO_2 handpiece is moved toward and then away from the tissue, the spot size changes.

Sometimes tubing is connected to the handpiece or microscope adapter to conduct a gas purge using compressed air that blows the laser smoke away, keeping the lens cool and free from debris. If this tubing is unavailable, a smoke evacuator can be used to prevent plume from flowing back into the handpiece and coating the focusing lens.

The CO_2 laser beam also can be conducted through a narrow wave guide, which consists of a hollow, semiflexible tube that allows energy to "wiggle" down its path by being reflected off the surface of the inner lumen. With this reflection, some beam power is lost as it exits the delivery device. Solid fibers that will conduct the CO_2 wavelength to target sites are being developed.

The CO_2 laser energy can be delivered to tissue in several modes. *Continuous mode* allows laser energy to be delivered continuously as long as a foot pedal is depressed. *Timed pulsed mode* delivers energy one pulse at a time or in a repetitive manner that specifically controls the duration of exposure. *Superpulse* or *ultrapulse mode* delivers energy in an extremely quick sequence of interrupted pulses that may appear to be continuous. Energy may peak 5 to 10 times higher than the desired wattage, but the duration of exposure is extremely limited, providing greater precision. This type of interaction allows adjacent tissue to cool, minimizing tissue destruction from thermal buildup.

ERBIUM:YAG LASER. One of the newer YAG lasers in healthcare is the erbium:YAG solid crystal laser, generating a wavelength of approximately 2940 nm. Laser energy is usually delivered in a pulsed mode. The erbium laser beam is highly absorbed by water, allowing a shallow penetration of energy into tissue. The erbium is frequently used in dermatology for skin resurfacing and ablation.

HOLMIUM:YAG LASER. The holmium:YAG laser crystal is doped with holmium, a rare earth element. This laser produces a wavelength of 2140 nm and is delivered to tissue in a quick, pulsed mode. The holmium wavelength is absorbed intensely by water, so depth of penetration is limited to approximately 0.4 to 0.6 mm. Like the CO_2 laser, it can ablate tissue precisely. The difference is that it can be conducted to the target through a flexible fiber. This wavelength can be delivered to tissues in a fluid environment because it produces a vapor bubble that transmits laser energy within a short distance. If the fiber is held almost in contact or directly in contact with the tissue, cutting occurs. If sculpting or ablating is needed, the fiber is held at a distance of approximately 2 mm from the target. Adjacent tissue is left significantly unharmed, enhancing precision. If the fiber is held 5 mm from the target, no tissue response is noted. The holmium:YAG laser also is used to produce a photoacoustical effect to fragment urinary stones and gallstones.

ND:YAG LASER. The Nd:YAG laser wavelength is in the near-infrared region of the electromagnetic spectrum at approximately 1064 nm. This invisible wavelength usually is accompanied by a visible helium-neon beam or other colored light, such as white light, to provide an aiming source. The Nd:YAG laser consists of a solid crystal of YAG that is doped with neodymium, which then produces lasing energy when exposed to bright flash lamps.

The Nd:YAG energy is delivered to tissue through a fiber system. The core fiber, usually made of quartz, is surrounded by a polytetrafluoroethylene (Teflon) silicone coating or cladding that retains the light. This is known as a bare fiber. If the bare fiber is encased by a catheter sheath, a purge gas, air, or fluid can be conducted down the length of the fiber. This purge is used to cool the fiber tip and keep debris from accumulating.

The Nd:YAG laser wavelength can be delivered to the tissue in a *noncontact mode,* meaning that the fiber does not touch the tissue. If the noncontact fiber contacts the tissue, any debris on the end of the fiber can cause the fiber to heat to the point of destroying the tip. Noncontact Nd:YAG wavelength is transmitted through clear fluids and structures and is more highly absorbed by darker tissue. This laser light tends to scatter within the tissue and cause thermal damage from a range of 3 to 5 mm. Tissue absorption produces a homogeneous coagulative effect as tissue is heated to the point of coagulation without vaporization occurring. A noncontact Nd:YAG beam can backscatter, posing an eye safety risk when used through an endoscope.

Nd:YAG laser energy also can be delivered to the tissue using the *contact method*. A synthetic sapphire contact probe or scalpel is attached to the end of a fiber with a special connector to deliver the Nd:YAG laser energy directly to the tissue in a more concentrated manner. The depth of penetration from the laser energy is limited to less than 1 mm. These contact tips are available in a variety of configurations. Depending on the desired tissue effects, the appropriate contact tip is chosen. A scalpel is used to cut while a rounded probe is used to vaporize. A flat probe may be used to coagulate tissue.

The end of the quartz fiber also may be sculpted into a configuration that can be used in direct contact with the tissue. Contact technology provides precision because the power output of the beam is confined to a small area and less wattage is needed. It causes less thermal buildup, so adjacent tissue is relatively unaffected. The beam does not scatter as readily as the noncontact Nd:YAG laser fiber energy, and less plume is generated.

Besides the continuous-mode Nd:YAG laser, a special *pulsed-mode Nd:YAG laser* for ophthalmic applications (Class 3B laser) delivers energy to tissue in extremely short pulsations of nanoseconds. This laser works with an acoustic effect instead of a thermal effect. A clouded membrane behind an artificial lens implant can be ruptured quickly and painlessly with this ophthalmic Nd:YAG laser beam through production of an acoustic effect at the target site.

KTP LASER. The frequency-doubled YAG (KTP) laser is often utilized for the ablation of hypertrophied prostatic tissue. An Nd:YAG beam of 1064 nm is passed through a potassium titanyl phosphate (KTP) crystal to produce an intense green laser light of 532 nm. Delivering the Nd:YAG incident beam of 1064 nm through the KTP crystal shortens the wavelength by half, to 532 nm, while doubling the beam's frequency. The emergent beam then is visible. If the original Nd:YAG beam is again desired, the crystal is rotated out of the way when a button is pressed on the control panel (if this feature is available). The aiming system of the KTP laser can be a low-power KTP laser beam or a helium-neon beam.

The 532-nm wavelength responds to tissue in the same manner as the argon beam. It is color selective and highly absorbed by hemoglobin, melanin, and other similar pigmentation. The beam is conducted to tissue through a fiber, and this wavelength can be transmitted through clear solutions and structures. The depth of penetration is approximately 1 to 2 mm.

ARGON LASER. The argon laser is a widely accepted visible laser beam system used for ophthalmology, dermatology, and general applications. This laser produces an intense, visible, blue-green light of approximately 488 nm and 514.5 nm (or 457 nm and 528 nm). In clinical applications, this combination of light wavelengths allows for more complete tissue absorption. Depth of penetration is usually 1 to 2 mm. The aiming system can be a low-power argon laser beam or a helium-neon beam.

Argon energy is highly absorbed by hemoglobin, melanin, and other similar pigmentation and is less absorbed by lighter tissue. Absorbed laser energy is converted to heat to cause coagulation or vaporization. As a result of the high color selectivity

of the beam, adjacent tissue injury is reduced significantly when the laser is being used on a localized pigmented area.

The argon wavelength, similar to that of the Nd:YAG laser, is transmitted through clear fluids and structures while being delivered to the target site through a fiber. The fiber can be attached to a slit lamp, microscope, or handpiece, depending on surgical approach. As with other fiber-directed lasers, the argon light diverges 10 to 14 degrees when leaving the fiber. The size of the spot can be altered by changing the distance of the fiber tip from the tissue. Special handpieces that contain an internal lens can be adjusted to change the spot size of the beam for dermatology and other procedures.

TUNABLE DYE LASER. This laser allows the operator to dial in the desired wavelength within a limited range of visible light (i.e., 400 to 1000 nm). By changing dyes or other parameters, the wavelength can be altered. Tunable dye lasers produce a range of colors by exposing a liquid dye to an intense light source, such as an argon laser beam. The dye then absorbs the laser light and fluoresces over a broad spectrum of colors. By using special crystal prisms, diffraction gratings, or birefringent filters within the laser, a specific wavelength can be produced.

Flash lamp pulsed dye lasers are used in treating pigmented dermatologic conditions. A yellow laser beam can be generated at 585 nm, which is readily absorbed by hemoglobin and less absorbed by the epidermal melanin, resulting in less scarring. These tunable dye lasers have been refined to provide quick pulsations in milliseconds that allow increased power. Automatic scanners attached to the delivery system have been perfected for this quick pulsation while moving the beam over the target area. Less adjacent tissue damage occurs with shorter durations of exposure, and there is greater tissue response through the increased wattage used. Advancements to produce an array of different wavelengths with a variety of pulsation modes continue to be developed to treat dermatologic conditions and to fracture urinary stones and gallstones.

DIODE LASER. Extremely compact and reliable, diode lasers are used in many consumer products, such as video disc players and computers. This technology also is being used in surgical lasers with low wattage and an output in the 532- to 908-nm range. Given the efficiency, small size, and reliability of these systems, medical applications have been introduced. With the advent of high-power semiconductor diode lasers in the gallium arsenide family (840 to 910 nm), smaller laser photocoagulators for ophthalmic, urologic, and other applications have been developed. This laser energy can be delivered directly to the tissue through a fiber or can be attached to an existing slit lamp microscope for ophthalmic applications. Other clinical applications that allow this laser to be used in place of other wavelengths, such as the Nd:YAG or argon lasers, are available.

EXCIMER LASER. Invisible excimer laser wavelengths are located in the ultraviolet area (short wavelengths) of the electromagnetic spectrum. The excimer laser derives its name from use of an active medium, an excited dimer. This laser also is known as a rare gas-*n*-halide laser in that it combines a rare gas with a halide, usually a halide-oxide or a halide-halide dimer. The dimeric media are excited to emit laser energy. Depending on the chemical composition of the active medium, various short ultraviolet wavelengths can be produced. Four of the most popular wavelengths are argon fluoride (ArF) at 193 nm, krypton fluoride (KrF) at 248 nm, xenon chloride (XeCl) at 308 nm, and xenon fluoride (XeF) at 351 nm. One hazard of the excimer laser is that its gases are extremely toxic; appropriate protective laser housings have been manufactured to minimize this risk.

Excimer lasers are chosen for their effective ablative capabilities. The beam penetrates less than 1 mm into tissue and disassociates the molecular bonds of cells. Adjacent tissue is not significantly damaged because the beam provides a sharp, clean-cutting action at the target site without significant thermal damage. This laser has been used successfully to sculpt corneas for refractive purposes and to ablate plaque in arteries. Excimer lasers producing wavelengths from 308 to 311 nm are used to treat psoriasis and vitiligo. Other applications continue to be researched for FDA approval.

FUTURE LASERS. As technology continues to advance, laser wavelengths are being combined into a single unit so that a selection of wavelengths, such as the Nd:YAG, erbium:YAG, or holmium:YAG, can be offered easily during a procedure. Delivery systems must be compatible for this setup. A variety of wavelengths are being developed as other active media are also being explored. New delivery systems are being perfected as well that more efficiently conduct the laser energy to the tissue.

Benefits of Laser Technology. Laser technology evolves as more surgical applications are explored and introduced. As physicians become more adept in laser applications, use continues to grow. The laser has fostered the development of new minimally invasive procedures and endoscopic techniques along with ophthalmic and dermatologic applications. The true potential of the laser has yet to be realized as healthcare practitioners explore different procedures that can benefit from its use. Following are some advantages that have been associated with laser technology, depending on the procedure performed:

- Seals small blood vessels (less intraoperative and postoperative blood loss)
- Seals lymphatics (decreases postoperative edema and potential spread of malignant cells in the lymphatic system)
- Seals nerve endings (on selective procedures, decreases postoperative pain)
- Sterilizes tissue (from the heat generated at the laser-tissue impact site)
- Decreases postoperative stenosis (by decreasing the amount of scarring that could lead to stenosis)
- Produces minimal tissue damage (from precision of the laser beam)
- Reduces operative and anesthesia time
- Allows a shift to more ambulatory surgery procedures
- Allows more use of local anesthetics instead of general anesthetics
- Provides quicker recovery and return to daily activities

Laser Safety. As laser systems are capable of concentrating high amounts of energy within very small areas, they present hazards. Safe and appropriate use of lasers is the responsibility of the entire healthcare team. Each member must be acutely aware of the many controls needed to prevent accidental injury. Often the laser team member is given responsibility and authority to shut down the laser system if safety policies are not being followed.

The laser is a class III medical device that is subdivided into four subclasses. Lasers designated as subclasses 3 and 4 have the potential to cause injury. Some ophthalmic Nd:YAG lasers that cause a photoacoustic, instead of a photothermal reaction, are classified in the subclass 3B category and can cause injury with sustained interaction. Most of the lasers used in surgical applications are subclass 4 lasers and can cause photothermal reactions that may lead to fire, skin burns, and optical damage by either direct or scattered radiation. Specific safety precautions must be followed to prevent injury from these lasers.

Many agencies regulate laser safety. Healthcare facilities must develop safety protocols in anticipation of mandates by these regulatory agencies as technology advances and grows.

The American National Standards Institute (ANSI), a nongovernmental organization of experts, first published standards (Z136.1) in 1973 as safety guidelines for laser use in warfare, industry, and healthcare. Standards were expanded to provide specific recommendations for laser use in healthcare environments (ANSI Z136.3) (ANSI, 2005). The appendix of ANSI Z136.3 (revised and published in 2005) discusses a consensus on laser safety in each of the special areas of medicine and surgery. These standards are reviewed periodically and revised as surgical trends change. It is recommended that the most current versions of both ANSI standards be acquired for reference because the Z136.3 document often refers to the Z136.1 publication.

Other guidelines have been suggested by the Center for Devices and Radiological Health (CDRH), Association of periOperative Registered Nurses (AORN), American Society for Laser Medicine and Surgery (ASLMS), Laser Institute of America (LIA), FDA, OSHA, and individual state and local regulatory bodies.

Hospitals and other healthcare delivery facilities need to create laser safety policies and procedures using these expert references as resources. In developing safety guidelines for a facility, protocols should address various situations while being neither too general nor too specific. A policy or procedure must be general enough to address the need, but not so detailed that the surgical team cannot follow it. Staff must realize that they are accountable for following their own safety policies and procedures. Basic education on written laser policies and procedures for all personnel in the surgical environment (including orderlies, aides, and housekeeping personnel) should be mandatory. Topics for policy and procedure development for laser safety should include the following areas, each of which is addressed below:

- Eye protection
- Controlled access
- Fire safety
- Smoke (plume) evacuation
- Documentation
- Laser team responsibilities
- Skin/tissue protection
- Electrical safety
- Education/training
- Credentialing

EYE PROTECTION. The eye is extremely sensitive to laser radiation and great care must be taken to protect eyes during laser intervention. Even low levels of laser radiation can lead to permanent optical damage. Possible ophthalmologic injuries depend on laser wavelength. The CO_2 laser can damage the cornea because this beam is absorbed readily by water within surface cells, causing a burn. Immediate pain is associated with this corneal injury. The argon and Nd:YAG laser beams, in contrast, are transmitted through clear optical structures and fluids and can be refocused by the lens of the eye. The intensity of the beam after refocusing can permanently damage the retina. No pain may be felt during this injury (Figure 7-55).

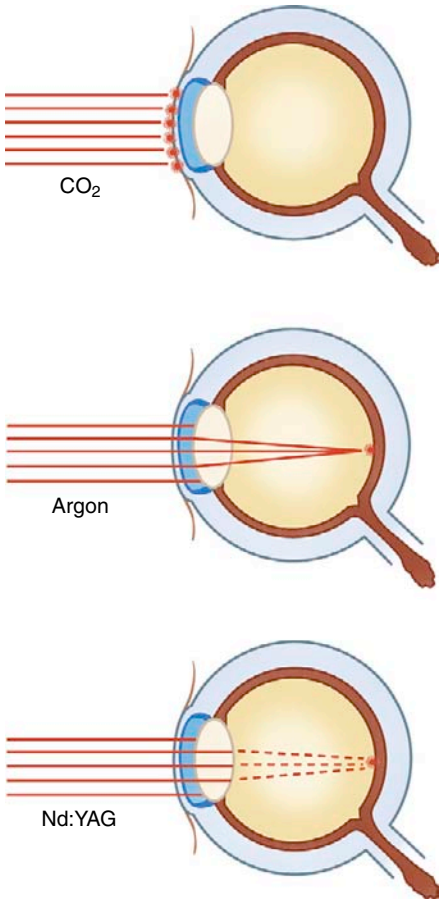


FIGURE 7-55 The CO_2 laser beam can damage the cornea; the argon and Nd:YAG beams can injure the retina.

Adequate eye protection requires understanding the two concepts of maximum permissible exposure (MPE) and nominal hazard zone (NHZ). According to the ANSI Z136.3 standards, the MPE is the level of laser radiation to which a person may be exposed without hazardous effects to the eye or skin. MPE levels are determined through consideration of laser wavelength, power, exposure time, and pulse repetition.

The NHZ is the space where the level of direct, reflected, or scattered radiation during normal laser operation exceeds MPE; eye, skin, and fire safety precautions must be followed while one is working within this hazard zone. The NHZ can be calculated mathematically to determine the distance from the laser beam emission in which the beam can cause skin and eye damage. With power, operating modes, and other parameters changing frequently during a procedure, this calculation also changes. The area inside the surgical room usually is considered to be within the NHZ so that consistency and simplicity can be maintained when lasers are used.

FIGURE 7-56 The frame of the protective eyewear displays wavelength and optical density information.

It is recommended that protective goggles and glasses be inscribed with the appropriate filtering capabilities and adequate optical densities for the specific wavelength being used (Figure 7-56). For example, a pair of Nd:YAG goggles may be inscribed "1064 nm, optical density 5." The optical density of the lens is the capability of the lens material to absorb a specific wavelength. Darker lens shades do not indicate higher optical density, nor do they give more protection than lighter ones. There are lighter lens shades with high optical densities that provide adequate safety. Laser team members must ensure that eyewear is properly labeled, handled, and stored so that hazards are minimized, and scratching and damage of the eyewear avoided.

During surgical procedures using multiple wavelengths, protective eyewear must change as wavelengths change. Some eyewear protects against a limited range of wavelengths. If the range is expanded to block a greater variety of wavelengths, the transparency of the eyewear is reduced.

Controversy exists as to the appropriateness of using personal prescription eyeglasses as CO_2 laser eye protection when the wearer is not in the immediate vicinity of the laser beam emission (e.g., the circulating nurse). Prescription eyeglasses do not have wavelength protection inscribed on them and have not been tested to determine the protective ability of the lens; therefore adequate protection cannot be guaranteed. Proponents state that the NHZ is so limited when the CO_2 beam is passed through the focusing lens that individuals who are not close to the laser emission port are not at high risk for eye damage. Facilities must address this controversy and develop a policy for the surgical team. Contact lenses and half glasses do not offer adequate protection against CO_2 laser energy and should not be used.

During a microscopic procedure, the optics of the microscope provide eye protection against CO_2 laser energy. When other wavelengths are used, such as argon or Nd:YAG, an automatic lens shutter can be connected to the microscope head. During laser activation, the shutter allows a lens filter to drop into place to provide a shield from any laser backscatter, protecting the eyes of the laser operator. When this device is attached to the microscope head, any observer tube being used also must be placed above the filter so that all portal optics offer protection. Others involved with the procedure must wear appropriate eyewear.

A lens filter can be placed over the eyepiece of a rigid or flexible endoscope. The lens must offer appropriate protection for the specific laser being used. Guidelines recommend that other surgical team members also wear eye protection, even though laser energy seems confined within an enclosed cavity. Optical injury is always possible if a fiber or articulated arm separates from the endoscope while the laser is activated, or if a fiber fractures and the beam escapes at the fracture site.

For healthcare professionals who routinely work with laser systems, a baseline eye exam is sometimes recommended, including visual acuity and an assessment of retinal health. Another eye exam can be performed after any ophthalmic accident or on termination of employment. The baseline exam provides a foundation for comparison with abnormal findings from subsequent exams. Performing baseline eye exams merely documents the ocular health of laser team members so that it can be used during a potential workers' compensation claim for retinal damage from accidental beam exposure. Some facilities opt not to follow this expensive and difficult-to-monitor guideline of performing baseline eye exams. Instead, they strictly enforce their eye safety policy, minimizing the chance of ophthalmic injury. These facilities state in their eye safety policy that an eye exam will be performed if an ocular accident occurs.

The patient's eyes also must be protected during laser intervention. When general anesthesia is used, patients' eyes are covered with wet gauze, eye pads, or a towel; the eyelids are taped closed. If awake or under local anesthesia, the patient wears appropriate eye protection. Explanations about this should be provided. If the laser is to be used in the immediate vicinity of the eye, such as to lighten a port-wine stain on the eyelid, a special laser eye shield can be placed on the surface of the eye after instillation of a drop of ophthalmic local anesthetic. If the laser eye shields are sterilized with steam, these devices must be cooled completely before being placed on the cornea to prevent burns. The Risk Reduction Strategies box summarizes actions to promote eye safety during laser surgery.

CONTROLLED ACCESS. Inadvertent access to rooms where laser treatments are being performed should be prevented. Laser warning signs must be placed at all entrances to the treatment area so that access is granted only to individuals who have been appropriately educated in laser safety. The word "Danger" and the universally accepted laser symbol should be present on laser warning signs to indicate the possibility of hazards (Figure 7-57). Laser signs should be removed when the procedure has been completed.

Windows and ports into rooms where lasers are used must be covered with appropriate protection for the specific laser being used. The CO_2 laser beam, passed through a lens, and the holmium laser beam, delivered through a fiber, provide a limited NHZ, so window coverage is not required. Argon, Nd:YAG, and certain other laser wavelengths can be transmitted through window glass and have longer NHZs. Windows and ports must be covered with a blocking barrier that stops transmission of specific wavelengths with more extensive NHZs.

The laser key must not be left in the laser during storage. The key should be available only to authorized personnel who

RISK REDUCTION STRATEGIES

Eye Safety During Laser Surgery

- Ensure that everyone in the laser room wears appropriate eye protection with side shields before activating the laser. Inscribed on the eyewear should be the laser wavelength protection and optical density of the lens material.
- Place a special lens cover over the eyepiece of an endoscope to protect the physician's eye from laser backscatter. Remember the physician's other eye is unprotected.
- Ensure everyone in the laser room wears eye protection during laser endoscopic procedures.
- Connect an automatic lens shutter to a microscope head, if needed, to provide eye protection for individuals viewing the procedure through the microscope.
- When general anesthesia is used, cover the patient's closed eyes with moistened gauze pads. When the patient is awake, place appropriate glasses or goggles on the patient. Explain the need for eye protection to the patient.
- During laser surgery near the eye, place a special laser eye shield directly on the anesthetized eye surface.
- Ensure that appropriate protective eyewear is available at all entrances to the laser room for anyone entering the room.
- Cover windows in the laser treatment area appropriately, depending on the wavelength of the laser used.
- To prevent reflection of the laser beam, follow special precautions (e.g., use anodized or ebonized instruments near the laser-tissue impact site and cover large reflective retractors with wet towels or sponges).
- When storing protective eyewear, guard against scratches and mishandling. Scratches may decrease effectiveness. Inspect eyewear regularly to ensure that integrity of lenses has not been compromised.

FIGURE 7-57 Warning signs should be placed at all entrances to the surgical room to notify personnel that a laser is being used, and that appropriate eye protection is needed before entering the room.

have appropriate education and training to operate the laser. Laser keys can be stored in the narcotics cabinet or in a special key lockbox to control access. The Risk Reduction Strategies box summarizes how best to control access to laser rooms and laser equipment.

RISK REDUCTION STRATEGIES

Guide to Controlled Access During Laser Surgery

- Post laser warning signs at all entrances to the laser room to prevent unauthorized individuals from entering. Warning signs should include the word *Danger* along with the universal laser symbol.
- Cover windows or ports with the appropriate protection for the specific laser wavelength being used.
- Do not store the laser key in the laser ignition port; the laser key must be available only to authorized individuals.

FIRE SAFETY. An awareness of laser biophysics and tissue interaction is necessary to understand actions needed to prevent laser fires. A fire can be started by a reflected beam as easily as from direct impact. The laser team responds quickly if a fire occurs. Immediate action is key to minimize injury to the patient and the surgical team. The Patient Safety box provides important detailed measures for fire safety during laser surgery.

Sterile water or saline solution should be readily available to douse a small fire on the patient. A laser-appropriate fire extinguisher should be available to control a fire within the laser system. During surgery, combustibles, such as sponges or towels near the laser target site, should be kept wet to prevent ignition. The surgical team should monitor constantly the moisture level of sponges and other materials to prevent drying, which eventually could support a fire.

A laser beam can ignite flammable draping material easily. Some water-repellent drapes and other laser-safe materials are able to withstand laser impact since the flammability of the material is minimal. If the flammability of draping material or any other supplies is questionable (e.g., plastic tooth protectors), the suspect item can be tested in the manufacturer's or researcher's laboratory.

Instruments used in the immediate vicinity of the laser target site should be nonreflective to decrease the chance of the laser beam bouncing off the surface and accidentally impacting another area. The laser beam can easily be reflected off shiny instrument surfaces and can cause skin or eye injury or ignite flammable materials. To decrease reflectivity, an instrument may be ebonized by coating it with a special substance (usually black). The instrument should be inspected regularly to ensure integrity of the coating. Any scratched surface where ebonization has worn off should be recoated.

Instruments also may be anodized or surfaced with a matte finish to decrease reflectivity. Other coatings and surfaces that cause laser light to scatter and diffuse on impact are being introduced. Large retractors can be covered with wet sponges or towels so that the laser beam cannot accidentally reflect off a shiny surface.

Special instruments have been designed to provide backstops for laser energy to decrease adjacent tissue damage and fire risk. Titanium rods are effective backstops. Quartz rods often are used as backstops for the CO_2 laser beam, but argon and Nd:YAG beams may be transmitted through them. Glass rods are never to be used with a CO_2 laser because glass material heats and shatters after continuous impact by a laser beam. Teflon backstops are not to be used because they can melt when heated and produce toxic fumes. Wet sponges also can be used as backstop material.

PATIENT SAFETY

Fire Safety During Laser Use

- Ensure sterile water or saline is immediately available to douse a small fire near or on the patient.
- Have a laser-appropriate fire extinguisher available in the department in case the laser catches fire. Surgical team members must know how to operate the fire extinguisher.
- Do not place fluids or solutions on the laser unit. The laser system should be protected from spillage or splatter, which could cause short-circuiting and fire.
- Do not place dry combustibles in the vicinity of the laser impact site. Use wet towels, nonflammable drapes, or special laser-retardant materials near the laser target area. Moisten dry drapes and sponges with sterile saline or water to prevent ignition. Monitor the moisture level constantly throughout the procedure. Remoisten as needed.
- Do not use flammable materials near the laser-tissue impact site.
- Use nonreflective instrumentation in or near the laser-tissue impact site to decrease accidental reflection of the laser beam. Cover larger instruments, such as retractors, with wet sponges or towels to protect against reflection.
- Do not use flammable skin preparations, such as alcohol, as prepping solutions.
- Insert a wet pack into the rectum as a tamponade to prevent methane gas from escaping into the surgical area if ordered by the physician. A cleansing bowel prep before surgery also decreases this risk.
- Use appropriate laser-resistant endotracheal tubes during upper airway surgery. Follow directions in product literature and on labels, which typically include information regarding the tube's laser resistance, use of dyes in the cuff to indicate a puncture, use of a saline fill to prevent cuff ignition, and immediate replacement of the tube if the cuff is punctured.
- Protect the endotracheal tube cuff with counted wet gauze sponges.
- Use nonexplosive anesthesia gases during laser procedures.
- Keep oxygen concentrations between 21% and 30% to minimize the possibility of an airway fire during laser procedures of the airway.
- Do not use nitrous oxide as it supports combustion.
- Place the laser in the standby mode when it is not in active use.
- Identify and verify the laser foot pedal with the operating physician to avoid accidental activation. Allow only the individual using the laser to activate it. Only activate the laser when the delivery tip is within the user's direct field of vision.

Special laser mirrors that directly reflect the beam onto a hard-to-reach area are available. Mirrors may be made of rhodium or stainless steel. Glass-surface mirrors do not withstand laser impact and heat and shatter instead. Using a laser mirror requires skill because the beam must be focused on the target area and not on the mirror to deliver the full impact of laser energy. A laser beam that is misdirected off a mirror can easily cause a fire.

Flammable skin preparations should not be used for laser procedures. During skin cleansing, prep solution can pool underneath a patient, and ethanol vapors from alcohol-based preparations can be trapped beneath drapes. The volatility of these vapors increases the risk of a surgical drape fire. Iodophor or any other tinted prep solution should be wiped before argon or Nd:YAG lasers are used because the tint may increase laser absorption by the skin.

FIGURE 7-58 A polyvinyl chloride endotracheal tube can become a blowtorch if ignited by a laser beam.

When a laser is used in the rectal area, a wet pack may be used to tamponade the bowel to prevent the escape of methane gas, which could enter the surgical area from the colon and cause an explosion. Wet sponges used for the pack must be counted so that packing is not inadvertently left in place after surgery. Some practitioners disagree with this practice, stating that wet sponges may stretch the colon walls, increasing peristalsis and the movement of methane gas into the surgical area. Whatever method is chosen, a cleansing bowel prep before surgery also helps decrease this potential hazard.

Airway explosion caused by the laser beam igniting the endotracheal tube (ETT) can cause a potentially lethal accident for the patient. A polyvinyl chloride (PVC) ETT is highly flammable, especially when a high concentration of oxygen flows through it during anesthesia administration (Figure 7-58). Specific laser-retardant ETTs should be used during oral, tracheal, or esophageal laser procedures that require general anesthesia. The laser power limitations of a commercially manufactured ETT must be followed closely to ensure proper protection. The cuff of the ETT should be inflated with sterile saline to provide a heat sink and retard a fire if perforated by the laser beam. Saline may be tinted with methylene blue to note a cuff rupture more quickly as the blue dye escapes. A protocol should be developed to describe the emergency steps needed to control an endotracheal fire. Immediate considerations include the following:

- Stop ventilation (disconnect gas flow).
- Extinguish all flames with saline.
- Remove the ETT, ensuring entire tube is removed.
- Ventilate the patient by mask or reintubate immediately to prevent laryngospasm.
- Examine the airway (mouth, oral cavity, bronchial tree) for burns, foreign bodies, or both.
- Decide on the next course of action (anesthesia provider and surgeon), that is, cancel or continue with procedure.

A nonintubation technique involving jet ventilation also may be used during laser microlaryngoscopy. A jet ventilator is a mechanical ventilation unit that delivers oxygen through

a small metal needle used with a rigid laryngoscope. Under pressurization, the jet ventilator is set to deliver a predetermined amount of oxygen with a set rate, pressure (in pounds per square inch [psi]), and percentage of inspiratory time. The needle is positioned between the vocal cords on the side opposite the lesion. The needle extends into the trachea so that the proper amount of oxygen is easily delivered. After surgery, the patient may be intubated to maintain an open airway if postoperative edema or tracheal spasm is anticipated.

Other nonintubation techniques, such as apneic methods, can be used to avoid intubation. The patient's oxygen saturation must be monitored closely when these techniques are used.

ENDOSCOPE SAFETY. Special precautions should be followed when using the laser during an endoscopic procedure. When a laser fiber is introduced through the biopsy port of a flexible or rigid endoscope, the operator must view at least 1 cm of the tip of the fiber before activating the laser (Figure 7-59). If the end of the fiber is still within the sheath of the endoscope and the laser is fired, the heat from the laser energy quickly damages the optics and channel of the endoscope.

When a "bare" fiber is placed down the biopsy channel of a flexible endoscope, the sharp tip possibly can tear the inside lumen of the channel. A length of medical-grade tubing can be placed over the fiber with the tip recessed within the sheath. The entire unit is then passed through the endoscope. When the end of the tubing is observed, the medical-grade tubing is withdrawn sufficiently to expose the end of the fiber. This procedure effectively protects the inside lumen of the endoscope channel during fiber insertion.

SMOKE EVACUATION. Smoke evacuation and odor control must be adequate whenever a plume is generated, whether it is from the laser, electrosurgical unit (ESU), or other surgical devices being used. When "hot" tools such as these are used to cut, excise, ablate, or coagulate tissue, cells of the target tissue are heated to the point of boiling. This causes cellular membranes to rupture, spewing cell contents into the air and producing surgical smoke. Research and reports about the hazards of surgical smoke are described in Box 7-3.

One of the crucial elements of adequate smoke evacuation is to determine the method of smoke evacuation. The method selected depends on the amount of plume produced.

An *in-line smoke evacuation filter* is appropriate only for small amounts of plume generation, similar to what is produced during microlaryngoscopy vaporization of vocal cord polyps. The in-line filter connects to the existing suction line by positioning it between the wall connection and suction canister (Figure 7-60). If the filter becomes wet, it loses its effectiveness.

If an in-line filter is not used, particulate matter from surgical smoke can occlude and corrode suction pipes and contaminate the building. Also, suction flow may not be forceful enough to capture the plume adequately. Wall suction usually generates 2 cubic feet per minute (cfm) of air movement, whereas an individual smoke evacuator may move air at 35 to 50 cfm. An in-line filter is changed after each procedure (or according to the manufacturer's instructions).

When greater amounts of surgical smoke are generated, an *individual smoke evacuator* is used. Individual smoke evacuators have filtration systems that include a charcoal filter and an ultra–low penetration air (ULPA) filter (Figure 7-61). The charcoal filter removes toxic gases and odor, whereas a ULPA filter removes small particulates with filtration of 0.12-μm size matter at 99.9999% efficiency (Ulmer, 2008).

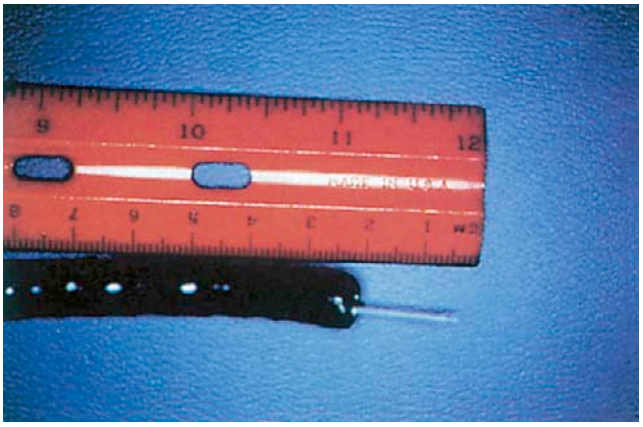


FIGURE 7-59 The laser fiber should extend past the end of the endoscope before the laser is activated.

Maintenance of a smoke evacuator requires changing the filter per the manufacturer's written instructions. Standard Precautions should be used when changing a contaminated filter because this is an occupational hazard (AORN, 2009, pp. 428-429). Usually, the used filter can be placed in a plastic disposal bag and discarded in the general waste receptacle. Some practitioners believe that a contaminated filter need not be treated as infectious or as regulated medical waste (biohazardous) because it is not listed as an environmental hazard. Some manufacturers have provided contaminated filter disposal guidelines, however, that suggest the filter be treated as biohazardous. A contaminated filter is considered an occupational hazard and Standard Precautions should be used when handling it. It is not designated as an environmental hazard, however, and it need not be treated as biohazardous medical waste.

Centralized smoke evacuation systems provide smoke evacuation for several surgical rooms at the same time. The smoke evacuation line needs to be routinely flushed and cleaned to prevent debris buildup and pathogen growth within the system. A central system is convenient because it is always available; however, if it malfunctions, smoke evacuation is not available to multiple surgical areas.

Contamination by surgical plume and tissue splatter is decreased when the surgical team wears gloves, gowns, and masks. The surgical team must ensure that the smoke evacuation wand or suction device is close to the target site so that all plume is evacuated. Devices are available that attach or are built into the ESU or laser delivery system that effectively evacuate surgical smoke as it is generated (Figure 7-62). Using appropriate smoke evacuation methods (Evidence for Practice) to ensure that all plume is eliminated is the only practice that protects the surgical team from exposure to hazardous surgical smoke. The Research Highlight box describes a study performed to identify key indicators of compliance with surgical smoke evacuation recommendations.

Surgical smoke that arises during flexible endoscopic or laparoscopic procedures impairs visibility. Hand control suction devices and valve filters provide gentle movement of plume during laparoscopy without destroying pneumoperitoneum.

BOX 7-3

Research and Reports About Surgical Smoke Hazards: A History

1975
Mihashi and associates vaporized tissue with a CO_2 laser in a laboratory setting to note the size of the particles within the smoke. Their results determined that approximately 77% of the particulate matter in the plume was less than 1.1 μm in size. Note: A regular surgical mask may filter particulate matter that is 5 μm in size; surgical smoke can pass easily through these masks and be deposited in the alveoli of lungs when inhaled. This potentially can cause chronic irritation, bronchitis, or emphysema-like or allergic-like conditions.

1985
The National Institute for Occupational Safety and Health (NIOSH) published and distributed a *Health Hazard Evaluation Report,* which stated there is "potential hazard from exposure to smoke generated by electrosurgery knives."

1988
The NIOSH issued a *Health Hazard Evaluation Report,* which stated "smoke generated during laser surgery presents a potential health hazard."

1988
Baggish and associates compared the effects of unfiltered laser smoke on rat lungs with plume that had been filtered. The rats breathing unfiltered plume developed hypoxia and pulmonary congestion with bronchial hyperplasia and hypertrophy. Rats subjected to plume filtered to 0.1 μm in size (similar to smoke evacuators) developed no lesions and remained identical to control rats.

1988
Garden's research team used the CO_2 laser to vaporize bovine fibropapillomavirus. Intact viral DNA was extracted from the plume emitted. The viral DNA material was reinjected into the cow at another site, and the same papilloma viral lesion grew again. This study demonstrated that viral DNA can cause viral growth in the host if the transmission mode is through injection.

1989
Tomita and associates compared the hazards of cigarette smoke with the hazards associated with laser and electrosurgery smoke. CO_2 laser vaporization generated a plume with the same hazard potential as smoking three unfiltered cigarettes. The ESU created a plume equivalent to smoking six unfiltered cigarettes.

1991
A report described a 44-year-old surgeon in Norway who developed laryngeal papillomatosis, probably at his workplace where he used lasers to vaporize condylomas. The surgeon's own laryngeal biopsy revealed human papillomavirus DNA types consistent with the anogenital condylomas being lased on his patients.

1993
Ott and his team demonstrated that when surgical smoke is not evacuated during a laparoscopic procedure, the patient's methemoglobin and carboxyhemoglobin levels increase, while oxygenation of tissues decreases. The patient usually responds with nausea, vomiting, or headaches.

1995
Hoglan's analysis indicated that more than 600 compounds within surgical smoke have yet to be identified.

2008
AORN ratified a position statement on *Surgical Smoke and Bio-Aerosols*.

2009
AORN introduced its on-line *AORN Surgical Smoke Evacuation Tool Kit* to assist surgical team members in the implementation of smoke evacuation practices for all surgical smoke. This resource contains a sample PowerPoint presentation for educational sessions, a checklist for smoke evacuation practices, and a bibliography of surgical smoke evacuation studies and articles.

There are four issues of concern associated with the hazards of surgical smoke:

1. Odor
2. Size of the particulate matter
3. Viability of the particulate matter
4. Endoscopy concerns

When surgical smoke is generated, a noxious odor is emitted with the smoke. This odor results from tissue destruction that produces chemical by-products and toxins. Some of these chemical by-products already have been identified as toxic carcinogens, such as polycyclic aromatic hydrocarbons, benzene, toluene, formaldehyde, and acrolein. It has not been conclusively proven if particulates within surgical smoke are viable. Further studies are needed to note if inhalation of surgical smoke containing viral DNA can be transmitted and lead to regrowth. Nonetheless, surgical smoke continues to be recognized as hazardous as more research studies are published. The following professional organizations, agencies, and research groups have recommended guidelines and statements regarding these hazards and how to minimize them:

- ANSI Z136.3: *Safe Use of Lasers in Healthcare Facilities,* 2005
- NIOSH: *Control of Smoke From Laser/Electric Surgical Procedures,* March 1998
- AORN: *Recommended Practices for Laser Safety in Practice Settings; Recommended Practices for Electrosurgery; Recommended Practices for Endoscopic Minimally Invasive Surgery; Recommended Practices for Safe Environment of Care,* 2009.
- AORN: *Position Statement on Surgical Smoke and Bio-Aerosols,* 2008
- AORN: *Surgical Smoke Evacuation Tool Kit,* 2009
- ASLMS
- OSHA

Modified from Baggish M et al: Protection of the rat lung from the harmful effects of laser smoke, *Lasers Surg Med* 8:248-253, 1988; Garden J et al: Papillomavirus in the vapor of carbon dioxide laser-treated verrucae, *JAMA* 259:1199-1202, 1988; Hallmo P, Naess O: Laryngeal papillomatosis with human papillomavirus DNA contracted by a laser surgeon, *Eur Arch Otorhinolaryngol* 248(7):425-427, 1991; Hoglan M: Potential hazards from electrosurgical plume, *Can Oper Room Nurs J* 13:10-16, 1995; NIOSH: *Health hazard evaluation report,* Washington, DC, 1985, The Institute; Mihashi S et al: *Some problems about condensates induced by CO_2 laser irradiation,* Karume, Japan, 1975, Department of Otolaryngology and Public Health, Karume University; NIOSH: *Health hazard evaluation report,* Washington, DC, 1988, The Institute; Ott D: Smoke production and smoke reduction in endoscopic surgery: preliminary report, *Endoscop Surg Allied Technol* 1:230-232, 1993; Tomita Y et al: Mutagenicity of smoke condensates induced by CO_2 laser irradiation and electrocauterization, *Mutat Res* 89:145-149, 1981.

FIGURE 7-60 An in-line filter is placed between the suction canister and the wall outlet and is used to evacuate small amounts of surgical smoke.

FIGURE 7-61 Individual smoke evacuator.

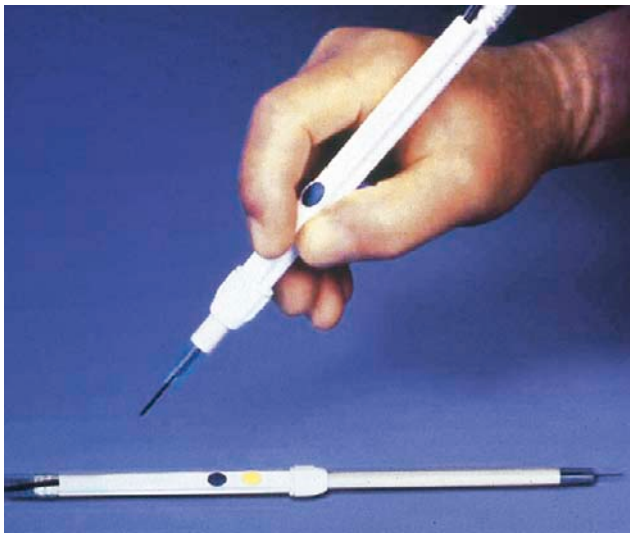


FIGURE 7-62 Electrosurgery pencil with the smoke evacuation system built into the device.

A high-flow insufflator is recommended for continual replacement of CO_2 gas. A special smoke evacuator may be used that automatically provides a slow evacuation of plume without destroying the pneumoperitoneum.

OTHER SAFETY MEASURES. Foot pedals present safety problems if mistakenly activated. Multiple foot pedals placed on the floor can be confusing and lead to accidents. The laser pedal should be identified clearly and used only by the physician delivering laser energy to the target area.

Laser team members must appreciate potential electrical hazards because the laser, similar to the ESU, is high-voltage equipment. Water and other solutions should not be placed on the laser unit, and the components of the laser should be protected against spillage or splatter, which could cause short-circuiting. The outside housing of the laser should never be removed by unauthorized personnel because of the potential for electrical shock or electrocution.

Transportation hazards are always a threat because some laser systems are quite heavy. When these units need to be moved, proper body mechanics must be employed to prevent

EVIDENCE FOR PRACTICE

Smoke Evacuation During Laser Surgery

- Use the appropriate smoke evacuation system, depending on the amount of plume generated. If small amounts of plume are generated and room suction is to be used, an in-line suction filter is positioned between the suction canister and the wall outlet to capture surgical smoke particulate. An individual smoke evacuation system is used if larger amounts of plume are generated.
- Change the smoke evacuation filter or filters according to the manufacturer's written instructions.
- Hold the smoke evacuation suction tube close (<1 inch away) to the tissue interaction site to remove as much plume (odor and particulate matter) as possible.
- Smoke evacuation tubing should have a smooth inner lumen to eliminate any whistling.
- Use a reducer fitting to adapt a large smoke evacuation tube to a smaller suction or evacuation tube.
- The scrub person or first assistant can operate the smoke evacuation foot pedal (if available) to minimize wear and tear on the smoke evacuator motor and to decrease noise. Some smoke evacuators have sensing mechanisms that automatically activate the smoke evacuator when plume is generated.
- Evacuate surgical smoke generated during endoscopic or laparoscopic procedures. Endoscopic smoke evacuation instruments, such as suction tubes, help decrease the presence and retention of plume inside a body cavity or organ. A low-pressure suction valve can be used to remove plume gently during a laparoscopic procedure without destroying pneumoperitoneum. A high-flow insufflator is recommended to replace any lost insufflation gas quickly. A special smoke evacuator that provides automatic plume removal also can be used to evacuate the intraabdominal smoke without destroying pneumoperitoneum.
- Wear a surgical mask that provides adequate filtration (0.1-μm filtration) to protect against residual smoke particulate that has not been evacuated. The high-filtration mask must fit snugly around the face. Wearing a high-filtration mask does not replace the use of a smoke evacuation system to remove surgical smoke from the environment.
- Continuing education helps healthcare personnel to understand the hazards of surgical smoke and encourages the use of appropriate methods for evacuation.

Modified from AORN: *Perioperative standards and recommended practices,* Denver, 2009, The Association; Ball KA: *Lasers: the perioperative challenge,* ed 3, Denver, 2004, AORN.

RESEARCH HIGHLIGHT

Compliance with Surgical Smoke Evacuation Recommendations

This study was performed to identify key indicators for compliance with surgical smoke evacuation recommendations. A piloted and validated survey that focused on individual perioperative nurse characteristics, organizational characteristics, and perceptions of the attributes of smoke evacuation recommendations using the Diffusion of Innovations Model by Rogers (2003) was sent to a random sampling of 4000 staff nurse members of AORN. Responses from 777 perioperative nurse participants revealed that the more education a nurse receives about smoke evacuation hazards and the more a nurse is trained on smoke evacuation equipment and devices, the more compliant the nurse will be with smoke evacuation recommendations. Age, level of education, and years of experience do not make a significant difference in compliance. If the smoke evacuation recommendations are perceived to be easy to understand and implement, then compliance is greater. Compliance is also greater within larger urban facilities that offer multiple specialties and have strong leadership support and interconnectedness (collaboration among professionals). Freestanding surgery centers are more apt to have greater compliance with smoke evacuation recommendations than surgical departments within hospitals. Lack of smoke evacuation equipment, resistant physicians, noisy smoke evacuators, and staff complacency are all listed as substantial barriers to implementing smoke evacuation recommendations. Perioperative nurses report a greater incidence of respiratory problems (e.g., allergies, asthma, or nasal polyps) than the general population. Research results can be used to target audiences and develop education and training sessions to improve OR practices regarding evacuation of surgical smoke.

Modified from Ball K: Surgical smoke evacuation guidelines: assessing compliance among perioperative nurses, unpublished doctoral dissertation, Virginia Commonwealth University, 2009.

Date _____ OR Room No. _____

PATIENT INFORMATION:
Name _____ Patient ID No. _____
Zip Code _____ Sex: M F Age _____
Status: IP OP

SURGERY INFORMATION:
Physician _____ Anesthesia: General MAC Local
Procedure _____

LASER INFORMATION:
Laser and wavelength _____
Power _____ Duration _____
Total spots _____ Total energy _____
Laser time on _____ Laser time off _____

DELIVERY SYSTEM:
Laser fiber _____
Contact tip _____
Microscope handpiece _____

LASER SAFETY:
Eye protection _____
Smoke evacuation _____
Fire safety _____
Other safety measures _____
_____

COMMENTS:
_____
_____
Laser team member _____

FIGURE 7-63 Sample laser log.

injury to the transporter. The laser unit should be pushed instead of pulled to provide less stress on the transporter's back muscles. The laser should never be bumped against a wall as its internal components can be damaged or become misaligned.

DOCUMENTATION. Closely following written laser safety procedures is crucial for safety and legal reasons, as with any hazardous equipment. Specific notes about laser safety can be written on a laser log form or as part of the intraoperative nursing note. Either record should be placed on the patient's chart so that safety activities can be recorded. Safety measures may not be specifically documented if already described and mandated in the facility's policies and procedures. This is referred to as "documentation by exception."

A special laser log can be designed to be a permanent part of the patient's record and might include information such as the laser used, power, pulse duration, and other laser parameters. The use of smoke evacuation, fibers, and contact tips also may be documented, especially if specific charges for these items are made. A sample laser log is shown in Figure 7-63.

ROLE OF THE LASER TEAM MEMBER. As the use of laser technology grows, the role of the laser team member becomes more important. The backbone of a progressive and successful laser program is the enthusiastic and dedicated laser team. Expanded responsibilities are being assumed by the laser team member to provide consistency and promote a safe environment for the patient and the surgical team. Some roles of the laser team member may include serving as the laser safety officer, serving on the laser committee, becoming actively involved with laser procurement, and promoting the laser program through marketing.

According to ANSI Z136.3 (2005), the definition of the laser safety officer (LSO) is "the person responsible for the laser safety program in the facility…[who] has the training and experience to administer a laser safety program…is authorized by the administration and is responsible for monitoring and overseeing the control of laser hazards (p. 6)." Following are some of the duties of the LSO:

- Labels laser with appropriate hazard classification
- Evaluates potential hazards of the laser
- Serves on laser committee
- Enforces standard operating procedures (e.g., maintenance, service, perioperative checklists, policies)
- Ensures protective equipment and devices are in good working order (e.g., protective eyewear)
- Ensures laser installation and maintenance are carried out by qualified individuals, documented, and performed regularly
- Ensures appropriate training and education on laser safety are conducted and documented
- Documents incidents with lasers that could cause or has caused harm to patients or healthcare providers
- Delegates duties within the laser program as appropriate

Perioperative nurses who are part of the laser team are often involved with patient education. The perioperative nurse reinforces what the physician has described to the patient before a laser procedure. When told that surgery is needed, the patient is often anxious because of the unknown. Anxiety may be compounded because the patient is confronted with two alarming unknowns. Many patients develop uneasiness about laser procedures based on information from science-fiction movies, talk shows, and other such sources. The patient always should have the opportunity to discuss a proposed procedure to allay any worries. The perioperative nurse may provide additional information if the patient has further questions about laser technology. After the physician has explained the procedure, a surgical consent is signed. Sometimes, the consent form reflects that a laser will be used during surgery. Some physicians, however, suggest that a laser is merely a tool used during surgery and do not believe it is necessary to list laser use on the consent form.

Adequate time should be allotted for patient questions before the procedure. If a local anesthetic is used, the patient should understand what to anticipate during surgery, what sounds or odors will arise, why eye protection is needed, and what the patient's role is during the procedure. If the patient understands the application, the role of the laser, and his or her responsibility during and after the procedure, the perioperative nurse can expect better compliance and less anxiety in the patient.

Discharge instructions are required for any ambulatory procedure; laser discharge instructions may be preprinted for each surgical application. These written instructions should be reviewed and given to the patient on discharge. A follow-up phone call helps the perioperative nurse evaluate the care delivered during the laser intervention and the patient's compliance with the postoperative instructions.

Sometimes, the perioperative nurse is placed in a compromising position by being expected to circulate during the surgical procedure and also to operate the laser. This nurse has the tremendous responsibility of being accountable for two crucial roles in the OR; the risk of a laser incident may increase. In the traditional setting, one nurse circulates while another nurse or a technologist, a member of the laser team, operates the laser. The healthcare facility must determine which procedures require more staffing to deliver safe patient care.

Electrosurgery

Electrosurgical units (ESUs) have been used for many years to cut and coagulate tissue (Box 7-4), but ESU use also has been associated with numerous patient injuries and accidents. The same laser safety measures used to prevent surgical fires and to evacuate surgical smoke are also used for electrosurgery. (See the Laser Safety section in this chapter for detailed information.) Education is vital to ensure safe use of electrosurgery by understanding the principles and actions of this surgical energy.

Physics of Electrosurgery. The basic principles of electricity underpin electrosurgery. Electricity involves the motion of subatomic particles that behave in a consistent and predictable manner. Electrons orbit the nucleus of an atom. Once electrons are charged, they jump from one atom to the orbit of another, creating a charged particle or ion, and an electrical current is generated.

BOX 7-4

History of Electrosurgery

Around 1926 Dr. Harvey Cushing, a neurosurgeon, and Dr. William T. Bovie, a biophysical engineer, combined their talents and knowledge to develop electrosurgical technology for use during neurosurgical procedures. In 1928 they published a series of 500 neurosurgical procedures performed using an electrical device developed by Bovie. This primitive electrosurgical tool provided hemostasis for surgery in highly vascular areas. The first commercial ESU was produced in the early 1930s. The unit stood chest high, weighed about 300 lb, and was set in a beautifully crafted wooden cabinet. In the third edition (1958) of *Alexander's Care of the Patient in Surgery* it was noted, "Electrocoagulation has become an essential part of the neurosurgical setup. The nursing personnel must understand the construction of the machine before attempting to regulate it and they must carry out proper safety measures." Electrosurgery began to gain wide acceptance as the benefits of tissue coagulation and a drier surgical field became recognized by many surgical disciplines. Today it remains one of the most important and basic surgical modalities used in operative and other invasive procedures.

Three terms describe the properties of electricity—current, voltage, and impedance. *Current* is the flow of electrons measured in amperes or amps. *Voltage* is the force or push that moves the electrons from one atom to another and is measured in volts. *Impedance* is the opposition to the flow of current (electrons) and is measured in ohms (Ulmer, 2007). As electrons encounter impedance, heat is produced, and a tissue effect results.

Electricity must have a complete circuit or pathway so that electrons can flow. That is, if an electrical current originates from earth, the electricity must be returned to ground to complete the circuit. Two forms of electrical current are used today—direct current (DC) and alternating current (AC). With DC the electrons flow in only one direction, whereas with AC the electrons flow back and forth as polarity changes. During electrosurgery, AC enters the patient's body, causing the patient to become part of the circuit as the energy is returned to the source of the energy.

"Electrocautery" often is misused as a reference for electrosurgery. Electrocautery devices use direct current because electrons flow in one direction through a wire. The wire provides resistance and becomes hot. As the hot wire is held in contact with tissue, coagulation results. Electrocautery units are usually battery-operated, such as the small disposable units used during ophthalmic procedures to coagulate small blood vessels.

Frequency is the number of waves passing through a given point over a specified time. This is measured in hertz (Hz) or cycles per second. Electrosurgical systems operate at frequencies greater than 100,000 Hz, which also is the frequency at which nerve and muscle stimulation ceases. In comparison, the electrical current in a normal household wall outlet in the United States alternates at 60 cycles per second, or 60 Hz. An ESU generator takes the 60-cycle current and increases its frequency to greater than 200,000 Hz so that it can pass through the patient's body without muscle or nerve stimulation and with no risk of electrocution (Figure 7-64).

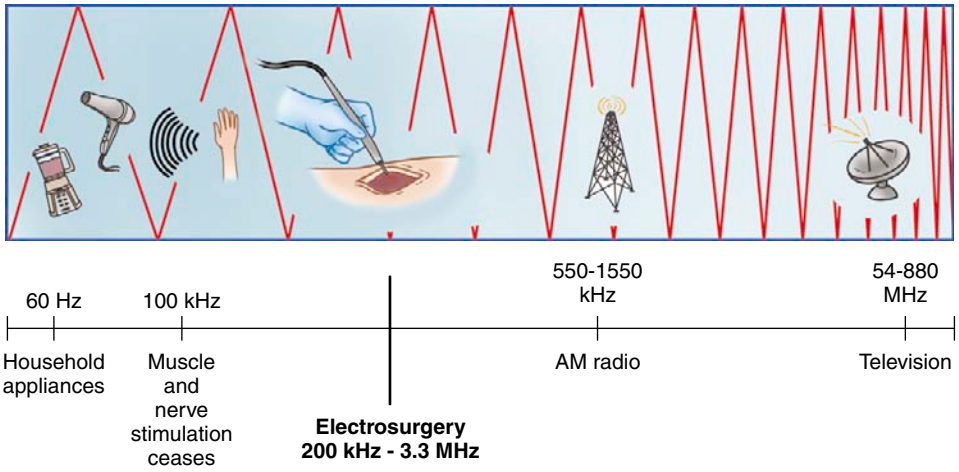


FIGURE 7-64 Frequency spectrum.

Electrosurgical Modes. The two modes used for electrosurgical cutting or coagulation are *monopolar* or *bipolar*. In a monopolar system, electrical energy flows from the generator through an active electrode to the patient (Figure 7-65). If energy is concentrated in a small area, and the tissue provides increased impedance, controlled heat is generated and cutting or coagulation is achieved. Electrical energy passes through the patient to a dispersive electrode (pad) or patient return electrode (PRE) placed on the patient's body. The dispersive electrode surface area is larger so that the energy is not concentrated enough to generate significant heat. Energy is then returned to the generator as the circuit is completed. If the dispersive electrode is tented, or only a small part of the pad is in contact with the patient's body, electrical energy becomes concentrated, and a burn can result. With monopolar electrosurgery, the patient completes the electrical circuit; it is the most common mode of electrosurgery used today.

In a bipolar system, a dispersive electrode is not needed because electrical energy flows from one tine (or prong or blade) of the bipolar instrument to the other tine as it passes through the tissue located between these tines (Figure 7-66). Energy returns directly through the instrument to the generator to complete the circuit, eliminating flow of current through the patient. During bipolar electrosurgery, the flow of electricity stops if a certain impedance level is reached. This is frequently 100 ohms but may differ for various bipolar generators available today. Although the ESU seems to be activated because an audible sound is heard while the pedal is depressed, the flow of current significantly decreases when the specified impedance is met. Impedance meters (or ammeters) are often used to alert the physician when tissue desiccation is occurring or when complete desiccation has occurred.

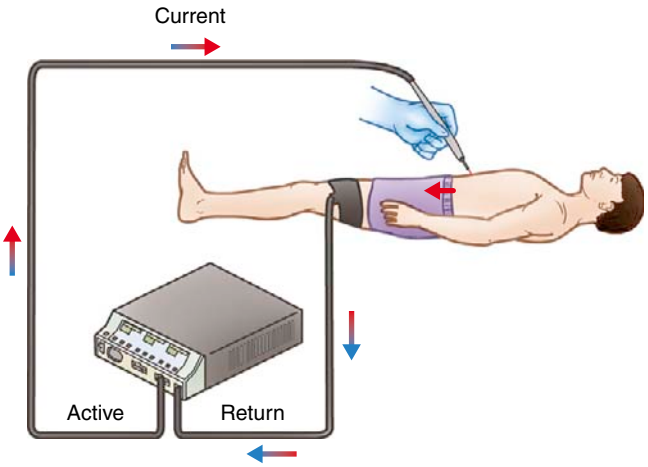


FIGURE 7-65 Monopolar electrosurgical circuit.

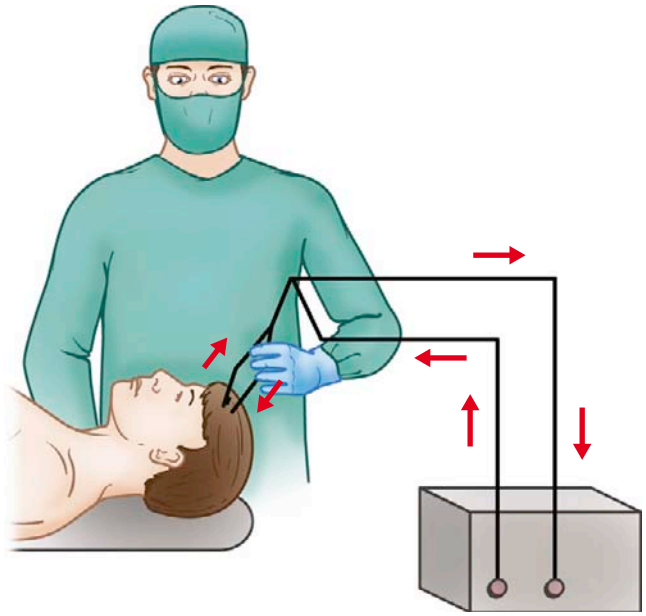


FIGURE 7-66 Bipolar electrosurgical circuit.

Tissue Effects. As electrosurgery variables change, different tissue effects can be achieved. Electrosurgery variables, explained below, include the following:

- Waveform
- Power setting
- Length of exposure
- Active electrode size
- Type of tissue
- Eschar presence

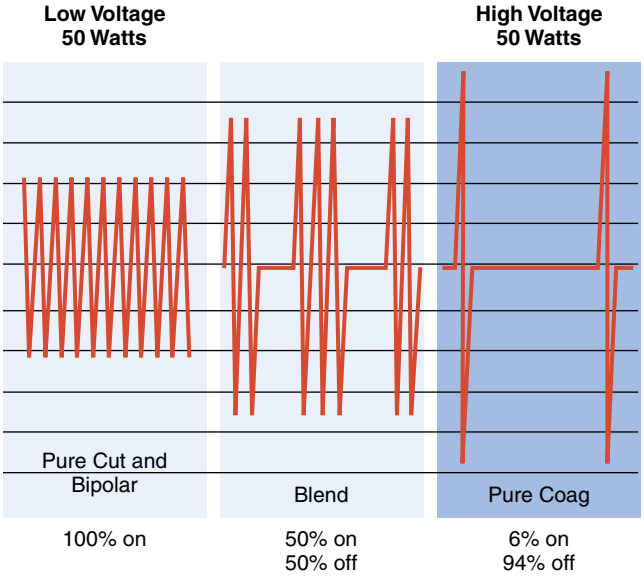


FIGURE 7-67 Electrosurgery waveforms: typical examples.

As waveform changes, so does tissue effect. Waveforms range from pure cut to pure coagulation. To produce a pure-cut mode, the generator must be on a 100% duty cycle, meaning that the electrical flow is continually applied, and heat is quickly generated for cutting and tissue vaporization (Figure 7-67). Current is high, but voltage is low. As less force is used to push the current, the cut mode may be considered safer than other modes. As the cut mode produces a constant bombardment of electrons on the tissue, heat is produced, cells rupture, and the tissue is cut. For maximum activity, the active electrode used to deliver the current should be held slightly above the tissue so that the electrons have to jump through the impedance of the air to reach the target site. This generates even more heat. Most of the heat dissipates as steam as tissue cells vaporize.

In pure coagulation mode, current is decreased, but voltage is increased. The duty cycle is on only about 6% of the time, leaving 94% of the time with no flow of electrons to the surgical site (see Figure 7-67). To compensate for this "off" duty cycle, the voltage, or force of the push, must be increased to produce the desired wattage. During coagulation, this intermittent delivery of electrons causes cells to heat and then cool, producing a coagulative effect. Higher voltage allows the active electrode to be held over the area while a fulguration or spraying effect delivers the electrical energy to coagulate a larger area. The tissue effect is superficial, collapsing the cells and producing a coagulum.

Most ESUs have a blend mode that allows the operator to achieve different levels of simultaneous coagulation in the cut mode. Increasing voltage and decreasing the duty cycle provide increased coagulation effects (see Figure 7-67).

The power setting also influences tissue effect. Higher power settings produce more extensive tissue effects. Long activation of electrical current increases thermal effects in tissue. Thermal energy can spread from the target site, causing damage to adjacent tissue. Smaller active electrodes concentrate electrical energy and require lower power settings; larger electrodes disperse electrical energy and require higher power settings.

Tissue type also influences tissue effect. Tissue that is not well vascularized, such as adipose tissue, offers more impedance. As a result, electrical energy is not conducted as well, and higher power settings may be required. Muscle tissue is well vascularized and requires less power to achieve a tissue effect. Eschar is less conductive and impedes the flow of electrons, requiring more power to be used to achieve the desired tissue effect. Electrosurgical tips on the active electrode must be kept clean and free from debris to function properly. Electrode tips with nonstick coating make removal of eschar easier.

Electrosurgical Units. Four ESU systems have evolved over the years: grounded, isolated, dispersive electrode monitoring, and tissue response monitoring.

GROUNDED ESU. The grounded ESU system was the first ESU introduced to the surgical market during the late 1920s. The grounded ESU delivers electrical energy from the generator to the patient and returns energy to ground, which is intended to be the generator. As electricity takes the path of least resistance, current can flow or divide through any grounded alternative paths, such as an ECG pad or an intravenous pole that touches the patient, as it returns to a grounded site. Patients have sustained burns at these alternative path sites as the electricity searches for the most conductive object or path to return to ground. When an alternate path is chosen, the current may not be dispersed over a large area, so an alternate site burn may result as current concentrates.

ISOLATED ESU. In 1968 the isolated ESU was introduced. An isolated ESU has a transformer that causes current to return only to the generator and not use alternate pathways to return to its source. Current flows through the patient's body and must return to the generator to complete the circuit. If this is not possible, the generator shuts down, adding to the safety of this type of unit. An isolated ESU prevents alternative site burns, but not patient return electrode (PRE) burns. The function of a dispersive electrode is to remove electrical current from the patient safely, but this may not always happen. If the pad is tented, the electrical current arcs from the patient's skin to the pad to complete the circuit. The current concentrates in the reduced pad-patient interface surface area and may cause a burn at this site. With experience, surgical teams became more focused on proper dispersive electrode placement by choosing a well-vascularized site with a secure pad-patient interface. Monitoring pad placement with an isolated ESU is a crucial responsibility of the perioperative nurse.

DISPERSIVE ELECTRODE MONITORING. In the 1980s different dispersive electrode monitoring systems were introduced, using a variety of names: dispersive pad monitoring, REM (return electrode monitoring), RECQMS (return electrode contact quality monitoring system), contact quality monitoring system, and patient safety system. Dispersive monitoring protects the patient from dispersive electrode site burns caused by inadequate contact of the dispersive electrode. The system continually monitors impedance under the split pad as it transmits an interrogation circuit to measure impedance levels. The system deactivates current flow when impedance under the pad increases to an unsafe level, thus preventing a burn.

Placement of a dispersive electrode pad is crucial to prevent patient injuries. The pad should be placed over an area that is well vascularized, such as a muscle mass. Sites with excessive

FIGURE 7-68 Capacitance pad that provides pressure reduction to prevent skin breakdown.

hair, bony prominences, excessively dry skin, or adipose tissue should be avoided. When a patient is repositioned after the pad has been placed, the pad site must be inspected again to ensure proper adherence.

A capacitance pad working on the principle of "bulk resistivity" and "capacitive coupling" is an advanced technology. A capacitor is defined as two conductors separated by an insulator. In an ESU, the patient is one conductor (plate), and the conductive mesh (plate) inside the pad is the other conductor. The ability for current flow to be induced from one plate of the capacitor to the other is affected by three primary variables: (1) frequency of current, (2) size of the plates, and (3) distance between the plates. Higher frequency large plates and less distance between plates lead to better current flow. One small low-frequency plate or a great distance between the plates yields decreased current flow.

The large capacitive pad, approximately 2 feet × 3 to 4 feet, consists of a flexible conductive fabric surrounded by a nonlatex, urethane insulating material. The pressure reduction version of this pad is composed of a dry, viscoelastic polymer, one of the best materials to prevent the formation of decubitus ulcers.

This large reusable pad is placed on the OR bed (Figure 7-68) with a linen sheet and draw sheet placed on top of it. When the patient is lying on the OR bed, the electrode pad forms a large capacitor with the patient that capacitively couples or connects the patient into the ESU circuit. When in place, this dispersive electrode completes the circuit by capacitive reactance, allowing the ESU to function. The amount of current transmitted into the pad is directly proportional to the amount of contact with the pad. The pad serves as the gatekeeper for this current. With too little current, there is very little current flow, too low to cause burns.

The capacitive pad can be used for patients in all types of positions. A positioning chart is available from the manufacturer to assist the surgical team with safe and appropriate positioning. This larger pad is inappropriate for patients weighing less than 25 pounds because adequate contact (weight-bearing area) cannot be achieved. In 2009 a pediatric capacitive pad was introduced for patients between 0.8 and 50 pounds (Figure 7-69).

The large capacitive pad eliminates the need for an individual adhesive dispersive electrode pad, which is problematic if an ESU is used without dispersive electrode monitoring capabilities and the pad tents during a procedure. The bulk resistivity of this unique capacitive pad ensures that current densities are kept to a clinically safe level such that pad site burns rarely occur. Adhesive pads also can irritate sensitive skin, may require a shaved area for placement, or may become a hazard if not placed on the patient appropriately. As surgical teams learn more about the use and safety features of the capacitance pad, its acceptance continues to grow.

TISSUE RESPONSE MONITORING. This system represents a substantial advancement in ESU generator technology. It uses a computer-controlled tissue feedback system that senses impedance of the tissue and automatically adjusts current and voltage output to maintain a constant surgical effect.

FIGURE 7-69 Pediatric capacitive dispersive pad for infants weighing from 0.8 to 50 pounds.

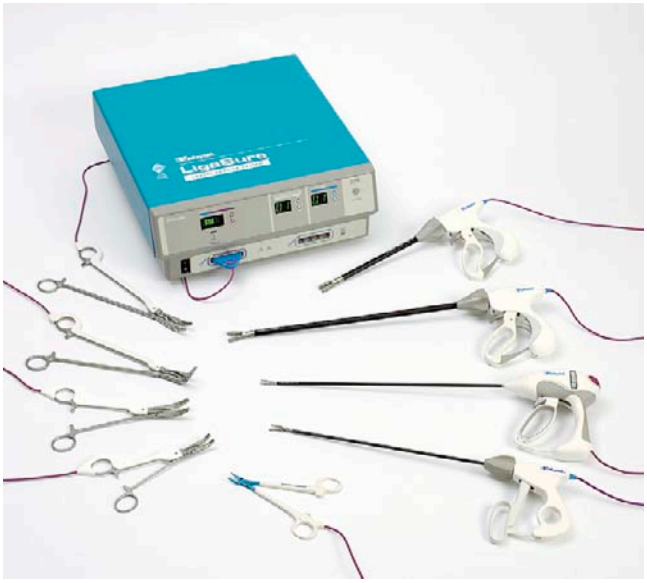


FIGURE 7-70 Vessel-sealing generator with instruments.

This feedback system eliminates the need to adjust power settings for different tissue types. In addition, improved performance at lower power settings and voltages reduces the risk of patient injury.

Another advanced feedback–controlled generator has been combined with a bipolar instrument to seal vessels and tissue bundles reliably for surgical ligation during open and laparoscopic procedures (Figure 7-70). The feedback system helps to achieve a reliable tissue seal in less time, reducing thermal spread compared with traditional bipolar systems. With a single activation, this system provides stable seals on tissue bundles or on vessels up to 7 mm in diameter. The surgeon is able to assess the level of hemostasis at the seal site before cutting. The strength of the seal compares favorably to mechanical ligation methods, such as suture or clips, and is significantly stronger than standard bipolar coagulation. It is important to note that tissue response systems use the cut mode while the new tissue sensing systems give feedback when implementing the coagulation mode of ESU generators.

Special Electrosurgery Considerations During Endoscopic Minimally Invasive Surgery. Three unique problems can occur during MIS procedures involving electrosurgery: direct coupling, insulation failure, and capacitive coupling.

DIRECT COUPLING. Direct coupling occurs when the active electrode accidentally touches a noninsulated metal instrument, allowing the electrical energy to flow from one to the other (metal-to-metal sparking) (Figure 7-71). Direct coupling may also occur if an active electrode is activated while in contact with a clip. When the metal instrument or clip receives electrical energy, a burn can easily result. This coupling is often called "pilot error" because it is within the surgeon's control to avoid. The surgeon should not activate the active electrode until the target site is within the field of vision and the active electrode is in close proximity or direct contact with target tissue and not a metal object.

INSULATION FAILURE. Insulation failure occurs when the insulation coating of an endoscopic instrument has been compromised. If a crack or break occurs in the insulation along

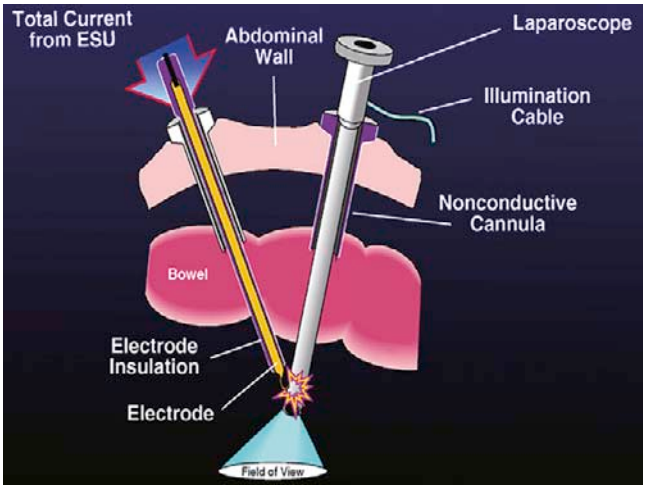


FIGURE 7-71 Direct coupling during laparoscopy.

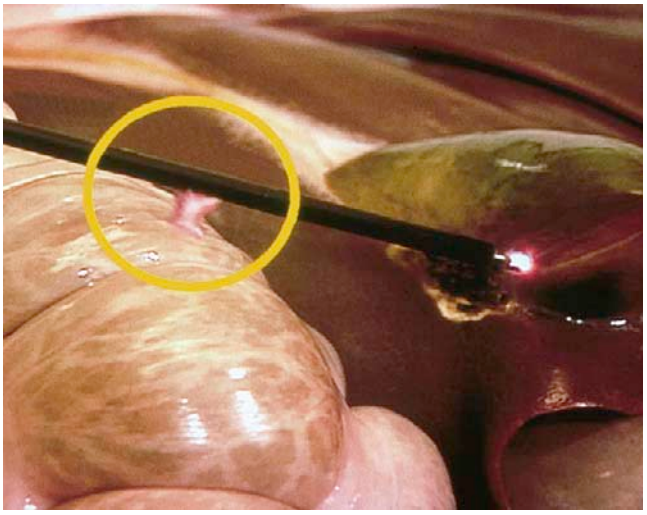


FIGURE 7-72 Insulation failure during laparoscopy.

the shaft of the instrument, electrical energy can escape at the point of the defect and burn untargeted tissue (Figure 7-72). Insulation must be inspected before, during, and after each use of the instrument. A scanning device can be used to ensure that insulation is not compromised during reprocessing. Even an area of insulation that is merely weakened may be penetrated by electrical flow if high voltage, or pure coagulation mode, is being used. Given that the force (or voltage) of electrons is greater in coagulation mode, any weakened area may become an actual break along the insulation sheath. Insulation failure presents the greatest risk to the patient because the full energy output can be delivered to nontargeted tissue. Insulation failure may result in an instantaneous, irreversible death to tissue as a result of the high power density that insulation failure creates on the instrument shaft. The resulting tissue burn may not be observed or realized by the surgeon because it may not be within the field of vision.

Laparoscopic instruments may be purchased with a dual layer of insulation. The outer black insulation layer lies on top of a bright yellow insulation layer. When the top black layer is penetrated, the bright yellow layer can be seen easily and alerts the user that insulation failure may be imminent.

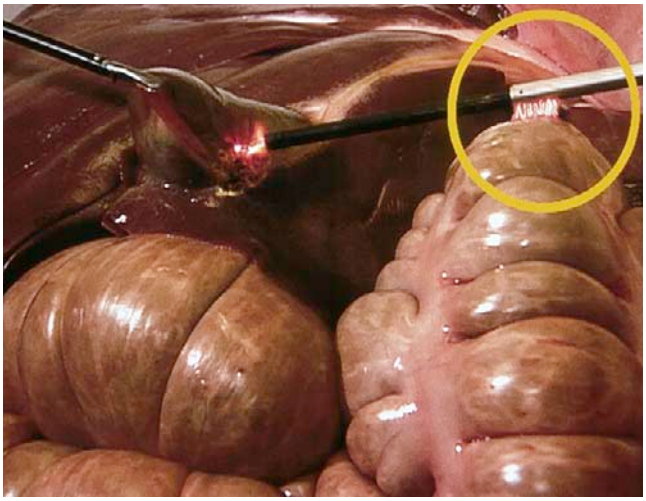


FIGURE 7-73 Capacitive coupling occurs when electrical energy flowing from an instrument charges a nearby metal trocar sheath or laparoscope.

CAPACITIVE COUPLING. Capacitive coupling is a natural RF (electrosurgical energy) phenomenon that occurs when energy is transferred through intact insulation on the laparoscopic instrument shaft to nearby conductive materials (Figure 7-73) (Dennis, 2005). A capacitor consists of *two conductors* separated by an *insulator.* The metal active electrode is one conductor, and an adhesion, an adjacent organ, or a conductive trocar/suction irrigation cannula can act as the second conductor. The primary insulation on the instrument represents the insulator. When an electrode is activated within a narrow suction irrigator, the RF energy can flow from the active electrode through the intact insulation and transfer 20% to 80% of the power displayed on the ESU to the metal suction irrigator. The induced current on the suction irrigator can cause a burn even though the outer insulation on the first instrument has been inspected and determined to be intact.

Monopolar ESU instruments used in concert with metal suction irrigators or shafts increase the risk of visceral burns through capacitive thermal energy. The laparoscope also can cause alternate-site burns if the ESU electrode is used through a narrow-lumen scope. In addition, long and narrow instruments with thin insulation, combined with high voltage, increase the incidence of capacitive coupling.

An electrical charge remains in the second metal instrument until it finds a path to the dispersive electrode to complete the circuit. Usually this energy disperses safely through the large surface of the abdominal wall from the conductive cannula. However, if a nonconductive device, such as a plastic stability collar, is in this path, energy cannot be safely discharged and will burn any tissue touched by the metal instrument. These burns often are undetected by the surgeon, and the problem is not diagnosed until the patient presents with complications after surgery. Accordingly, surgeons avoid hybrid instruments (combination of plastic and metal) during laparoscopy to minimize capacitive coupling.

To eliminate the hazard of capacitive coupling and insulation failure, special instruments that provide active electrode monitoring (AEM) are available to capture stray energy that is transferred from one conductive device to another (Dennis, 2005). AEM laparoscopic instruments are shielded and monitored to detect stray RF current and prevent ESU burns. The protective shield built within an AEM instrument provides the neutral path for capacitive-coupled energy and returns it to the ESU (Figure 7-74). These safety devices also detect insulation failure and provide a path for stray current back to the generator. AEM is the only fail-safe technology currently designed to address insulation failure and capacitive coupling. AEM ensures that 100% of electrosurgical energy is delivered at the intended site.

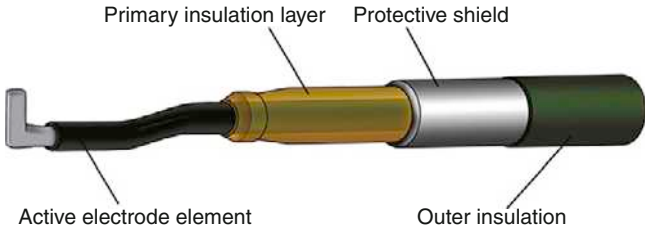


FIGURE 7-74 Cross section of active electrode monitoring instrument.

Many hospitals that have implemented AEM technology require documentation of its use on the patient's perioperative chart for liability and risk management, much like rationales for documenting needle count, sponge count, and pulse oximetry.

Argon-Enhanced Electrosurgery. An argon-enhanced ESU device combines argon gas with electrosurgical energy to improve the effectiveness of the electrosurgical current. As argon gas is heavier than air, inert, and noncombustible, it creates an efficient pathway for electrosurgical energy to travel from electrode to target tissue. The flow of argon gas also clears the surgical site of blood and fluids, allowing for greater visibility of the bleeding site or target area, and disperses oxygen, decreasing the chance of combustion and formation of surgical smoke.

Benefits of argon-enhanced electrosurgery include:

- Rapid coagulation of diffuse bleeding site with reduced blood loss
- Reduced risk of rebleeding
- Noncontact tissue coagulation
- Reduced depth of penetration by electrical energy and less adjacent tissue damage (Dooley and Braghieri, 2008)

When an argon-enhanced ESU is used during laparoscopic procedures, care must be taken not to overinsufflate (or overpressurize) the abdomen because the constant flow of argon gas could cause formation of a gas embolism. Often another port is left open during activation of argon-enhanced ESUs to allow excess gas to escape. An insufflator with an audible alarm indicating overpressurization should be used. The patient should be monitored closely so that early symptoms of an embolism can be detected and treated.

Ultrasonic Device Surgery

Vibrating energy devices provide a safe option for cutting and coagulation. High-frequency sound waves are propagated to a blade tip to produce ultrasonic energy. These ultrasonic waves have a frequency of greater than 20,000 Hz and cannot be sensed by the human ear.

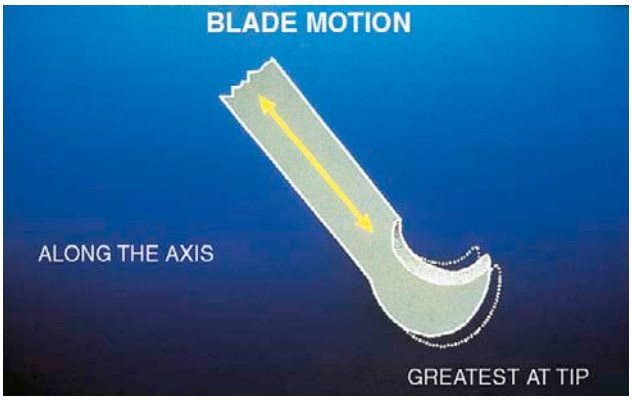


FIGURE 7-75 An ultrasonic blade may move longitudinally more than 55,000 times per second.

Production of ultrasonic energy begins with electrical current that generates an electrical signal sent through a co-axial cable to a transducer in a handpiece. The transducer converts electrical energy to mechanical motion through contraction and expansion of ceramic elements. A longitudinal vibratory response that moves the tip at the end of the handpiece from 23,000 Hz to greater than 55,000 Hz is produced (Figure 7-75). As the power increases, the frequency remains the same, but longitudinal excursion of the tip lengthens.

Because the tip is in contact with tissue, mechanical motion causes tissue protein to denature as hydrogen bonds are broken. As protein molecules become disorganized, a sticky coagulum forms that welds and coagulates smaller bleeding vessels. Aerosolization occurs during cellular destruction, consisting of a small amount of water vapor that usually dissipates quickly. Only a small amount of thermal energy is produced and any adjacent tissue damage is minimal.

Different tip configurations include a blade, ball, and hook. To obtain optimal tissue response, countertraction must be applied to the structure being treated. A shear-grasper to hold the tissue between a blade and tissue pad can be used to eliminate the need for countertraction.

The following are advantages of using an ultrasonic device to cut and coagulate:

- No surgical plume or odor is generated; only a small amount of aerosolization is created.
- Less adjacent tissue is damaged compared with laser and ESU devices.
- Tactile feedback is retained.
- No nerve or muscle stimulation occurs because no electrical current is delivered to the target area.
- No stray electrical or laser energy is produced.
- Precise cutting and control are offered.

Neutral Plasma Coagulation. A neutral plasma coagulator consists of a range of disposable handpieces that are used for coagulation by neutral argon or thermal plasma. In the PlasmaJet system, anode (where current enters) and cathode (where current exits) electrodes generate argon plasma. As the electrodes are contained in the handpiece, no ground plate is used. Risk for the patient is reduced because no electrical current passes through the patient. When the plasma coagulator handpiece reaches bleeding tissue, it releases its kinetic energy as heat and causes coagulation of the bleeding surface.

Microwave Ablation. Microwave ablation is a new technology that ablates tissue. Frictional heat is generated from rotation of water molecules that creates an ablation zone with simultaneous application of one or more antennas. When the antennas are spaced closely to each other (i.e., 1.5 to 2 cm apart), one combined ablation zone is created. No electrical current flows through the patient and no dispersive pad is required. The system automatically shuts off when the set ablation time is achieved. The advantage of microwave ablation is that the desired level of soft tissue coagulation can be reached more quickly compared to other RF ablation devices.

Hydrodissection and Irrigation

Irrigation is essential during most open and endoscopic procedures. Irrigation is accomplished with irrigation probes for open procedures; via irrigating channels built into endoscopes; or by irrigating systems inserted through an operating port, cannula sheath, or operative endoscope.

Irrigating fluid can be introduced manually through an endoscope by a syringe and stopcock attached to irrigation tubing on one end and an irrigation bag and tubing assembly on the other (original intravenous pole, Y-tubing, and irrigation system). Fluid flows by gravity and is manually forced through the distal tubing.

A pressure bag can be used to increase flow, if desired. Irrigation through a flexible endoscope also can be delivered directly by a syringe attached to the irrigation port. Fluid travels through a specific channel built into the scope. Rigid scopes, such as ureteroscopes, cystoscopes, and hysteroscopes, also have this capability, as do operative laparoscopes.

Pumps are utilized when large quantities of fluid are used and manual operation is cumbersome and time-consuming. Pumps are beneficial when irrigation is used for hydrodissection because more fluid can be introduced to the surgical site under pressurization. More force can be exerted over longer periods, and the pressure is adjustable.

A common pump irrigation system includes the irrigation pump (CO_2 or electric), irrigation bottle caps, irrigation probe with dual trumpet valves, and Y-tubing irrigation set. When a CO_2-controlled system is in use, an E-cylinder of CO_2 gas is attached by means of a tank yoke and input hose. A wrench must be available to turn off the tank when not in use. It is important to check tank pressure before and after each use. The pump usually has an adjustable pressure on-off capability and dual irrigation bottle selection. As one bottle empties, a flip of the switch redirects CO_2 flow to the second bottle. Bottles can be replaced as needed. The system operates by displacement of water or saline with CO_2 gas.

When an electric setup is used, a carrier bag with an inflatable bladder surrounds the solution bag (Figure 7-76). When the bladder inflates, adequate pressure can be achieved and controlled to provide irrigation and hydrodissection.

Distal tubing attaches directly to an irrigation probe. The length of time and volume of irrigation are controlled by a trumpet valve (Figure 7-77). Probes are available as reusable, disposable, or a combination of both. All three types incorporate a second trumpet valve for suctioning.

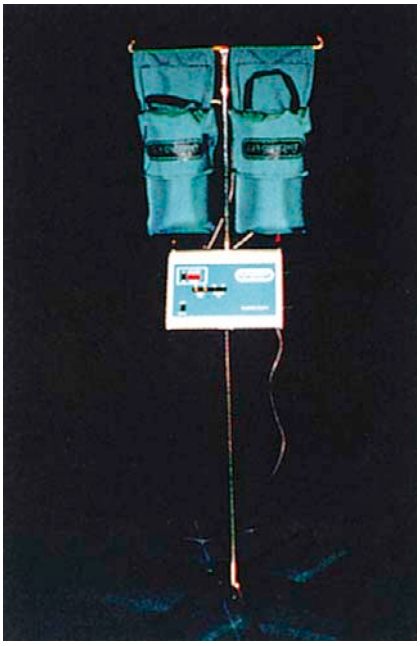


FIGURE 7-76 Hydrodissection system.

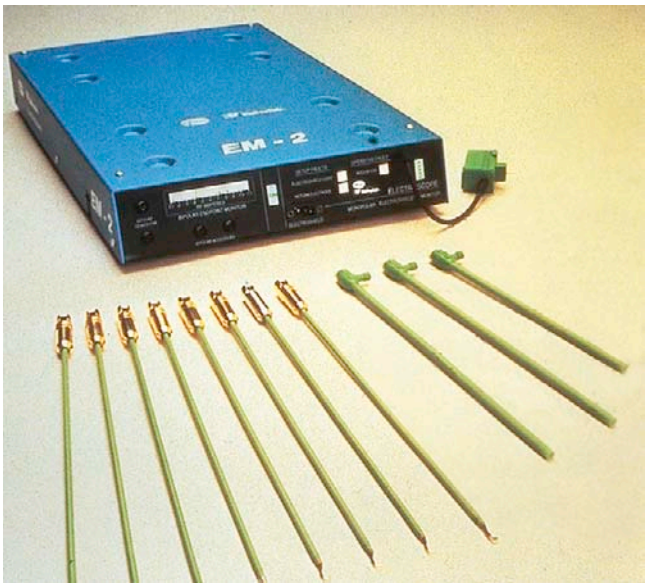


FIGURE 7-78 Disposable laparoscopic system with irrigation, suction, and monopolar electrosurgical capability. Electrosurgical probes are available in a variety of tips.

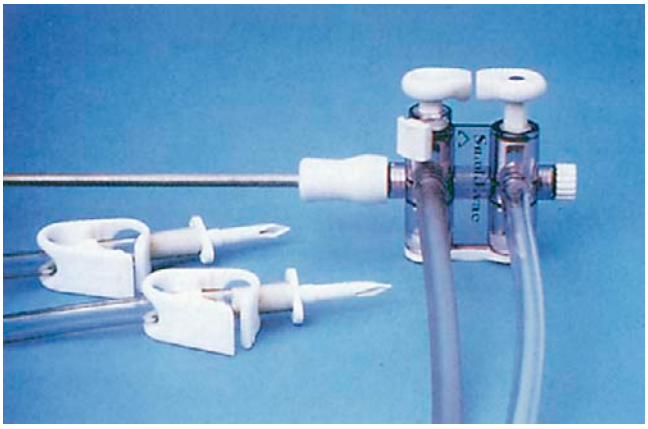


FIGURE 7-77 A trumpet valve controls the flow of irrigant and suction.

If reusable probes are used, they are completely disassembled for cleaning and sterilization or disinfection. Each trumpet valve has a spring mechanism (similar to that of a ballpoint pen). These springs are under pressure when the trumpet valve is inserted. During disassembly, it is important to hold a hand over the valve so that the spring cannot eject, disappear, or cause eye injury. Protective eyewear is worn during disassembly and extra springs should be available.

Completely disposable units are available; other systems incorporate disposable with reusable components. In the latter unit, tubing and pistol-grip handles containing the trumpet valves are disposable, but suction and irrigation probes are reusable. The disposable and disposable-reusable units may also incorporate electrosurgical capability (Figure 7-78), allowing the device to be used for three separate functions.

Choice of irrigation fluid depends on surgeon preference. Traditionally, normal saline has been used. Because saline is a conductive fluid, use of a monopolar ESU presents a safety hazard relating to potential for transfer of heat and current to adjacent tissues. As a result, sterile water or other nonconductive solutions should be considered to prevent ESU energy from transferring to alternative sites when extensive use of a monopolar ESU is anticipated. Sorbitol, also used for irrigation during hysteroscopy, can be absorbed rapidly into the vascular system, especially during excessive venous bleeding. The patient must be monitored carefully because of the potential for congestive heart failure from fluid overload.

Cryosurgery

Cryosurgery has been used in healthcare for many years, even though it may appear to be a space-age surgical technique. Archeological evidence indicates that in 2500 BC, freezing tissue was probably employed as an anesthetic. In the early 1800s, cancer was treated using different freezing techniques. Today, cryosurgery is used to destroy small quantities of unwanted tissue, such as skin tumors, and to ablate larger tissue targets, such as liver tumors, prostatic cancer, and cervical dysplasia. Cryosurgery causes tumor death by freezing. When internal tumors (e.g., liver cancer) are treated, dead tumor cells eventually are absorbed into surrounding tissue. Cryosurgery often involves cycles or steps during the treatment as a tumor is frozen, allowed to thaw, and then refrozen.

To freeze tissue properly, a cooling device or cryosurgical probe must produce an ice ball capable of destroying tissue at approximately –50° C and colder. Some devices produce temperatures as low as –240° C (–400° F). The cooling source is usually gaseous nitrogen or supercooled liquid nitrogen.

For external tumors, liquid nitrogen is applied directly to the dysplastic tissue either with a cotton swab or with a spraying device. For internal tumors, liquid nitrogen is circulated through the length of a cryoprobe with an insulated shaft to confine freezing to the distal tip. Ultrasound imaging often is used to guide the cryoprobe and to monitor tumor freezing. By

localizing the freezing effects, nearby healthy tissue is spared. Smaller cryoprobes are available that can be inserted through small trocar sites.

Cryosurgery may be used to treat early-stage skin cancers (basal and squamous cell carcinomas) and retinoblastoma (a childhood cancer that attacks the retina of the eye). Precancerous lesions, such as actinic keratosis and cervical intraepithelial neoplasia, may also be treated with this therapy. Cryosurgery has been used to treat a variety of cancers, including prostate, liver, breast, bone, brain, spinal, lung, and tracheal. It may be used in combination with other cancer treatments, such as radiation, hormone therapy, chemotherapy, and surgery. Cryosurgery has also been found useful in ophthalmology to reattach detached retinas and to treat other eye problems, such as retinoblastoma.

The primary advantage of cryosurgery over other therapies for cancer treatment is that it is less invasive. Only a small incision is needed to introduce the cryoprobe through the skin, and less bleeding, pain, and other complications occur. Cryosurgery is also less expensive compared with other treatments and often requires shorter hospital stays and recovery time. The main disadvantage of cryosurgery is the uncertainty of its long-term effectiveness because microscopic cancer cells can spread easily if these cells are missed during the freezing application. Cryosurgery continues to evolve as new cryosurgery techniques are explored for treatment and palliative therapy.

REFERENCES

American National Standards Institute, Inc: American national standard for the safe use of lasers in health care facilities, ANSI Z136.3, New York, 2005, ANSI.

Association of periOperative Registered Nurses (AORN): *Perioperative standards and recommended practices,* Denver, 2009, The Association.

Ball KA: *Lasers: the perioperative challenge*, ed 3, Denver, 2004, AORN.

Ball, KA: Surgical Smoke Evacuation Guidelines: Assessing Compliance Among Perioperative Nurses, unpublished doctoral dissertation, 2009, Virginia Commonwealth University.

Cohen M: Practicing medicine across state lines: telephone health advice, Complementary & Alternative Medicine Law Blog, 2009, available at www.camlawblog.com/licensure-and-credentialing-1008-practicing-medicine-across-state-lines-telephone-health-advice.html. Accessed June 24, 2009.

Dennis V: Advancing patient safety in laparoscopy: the active electrode monitoring system, Patient Safety and Quality Healthcare, May/June 2005, available at www.psqh.com/mayjun05/aems.html. Accessed June 24, 2009.

Dooley MM, Braghieri T: Take the path of least resistance with ESUs, *OR Nurse* 2(2):37–39, 2008.

FDA: Enforcement priorities for single-use devices reprocessed by third parties and hospitals, Rockville, Md, 2000, U.S. Department of Health and Human Services.

FDA: Guidance for Industry and FDA Staff: Medical Device User Fee and Modernization Act of 2002, Validation Data in Premarket Notification Submissions (510(k)s) for Reprocessed Single-Use Medical Devices, Rockville, Md, 2006, U.S. Department of Health and Human Servces, available at www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/ucm071434.htm. Accessed June 24, 2009.

Making your GI unit more effective, *OR Manager* 25(4):20–22, 2009.

Phillips N: Robots join the surgical team, *Nursing Spectrum* 17(2):30–33, 2008.

Poon JT et al: Impact of laparoscopic colorectal resection on surgical site infection, *Ann Surg* 249:77–81, 2009.

Sajid MS et al: Laparoscopic versus open repair of incisional/ventral hernia: a meta-analysis, *Am J Surg* 197:64–72, 2009.

Scheeres J: Surgeons here, patient there, Wired News, Sept 19, 2001, available at www.wired.com/medtech/health/news/2001/09/46946. Accessed April 17, 2009.

Schmock BA: Technological advances in the operating room, *Pennsylvania Nurse* 64(1):13, 28, 2009.

Schultz, D: Statement on reprocessing single use devices before the Committee on Government Reform, House of Representatives, Sept. 26, 2006, available at www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/ReprocessingofSingle-UseDevices/ucm121067.htm. Accessed June 24, 2009.

Ulmer BC: The Valleylab Institute of Clinical Education Electrosurgery Continuing Education Module, Boulder, CO, 2007, Valleylab, available at www.valleylabeducation.org. Accessed April 17, 2009.

Ulmer B: The hazards of surgical smoke, *AORN J* 87(4):721–734, 2008.

CHAPTER 8

Wound Healing, Dressings, and Drains

DONNA R. McEWEN

The ability to heal wounds is one of the most powerful defensive properties humans possess. Wound healing is a complex, highly organized response by an organism to tissue disruption caused by injury. This process is highly reliable in the absence of endogenous and exogenous infections, mechanical interferences, or certain disease processes. Apposition and maintenance of the edges of a cleanly incised wound almost always result in prompt healing. A primary goal of perioperative patient care is the prevention of surgical wound infections. Surgical wound infections are an important cause of illness, death, and excessive healthcare costs. Surgical wound infections have been complicated further by the potential for infection from new strains of antibiotic-resistant bacteria, such as methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant enterococci (VRE).

Postoperative surgical site infections (SSIs) are a major source of complications for the millions of individuals undergoing surgery annually in the United States and frequently are related to healthcare-associated infection (HCAI). SSIs are the third most commonly reported HCAI, numbering about 500,000 out of an estimated annual 27 million surgical procedures (Barnett, 2007). Although many surgeries are performed on an outpatient basis and the average number of admissions to hospitals and length of stay have decreased since the 1980s, the incidence of HCAIs has increased. In 2008, as part of the 2005 Deficit Reduction Act, the Centers for Medicare & Medicaid Services (CMS) began withholding reimbursement for eight conditions that have evidence-based prevention guidelines. Examples of these conditions are catheter-related infections and infections associated with coronary artery bypass grafts (Beaver, 2008), certain orthopedic procedures, and certain bariatric surgery procedures. Actions taken by perioperative personnel sometimes can mean the difference between developing an SSI and the normal healing process. A clear understanding of these actions and a solid knowledge of wound healing and factors adversely affecting healing are important for the appropriate management of patients undergoing surgery, not to mention imperative in light of continuing CMS-imposed refusals to reimburse for an expanding array of avoidable conditions that include wound-related infections.

ANATOMY

The skin is the largest organ of the body and acts as the first line of defense against infection. It provides protection and sensation, regulates fluid balance and temperature, and produces vitamins (e.g., vitamin D) and immune system components. The skin of the average adult covers about 3000 square inches, weighs about 6 pounds, and receives one third of the body's circulating blood volume. It varies in thickness from 0.5 mm in the tympanic membrane to 6 mm on the soles of the feet and the palms of the hands. Key structures of the skin are the primary layers of the epidermis, the dermis, and the subcutaneous. The *epidermis* is the outermost layer of the skin, lines the ear canals, and is contiguous with the mucous membranes. The epidermis is composed of several layers consisting of keratin and lipids. Keratin is the primary substance that hardens nails and hair and protects the body from fluid loss and invasion by pathogens. The epidermis is supported by the *dermis,* which is thicker than the epidermis and composed of collagen. The dermis is the largest portion of the skin, providing strength and structure. Contained within the dermis are blood vessels, lymph ducts, hair roots, nerves, and sebaceous and sweat glands. The dermis is vascularized and innervated (Figure 8-1). The innermost *subcutaneous* layer is composed of adipose tissue that merges with the deepest layer of the dermis to provide insulation, shape, and support. Any wound or disruption of the skin can provide a portal for bacteria and possible infection.

ETIOLOGY OF WOUNDS

The causes of wounds can be described as follows:

- *Surgical*—caused by an incision or excision
- *Traumatic*—caused by mechanical, thermal, or chemical destruction
- *Chronic*—caused by underlying pathophysiologic condition (e.g., pressure ulcers or venous leg ulcers) over time

The amount of tissue loss, the existence of contamination or infection, and the degree of damage to tissue are some factors that determine the type of wound closure selected by the surgeon. The healing process is inherently related to whether the wound is closed or left open. This process occurs in one of three ways: primary intention, secondary intention (granulation), and delayed primary closure (tertiary intention).

TYPES OF WOUND CLOSURE

Primary Intention

Healing through primary intention occurs when wounds are created aseptically, with a minimum of tissue destruction and postoperative tissue reaction. Wounds closed with sutures,

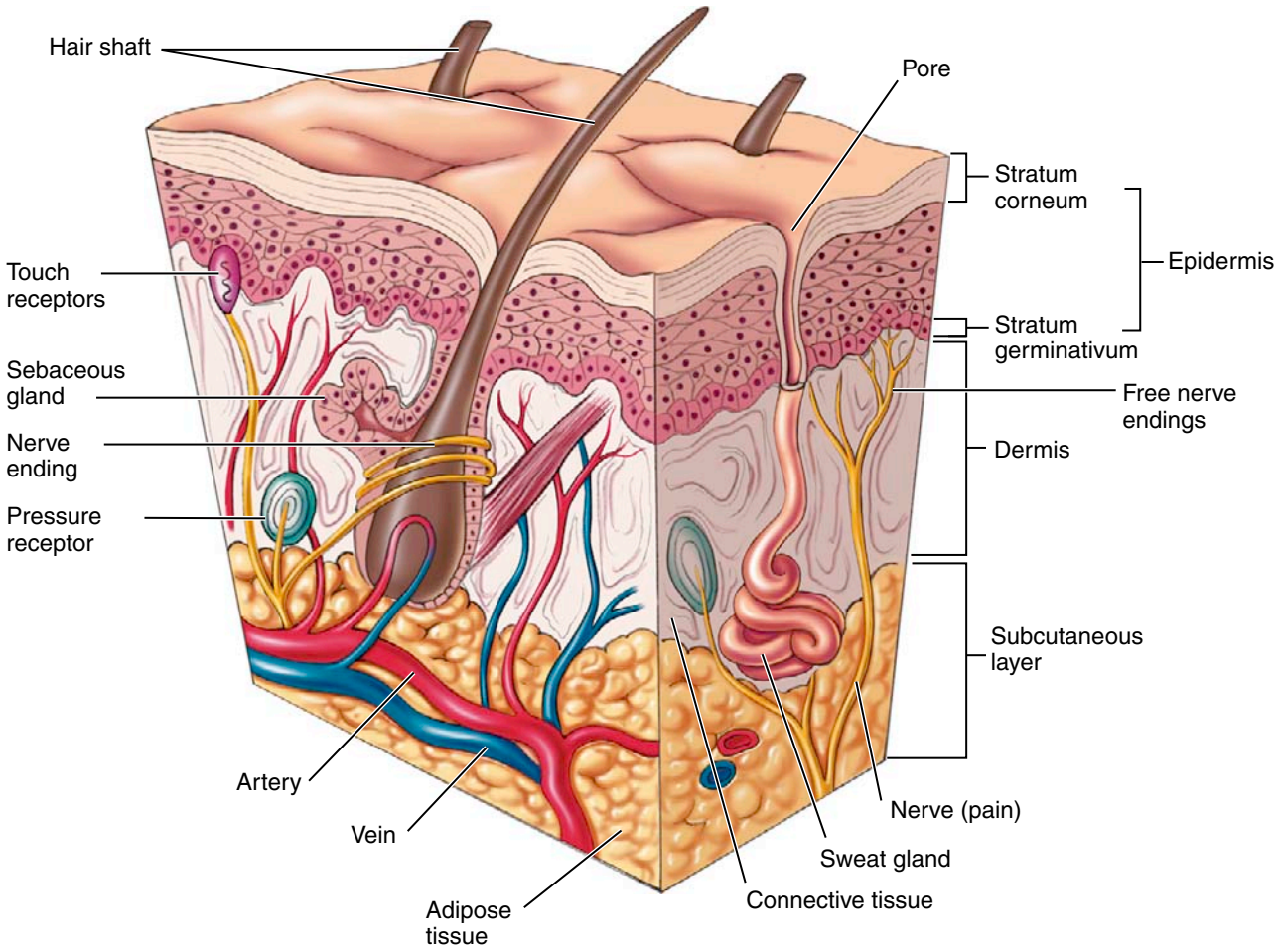


FIGURE 8-1 The skin.

staples, or tape applied as soon after the time of injury as possible fall into this category (Figure 8-2). When wounds are created under sterile conditions, healing is optimized and begins almost immediately. This type of healing is known as primary intention and occurs under the following conditions:

- Edges of an incised wound in a healthy individual are promptly and accurately approximated.
- Contamination is held to a minimum by rigid adherence to aseptic technique.
- Trauma is minimal.
- No tissue loss occurs.
- On completion of closure, no dead space remains to become a potential site of infection.
- Drainage is minimal.

Secondary Intention (Granulation)

When surgical wounds are characterized by tissue loss with an inability to approximate wound edges, healing occurs through secondary intention (see Figure 8-2). This type of wound is usually not closed; instead, it is allowed to heal from the inside toward the outer surface. In infected wounds, this process allows the proper cleansing and dressing of the wound as healthy collagen tissue expands from the inside. The area of tissue loss gradually fills with granulation tissue, comprising fibroblasts and capillaries. Scar tissue is extensive because of the size of the tissue gap that must be closed. The scar is referred to as a *cicatrix*. Contraction of surrounding tissue also occurs. Consequently, this healing process takes longer than primary intention healing. Healing by secondary intention is often seen in chronic wounds, dirty wounds, and traumatic wounds where large areas of tissue are lost.

Delayed Primary Closure or Tertiary Intention

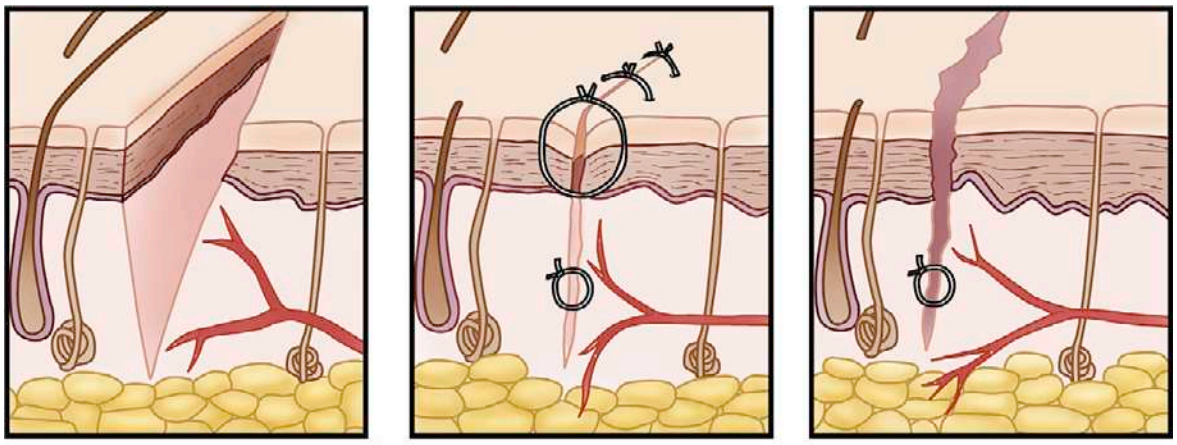
As the name *delayed primary closure* implies, this healing process occurs when approximation of wound edges is intentionally delayed by 3 or more days after injury or surgery (see Figure 8-2). These wounds may require debridement and usually require a primary and secondary suture line, such as when retention sutures are used. The conditions leading to a decision to delay closure are as follows:

- Removal of an inflamed organ
- Heavy contamination of the wound
- The critical nature of the patient's intraoperative condition, such as with hemodynamically unstable trauma patients

PHASES OF HEALING

Clean, full-thickness wound healing is an intricate biologic process that occurs in three overlapping phases: (1) inflammatory (also known as the reactive stage), (2) proliferative

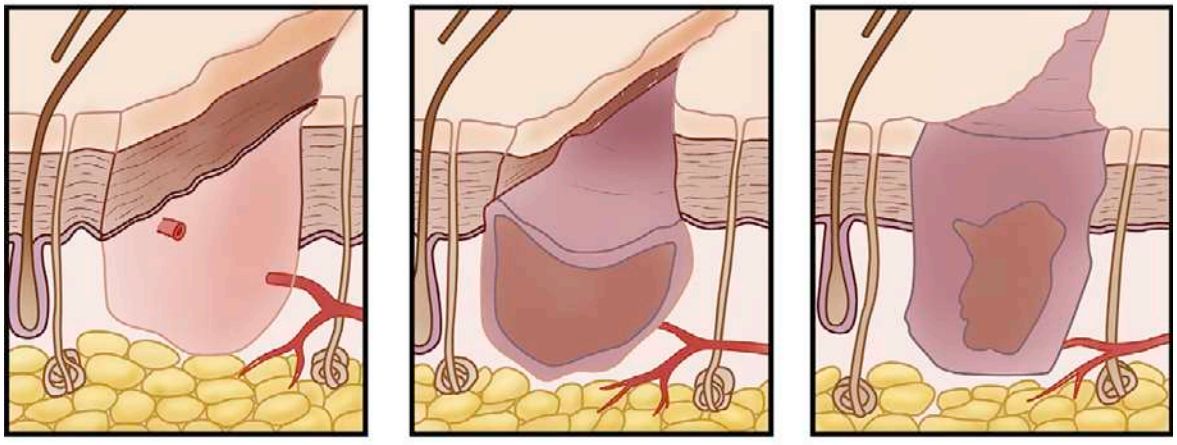
Healing by First Intention



Clean incision | Early suture | "Hairline" scar

An aseptically made wound with minimal tissue destruction and minimal tissue reaction begins to heal as the edges are approximated by close sutures or staples. No open areas or dead spaces are left to serve as potential sites of infection.

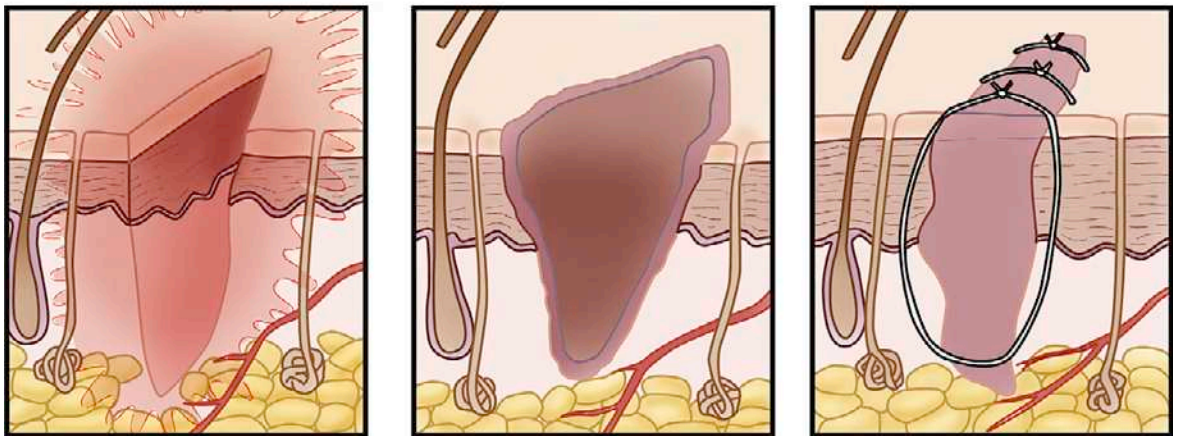
Healing by Second Intention (Granulation) and Contraction



Gaping, irregular wound | Granulation and contraction | Growth of epithelium over scar

An infected or chronic wound or one with tissue damage so extensive that the edges cannot be smoothly approximated is usually left open and allowed to heal from the inside out. The nurse periodically cleans and assesses the wound for healthy tissue production. Scar tissue is extensive, and healing is prolonged.

Healing by Third Intention (Delayed Closure)



Infected wound | Granulation | Closure with wide scar

A potentially infected surgical wound may be left open for several days. If no clinical signs of infection occur, the wound is then closed surgically.

FIGURE 8-2 The process of wound healing.

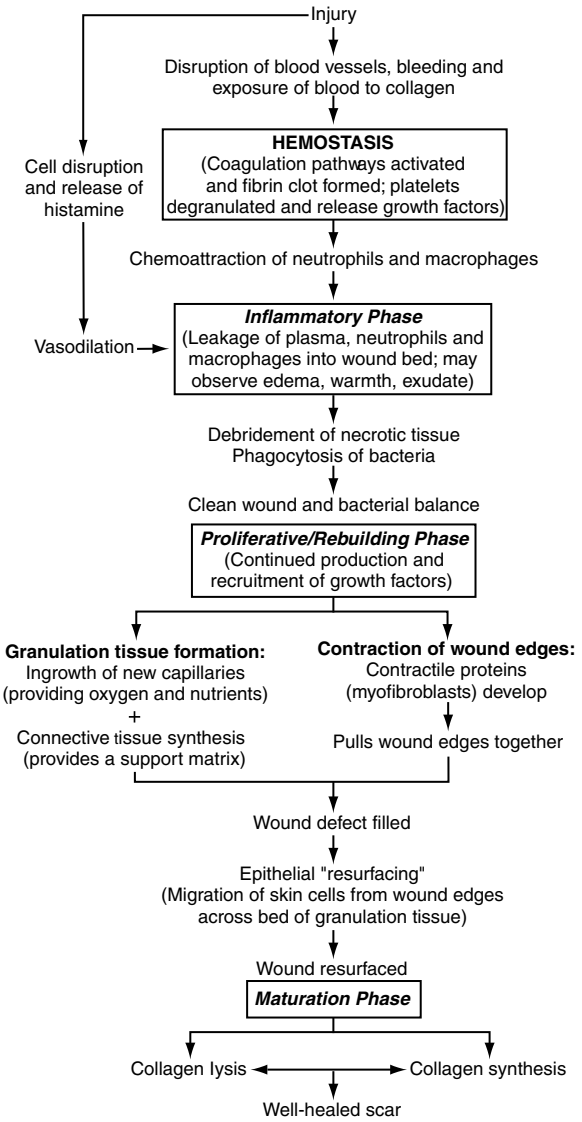


FIGURE 8-3 Cascade of events in wound repair process.

(also known as the regenerative or reparative stage), and (3) remodeling (also known as the maturation stage) (Ethridge et al, 2008) (Figure 8-3).

Inflammatory Phase

In the inflammatory phase, an exudate containing blood, lymph, and fibrin begins to clot and loosely binds the cut edges together. Blood supply to the area increases, and the basic process of inflammation begins. Inflammation is a prerequisite to wound healing and is a vascular and cellular response to dispose of bacteria, foreign material, and dead tissue. Leukocytes increase in number to fight bacteria in the wound area and by phagocytosis help to remove damaged tissues. The severed tissue is quickly glued together by strands of fibrin and a thin layer of clotted blood, forming a scab. Plasma seeps to the surface to form a dry, protective crust. This seal helps to prevent fluid loss and bacterial invasion. During the first few days of wound healing, however, the seal has little tensile strength. The inflammatory phase normally lasts 1 to 4 days. The skin edges may appear mildly swollen and slightly red in this phase as a result of the inflammatory processes at work. Many chronic wounds "stall" at this phase.

Proliferative Phase

The proliferative phase allows new epithelium to cover the wound, beginning the process within hours of the injury. Epithelial cells migrate and proliferate to the wound area, covering the surface of the wound to close the epithelial defect. Epithelialization also provides a protective barrier to prevent fluid and electrolyte loss and to reduce the incidence of infection. While reepithelialization takes place, collagen synthesis and wound contraction are occurring. Contraction begins approximately 5 days after the wound onset and peaks at 2 weeks, gradually shrinking the entire wound. Granulation tissue forms under the edges of the incision and can be palpated as a hard ridge, which eventually resolves during the remodeling phase. Epidermal migration is limited to about 3 cm from the point of origin. Larger wounds may require skin grafting because of this limited epidermal migration. Collagen synthesis produces fiber molecules that crosslink to provide strength to the wound.

Remodeling Phase

The remodeling phase begins after approximately 2 to 4 weeks, depending on the size and nature of the wound. It may last 1 year or longer. During the remodeling phase, scar tissue formed during fibroplasia changes in bulk, form, and strength. Throughout normal wound healing, new collagen is produced while old collagen breaks down in a balanced fashion. This collagen turnover allows randomly deposited connective tissue to be arranged in linear and lateral orientation. As the scar ages, fibers and fiber bundles become more closely packed and form a crisscross pattern, ultimately creating the final shape of the wound. At best, the tensile strength of scar tissue is never more than about 80% of the tensile strength of nonwounded tissue.

FACTORS AFFECTING WOUND HEALING

Patients should be assessed for factors that may impair wound healing. The patient's nutritional status, oxygenation level, and overall recuperative power are important factors in tissue repair and healing. The inflammatory response and oxygen tension both depend on microcirculation to deliver components to the wound. Decreased oxygen tension to the wound area inhibits fibroblast migration and collagen synthesis, resulting in decreased tensile strength of the wound. Nutritional status also has a profound effect on healing because of the need for an adequate supply of protein necessary for the growth of new tissues. Protein also is required for the regulation of the osmotic pressure of blood and other body fluids and the formation of prothrombin, enzymes, hormones, and antibodies. Other nutritional essentials are water; vitamins A, C, B_6, and B_{12}; iron; calcium; zinc; and adequate calories. It is also important to maintain body temperature (normothermia) in the OR as hypothermia contributes to vasoconstriction, which can adversely affect wound healing.

The most common cause of delayed wound healing in a surgical patient is surgical site infection (SSI). Box 8-1 lists types of SSIs and defines criteria for classification. There are many possible causes of SSIs, including patient susceptibility to and severity of illness, microbial contamination by the patient's microflora, and exogenous wound contamination from the OR environment and personnel. Adherence to strict

BOX 8-1

Criteria for Defining a Surgical Site Infection

SUPERFICIAL INCISIONAL SURGICAL SITE INFECTION

- Occurs within 30 days after the operation
- Involves only the skin and subcutaneous tissue of the incision *and* at least one of the following:
  1. Purulent drainage, with or without laboratory confirmation, from the superficial incision
  2. Organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision
  3. At least one of the following signs or symptoms of infection—pain or tenderness, localized swelling, redness, or heat—*and* superficial incision is deliberately opened by the surgeon, *unless* the incision is culture-negative
  4. Diagnosis of superficial incisional SSI by the surgeon or attending physician

DEEP INCISIONAL SURGICAL SITE INFECTION

- Infection occurs within 30 days of the operation if no implant is left in place or within 1 year if implant is in place, and the infection seems to be related to the operation, *and* infection involves deep soft tissues (e.g., fascial and muscle layers) of the incision *and* at least *one* of the following:
  1. Purulent drainage from the deep tissue, not from the organ/space component of the surgical site
  2. Deep incision spontaneously dehisces or is deliberately opened by a surgeon when the patient has at least one of the following signs or symptoms—fever (38° C [100.4° F]), localized pain, tenderness—unless site is culture-negative
  3. Abscess or other evidence of infection involving the deep incision is found on direct examination, during reoperation, or by histopathologic or radiologic examination
  4. Diagnosis of a deep incisional SSI by a surgeon or attending physician

ORGAN/SPACE SURGICAL SITE INFECTION (AREA CONTIGUOUS WITH ORGAN OR SPACE OF THE OPERATING SITE)

- Infection occurs within 30 days of the operation if no implant is left in place or within 1 year if implant is in place, the infection seems to be related to the operation, *and* infection involves any part of the anatomy (e.g., organs or spaces), other than the incision, that was opened or manipulated during an operation, *and* at least *one* of the following:
  1. Purulent drainage from a drain that is placed through a stab wound into the organ/space
  2. Organisms isolated from an aseptically obtained culture of fluid or tissue in the organ/space
  3. An abscess or other evidence of infection involving the organ/space that is found on direct examination, during reoperation, or by histopathologic or radiologic examination
  4. Diagnosis of an organ/space SSI by a surgeon or attending physician

Modified from Mangram AJ et al: *Special report: guidelines for prevention of surgical site infection,* 1999, National Centers for Infectious Diseases, Hospital Infections Programs, available at www.cdc.gov/ncidod/dhqp/pdf/guidelines/SSI.pdf. Accessed February 9, 2009; *National Nosocomial Infections Surveillance System,* Centers for Disease Control and Prevention, available at www.cdc.gov/ncidod/dhqp/nnis_pubs.html. Accessed February 9, 2009.

aseptic principles, careful observation of sterile technique, and thorough antimicrobial preparation of the patient and operative site are essential to minimize the risk of postoperative SSI. Perioperative personnel who are not scrubbed at the sterile field must maintain meticulous hand hygiene during the procedure to decrease the transmission of bacteria to the surgical field or the patient (Patient Safety).

Wound healing also can be impaired by poor surgical technique. Rough handling of tissue may cause trauma that can lead to bleeding and other conditions conducive to infection. Examples of surgical technique promoting wound healing include adequate hemostasis, precise cutting and suturing techniques, efficient use of time to minimize wound exposure to air, elimination of dead spaces, and minimal pressure from retractors and other instruments.

Additional factors affecting wound healing are the patient's age, stress level, immunologic status, and smoking history. Preexisting conditions, such as diabetes, anemia, malnutrition, cancer, obesity, certain drug therapies (e.g., steroid therapy), and cardiovascular or respiratory impairments, also contribute to poor wound healing. Additional terms used in connection with wound healing are shown in Box 8-2.

BOX 8-2

Additional Terms Used in Connection with Wound Healing

The following are additional terms used in connection with wound healing:

Adhesions—Adherence of serous membranes to one another, causing fibrous tissue to form; sometimes occur in healing and inflammatory processes; commonly occurs in or around gastrointestinal tract, where adhesions may form bands and cause obstructions and subsequent surgical emergencies

Dead space—Air or empty space between layers of tissue or beneath wound edges that have been approximated

Dehiscence—Separation of layers of surgical wound (Figure 8-4)

Evisceration—Extrusion of internal organs or viscera through gaping wound (see Figure 8-4)

Gangrene—Anaerobic infection process that may occur instead of healing; implies necrosis (death of tissue) and putrefaction (decomposition); usually caused by failure of nutriment or blood to reach a part

Keloid—Dense, unsightly connective tissue or excessive scar formation that is often removed surgically

"Proud flesh"—A mass of excessive granulation formed when a wound shows no other sign of healing or excessive cicatrization

WOUND CLASSIFICATION

The Centers for Disease Control and Prevention (CDC) recommends four surgical wound classifications: clean wounds, clean contaminated wounds, contaminated wounds, and dirty or infected wounds (Mangram et al, 1999). This classification scheme reflects the probability of infection and enables appropriate preventive measures to be taken. The *AORN Recommended Practices for Documentation of Perioperative Nursing Care* note the importance of documenting the wound classification in the patient record (AORN, 2009). Following are descriptions of each classification.

Clean Wounds (Class I)

Clean wounds are uninfected operative wounds in which no inflammation is encountered, and the respiratory, alimentary, and genitourinary tracts are not entered. They are primarily closed and can be drained with a closed wound drainage

PATIENT SAFETY

Perioperative Handwashing

The Joint Commission has made patient safety a priority through annual National Patient Safety Goals (NPSGs). One NPSG is the goal of reducing the risk of healthcare-associated infections. One of the criteria for meeting this goal is for organizations to comply with the current Centers for Disease Control and Prevention (CDC) hand hygiene recommendations. The OR typically is considered a "sterile" environment, but perioperative nurses must be especially vigilant about complying with hand hygiene guidelines. Patients are vulnerable whenever the intact skin barrier is breached. Activities that are not properly conducted in a sterile fashion, such as application of surgical dressings to a fresh incision, provide an opportunity for the establishment of pathogens. Healthcare workers (HCWs) often have a false sense of security about the protection that gloves offer and may think that frequent hand hygiene is unnecessary. The use of gloves cannot replace routine, faithful adherence to effective hand hygiene. Other reasons cited for noncompliance with hand hygiene include the following:

- Too busy
- Dry skin caused by hand hygiene agents
- Forgetfulness
- Denial about risks
- Inadequate time/staff
- Lack of supplies for hand hygiene
- Patient is a higher priority than infections

Effective hand hygiene is the easiest, least expensive, and most effective tool that perioperative nurses have at their disposal when acting in the role of patient advocate. The goal of hand hygiene is a sufficient reduction of microbial counts on the skin to prevent cross-contamination of pathogens. Good hand hygiene practices also provide safety and protection to the HCW.

After extensive research, the CDC published guidelines for hand hygiene. The guidelines are ranked by category ratings, which provide direction to facilities for implementation.

Category I rankings (IA and IB) are applicable to all settings and should be adopted. Subcategories A and B differ only in the strength of supporting research and evidence. Category II rankings are supported by less research and evidence. They may be appropriate for addressing specific situations or patient populations. The Unresolved category offers no recommendation for some practices, either because little research is available to support the effectiveness or because there is no consensus regarding their efficacy. Perioperative nurses must exercise judgment in determining policies and practice interventions based on the Unresolved category.

RANKINGS

Indications for Handwashing and Hand Antisepsis

Category IA

- When hands are visibly dirty or contaminated with proteinaceous material or are visibly soiled with blood or other body fluids, wash hands with a nonantimicrobial soap and water or an antimicrobial soap and water.
- If hands are not visibly soiled, use an alcohol-based hand rub for routinely decontaminating hands in all other clinical situations. Alternately, wash hands with an antimicrobial soap and water.
- Decontaminate hands after contact with body fluids or excretions, mucous membranes, nonintact skin, and wound dressings if hands are not visibly soiled.

Category IB

- Decontaminate hands before having direct contact with patients.
- Decontaminate hands before donning sterile gloves when inserting a central intravascular catheter.
- Decontaminate hands before inserting indwelling urinary catheters, peripheral vascular catheters, or other invasive devices that do not require a surgical procedure.
- Decontaminate hands after contact with a patient's intact skin (e.g., when taking a pulse, measuring blood pressure, and lifting a patient).
- Decontaminate hands after removing gloves.
- Before eating and after using a restroom, wash hands with a nonantimicrobial soap and water or with an antimicrobial soap and water.
- Antimicrobial-impregnated wipes (i.e., towelettes) may be considered as an alternative to washing hands with nonantimicrobial soap and water. Because they are not as effective as alcohol-based hand rubs or washing hands with an antimicrobial soap and water for reducing bacterial counts on the hands of HCWs, wipes are not a substitute for using an alcohol-based hand rub or antimicrobial soap.

Category II

- Decontaminate hands if moving from a contaminated body site to a clean body site during patient care.
- Decontaminate hands after contact with inanimate objects (including medical equipment) in the immediate vicinity of the patient.
- Wash hands with nonantimicrobial soap and water or with antimicrobial soap and water if exposure to *Bacillus anthracis* is suspected or proven. The physical action of washing and rinsing hands under such circumstances is recommended because alcohols, chlorhexidine, iodophors, and other antiseptic agents have poor activity against spores.

Unresolved Issue

- No recommendations can be made regarding the routine use of non–alcohol-based hand rubs for hand hygiene in healthcare settings.

Hand Hygiene Techniques

Category IB

- When decontaminating hands with an alcohol-based hand rub, apply product to palm of one hand, and rub hands together, covering all surfaces of hands and fingers until hands are dry. Follow the manufacturer's recommendations regarding the volume of products to use.
- When washing hands with soap and water, wet hands first with water, apply an amount of product recommended by the manufacturer to hands, and rub hands together vigorously for at least 15 seconds, covering all surfaces of the hands and fingers. Rinse hands with water, and dry thoroughly with a disposable towel. Use towel to turn off faucet. Avoid using hot water because repeated exposure to hot water may increase the risk of dermatitis.

Category II

- Liquid, bar, leaflet, or powdered forms of plain soap are acceptable when washing hands with a nonantimicrobial soap and water. When bar soap is used, soap racks that facilitate drainage and small bars of soap should be used.
- Multiple-use cloth towels of the hanging or roll type are not recommended for use in the healthcare setting.

Continued

PATIENT SAFETY

Perioperative Handwashing—cont'd

Surgical Hand Antisepsis

Category IB

- Surgical hand antisepsis using an antimicrobial soap or an alcohol-based hand rub with persistent activity is recommended before donning sterile gloves when performing surgical procedures.
- When performing surgical hand antisepsis using an antimicrobial soap, scrub hands and forearms for the length of time recommended by the manufacturer, usually 2 to 6 minutes. Long scrub times (e.g., 10 minutes) are unnecessary.
- When using an alcohol-based surgical hand-scrub product with persistent activity, follow the manufacturer's instructions. Before applying the alcohol solution, prewash hands and forearms with a nonantimicrobial soap, and dry hands and forearms completely. After application of the alcohol-based product as recommended, allow hands and forearms to dry thoroughly before donning sterile gloves.

Category II

- Remove rings, watches, and bracelets before beginning the surgical hand scrub.
- Remove debris from underneath fingernails using a nail cleaner under running water.

Selection of Hand Hygiene Agents

Category IA

- Do not add soap to a partially empty soap dispenser. This practice of "topping off" dispensers can lead to bacterial contamination of soap.

Category IB

- Provide personnel with efficacious hand hygiene products that have low irritancy potential, particularly when these products are used multiple times per shift. This recommendation applies to products used for hand antisepsis before and after patient care in clinical areas and to products used for surgical hand antisepsis by surgical personnel.
- To maximize acceptance of hand hygiene products by HCWs, solicit input from these employees regarding the feel, fragrance, and skin tolerance of any products under consideration. The cost of hand hygiene products should not be the primary factor influencing product selection.

Category II

- When selecting nonantimicrobial soaps, antimicrobial soaps, or alcohol-based hand rubs, solicit information from manufacturers regarding any known interactions between products used to clean hands, skin care products, and the types of gloves used in the institution.
- Before making purchasing decisions, evaluate the dispenser systems of various product manufacturers or distributors to ensure that dispensers function adequately and deliver appropriate volume of product.

Skin Care

Category IA

- Provide HCWs with hand lotions or creams to minimize the occurrence of irritant contact dermatitis associated with hand antisepsis or handwashing.

Category IB

- Solicit information from manufacturers regarding any effects that hand lotions, creams, or alcohol-based hand antiseptics may have on the persistent effects of antimicrobial soaps being used in the institution.

Other Aspects of Hand Hygiene

Category IA

- Do not wear artificial fingernails or extenders when having direct contact with patients at high risk (e.g., patients in intensive care units or ORs).

Category IB

- Remove gloves after caring for a patient. Do not wear the same pair of gloves for the care of more than one patient, and do not wash gloves between uses with different patients.

Category IC

- Wear gloves when contact with blood or other potentially infectious materials, mucous membranes, and nonintact skin could occur.

Category II

- Change gloves during patient care if moving from a contaminated body site to a clean body site.

Unresolved Issue

- No recommendation can be made regarding wearing rings in healthcare settings.

Healthcare Worker Educational and Motivational Programs

Category IA

- Monitor HCWs' adherence to recommended hand hygiene practices, and provide personnel with information regarding their performance.

Category II

- As part of an overall program to improve hand hygiene practices of HCWs, educate personnel regarding the types of patient care activities that can result in hand contamination and the advantages and disadvantages of various methods used to clean their hands.
- Encourage patients and their families to remind HCWs to decontaminate their hands.

Administrative Measures

Category IA

- As part of a multidisciplinary program to improve hand hygiene adherence, provide HCWs with a readily accessible, alcohol-based hand rub product.
- To improve hand hygiene adherence among personnel who work in areas in which high workloads and high intensity of patient care are anticipated, make an alcohol-based hand rub available at the entrance to the patient's room or at the bedside, in other convenient locations, and in individual pocket-sized containers to be carried by HCWs.

Category IB

- Make improved hand hygiene adherence an institutional priority, and provide appropriate administrative support and financial resources.

Category IC

- Store supplies of alcohol-based hand rubs in cabinets or areas approved for flammable materials.

PATIENT SAFETY

Perioperative Handwashing—cont'd

Category	Supporting Research and Evidence
IA	Strongly recommended for implementation and supported by well-designed experimental, clinical, or epidemiologic studies
IB	Strongly recommended for implementation and supported by some experimental, clinical, or epidemiologic studies and strong theoretic rationale
IC	Required for implementation, as mandated by federal or state regulation or standard
II	Suggested for implementation and supported by suggestive clinical or epidemiologic studies or theoretic rationale
No recommendation; unresolved issue	Practices for which insufficient evidence or no consensus regarding efficacy exists

Modified from Centers for Disease Control and Prevention: Guideline for hand hygiene in health-care settings: recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force, *MMWR* 51(RR-16), 2002, available at www.cdc.gov/Handhygiene/. Accessed January 4, 2009.

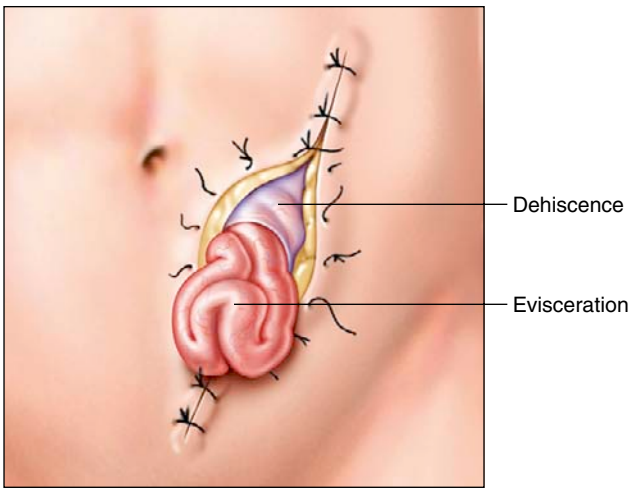


FIGURE 8-4 Complications of wound healing.

system. Clean wounds show no sign of infection. Examples are breast biopsy, total hip replacement, and open heart surgery.

Clean Contaminated Wounds (Class II)

Clean contaminated wounds are operative wounds in which the respiratory, alimentary, or genitourinary tract is entered under controlled conditions. There is no sign of infection and no break in surgical aseptic technique. Examples of clean contaminated wounds are nonperforated appendectomy, hysterectomy, and thoracotomy.

Contaminated Wounds (Class III)

Contaminated wounds are open, fresh, accidental wounds, such as penetrating trauma, open fractures, or operations with major breaks in aseptic technique. Incisions with signs of infection or gross spillage from the gastrointestinal tract also are included. Examples are a penetrating abdominal trauma involving bowel and a gunshot wound to the abdomen.

Dirty or Infected Wounds (Class IV)

Infected wounds include old, physically induced wounds with retained devitalized tissue and wounds that involve an existing clinical infection or perforated viscera. Examples are excision and drainage of abscess and delayed primary closure of a wound after appendectomy for ruptured appendix.

ANTIMICROBIAL PROPHYLAXIS

The most effective course of action in dealing with SSI is prevention. Appropriate antimicrobial prophylaxis (antibiotic administration) also is an important factor in the prevention of SSI (Evidence for Practice). Major considerations in administering prophylactic antimicrobial therapy include selecting the appropriate agent, properly timing the administration of the agent, and limiting the duration of therapy.

Proper selection of the prophylactic antimicrobial agent is based on clinical efficacy, safety, cost, and whether the agent is broad spectrum. The surgeon commonly considers the nature of the surgical procedure, noting the most common pathogens associated with it (e.g., common pathogens of the small bowel in undertaking a small-bowel resection). Cephalosporins often are used for elective clean or clean contaminated surgical procedures. For these procedures, a single dose usually is administered during the immediate preoperative period. It is important to carefully evaluate the need for antibiotics with the emergence of antibiotic-resistant microorganisms (see Chapter 3).

To enhance the effectiveness of prophylactic antimicrobial therapy, it is necessary for the optimal level of the antibiotic to be present in the tissue at the time of the incision. Equally important is the need to maintain circulating blood levels throughout some procedures. The antibiotic of choice should be administered within 1 hour before the skin incision. The anesthesia provider administers the antibiotic intravenously. If the surgical procedure is longer than the half-life of the antibiotic, another dose usually is administered intravenously during the procedure. Antibiotic therapy is usually discontinued within 24 hours; there is little evidence that ongoing administration contributes to decreased SSI rates in clean or clean contaminated procedures.

NURSING DIAGNOSES

The nursing diagnoses—Risk for Infection, Risk for Impaired Skin Integrity, Imbalanced Nutrition, Ineffective Tissue Perfusion, and Hypothermia—point the perioperative nurse toward strategies that can be used to prevent wound infections and promote healing.

EVIDENCE FOR PRACTICE

Antimicrobial Prophylaxis

A best practice based on evidence is important for improving patient outcomes. The long established practice of administering antimicrobials (i.e., antibiotics) prophylactically (antimicrobial prophylaxis [AMP]) in surgical patients is used to enhance the host defense by reducing any microbial burden that may result from surgical intervention. AMP should be viewed as an adjunct to other measures that nurses use to promote successful outcomes for their patients and can never substitute for strict adherence to aseptic technique. Optimizing AMP is a form of patient advocacy and can be maximized by understanding and implementing recommendations from the Centers for Disease Control and Prevention.

CENTERS FOR DISEASE CONTROL AND PREVENTION RECOMMENDATIONS FOR ANTIMICROBIAL PROPHYLAXIS

- Use an AMP agent for all operations or classes of operations in which its use has been shown to reduce surgical site infection (SSI) rates based on evidence from clinical trials (e.g., trauma, thoracic surgery, general surgery, head and neck procedures with incisions through the oropharyngeal mucosa, obstetrics and gynecological procedures) or for operations after which incisional or organ/space SSI would represent a catastrophe (e.g., when intravascular prosthetic materials or a prosthetic joint will be inserted, all cardiac operations including pacemaker insertion, limb revascularization).
- Use an AMP agent that is safe, inexpensive, and bactericidal with an in vitro spectrum that covers the most possible intraoperative contaminants for the operation.
- Time the infusion of the initial dose of antimicrobial agent within 1 hour before the surgery so that a bactericidal concentration of the drug is established in serum and tissues by the time the skin is incised.
- Maintain therapeutic levels of the antimicrobial agent in serum and tissues throughout the operation and until, at most, a few hours after the incision is closed in the OR. Because clotted blood is present in all surgical wounds, therapeutic serum levels of antimicrobial agents are logically important in addition to therapeutic tissue levels. Fibrin-enmeshed bacteria may be resistant to phagocytosis or to contact with antimicrobial agents that diffuse from the wound space.
- Do not use AMP for operations classified as contaminated or dirty. In such operations, patients frequently are receiving therapeutic antimicrobial agents perioperatively for established infections.

From Mangram AJ et al: *Special report: guidelines for prevention of surgical site infection,* 1999, National Centers for Infectious Diseases, Hospital Infections Programs, available at www.cdc.gov/ncidod/dhqp/pdf/guidelines/SSI.pdf. Accessed January 4, 2009.

The CMS and CDC provide SSI prevention guidelines for consideration in planning and implementing nursing interventions to optimize successful patient outcomes (Box 8-3). Attention also should be given to controlling perioperative serum glucose level in major cardiac procedures, to maintaining skin integrity through proper positioning and the use of pressure-reducing mattresses as needed (see Chapter 5), and to employing safe practices during electrosurgery (see Chapter 7). The perioperative nurse plays an essential role in the prevention of adverse events and patient injury by using intellectual and technical knowledge.

PATIENT AND FAMILY EDUCATION AND DISCHARGE PLANNING

Given that more patients are discharged from the acute care setting to the home care setting much earlier in their recovery, more surgical wound care is delivered by patients, their families, and home care providers instead of by the hospital nurse. Early planning and teaching about wound care, Standard Precautions, and medical waste disposal have become a vital part of preparing the patient to continue care after discharge (Patient and Family Education).

WOUND MANAGEMENT

A variety of treatments exist for acute and chronic wound management. Perioperative nurses often care for patients with infected wounds and are familiar with surgical wound debridement and sterile dressing changes performed under anesthesia. Patients also may come to the OR with chronic wounds being managed with a combination of surgical interventions and other treatment modalities. An understanding of adjunct wound therapies is essential to planning perioperative nursing care. These therapies include hyperbaric oxygenation (HBO), negative pressure therapy, hydrotherapy, use of engineered living skin substitutes, and the topical application of growth factors.

Debridement

Debridement is the act of removing dead and devitalized tissue from a wound. It is necessary because dead tissue in the wound provides a nidus for wound infection. Perioperative nurses often care for patients scheduled for surgical wound debridement (i.e., the sharp excision of dead or devitalized tissue). Debridement also can be accomplished through mechanical means (forceful irrigation, wet-to-dry dressings), enzymatic action (application of debriding agents containing papain and collagenase), and biologic methods (sterile maggot debridement therapy) (Ramundo, 2007). There are advantages and disadvantages to each method. Surgical debridement may not always be precise and healthy tissue may be sacrificed. Additionally, the act of surgical debridement may shower organisms into the bloodstream resulting in bacteremia. Mechanical debridement is painful and nonselective in the tissue it removes. Enzymatic debridement may be uncomfortable for the patient and may macerate surrounding tissue. Biologic debridement may not be accepted by most patients. Patients with chronic, nonhealing wounds may become well-known to the perioperative staff as they are scheduled for procedures such as debridement, grafting, flaps, and other wound coverage. Perioperative nurses play a key role in wound care and must be familiar with various wound care treatments in order to support patients throughout the course of their recovery.

Hyperbaric Oxygenation (HBO)

HBO has been used to enhance healing in problem wounds for many years. Although some form of HBO treatment for wounds has been used since 1662, the modern era of HBO use

PATIENT AND FAMILY EDUCATION

Wound Care and Dressing Changes

Although the surgeon may perform the initial dressing change after surgery, patients or their caregivers are often responsible for subsequent dressing changes and wound care. Patient compliance with wound care and dressing change techniques is important to prevent infection.

HOME CARE

Provide *written* and *verbal* instructions to the patient and the caregiver. Patients may be anxious about wound care. Provide reassurance and encouragement to the patient to bolster confidence in implementing this procedure at home. Assess the availability of dressing materials in the home setting and assist the patient with the appropriate referral if necessary to obtain the needed materials.

Warning Signs

Review the signs and symptoms that should be reported to a physician or a nurse:

- Redness, marked swelling (beyond ½ inch from the incision site), tenderness, increased warmth around the wound, or red streaks near the wound
- Temperature greater than 37.7° C (>100° F) or chills
- Purulent drainage or foul odor

Special Instructions

- Advise patients to ask the physician if bathing or showering is allowed.
- Review dressing change and wound care products with the patient and caregiver; explain the procedure and the frequency procedure should be performed.
- Emphasize the need to keep the wound dry and clean.
- Instruct patients not to remove casts and splints unless instructed to do so by the physician.
- Advise patients to assemble all supplies needed for the dressing change before starting. Explain how to maintain sterility of dressing supplies, and provide instruction on disposal of soiled dressings.
- Teach proper handwashing techniques, and instruct the patient to wash hands before changing the dressing.
- Instruct the patient to remove tape gently to avoid traumatizing the skin. Remove the old dressing and discard. Wash hands.
- Advise the patient to inspect the wound, and review the warning signs that should be reported to the physician.
- Describe how to clean the wound as ordered by the physician (i.e., with saline, povidone-iodine [Betadine], or alcohol, using cotton swabs, gauze, or other materials). Discuss how to clean around drain sites if applicable.
- Provide instruction on how to reapply the dressing, with emphasis on the order of materials used (i.e., nonadherent pad, gauze, any packing, top layer of dressing, and tape).
- Instruct the patient to wash hands after completing the dressing change.

Interventions to Reduce Swelling after Extremity Surgery

To avoid venous congestion and to enhance wound healing, advise patients recovering from extremity surgery to elevate the affected limb:

- Hand or arm
  - Sleep—elevate the arm on pillow at side
  - Sitting—place arm on pillow on adjacent table
  - Standing—rest affected hand on opposite shoulder; support elbow with unaffected hand
- Leg or foot
  - Sitting—place a pillow on the facing chair; provide support underneath the knee
  - Lying—place a pillow under affected leg

Wound Care after Suture/Staple Removal

- Remind patient that although the wound appears healed, it still may be tender and will continue to heal and strengthen for several weeks.
- Instruct the patient to keep the suture line clean; do not rub vigorously; pat dry after bathing or showering. Provide education about the appearance of the wound at this stage. Remind the patient that the wound edges still may be red and slightly raised.
- If allowed by the physician, advise the patient to massage around the wound gently using bland baby oil, petroleum, or moisturizing cream twice a day.
- Recommend that the patient report to the physician any swelling, redness, tenderness, or excessive scar thickening that persists beyond 8 weeks.

Modified from Canobbio MM: *Handbook of patient teaching,* ed 3, St Louis, 2006, Mosby.

in wound healing began in 1962 when it was used to treat gas gangrene (Frantz et al, 2007). HBO increases the capacity of blood to carry oxygen to the tissues. The increased oxygenation assists in cellular restoration, is directly bactericidal to anaerobes, and improves leukocyte migration and phagocytosis to the wound bed (Frantz et al, 2007). HBO therapy is administered in a pressurized chamber with the patient breathing 100% oxygen. Chambers may be monoplace to accommodate a single patient or multiplace to allow simultaneous treatment of multiple patients. Patients who undergo HBO therapy may require the insertion of myringotomy tubes to manage pressure changes while in the chamber. Perioperative nurses may be involved in the placement of the tubes and may be involved in wound debridement procedures for these patients.

BOX 8-3

Guidelines for Prevention of Surgical Site Infections

SSIs account for 14% to 16% of all hospital-acquired infections. An understanding of the Centers for Disease Control and Prevention guideline ranking system enables nurses to weigh factors that are viewed as effective in preventing SSIs. Category I rankings (including IA and IB) are applicable to all settings and should be adopted. Subcategories A and B differ only in the strength of supporting research and evidence. Category II rankings are supported by less research and evidence. They may be appropriate for addressing specific situations or patient populations. The Unresolved category offers no recommendation for some practices, either because little research is available to support their effectiveness or because there is no consensus regarding their efficacy. That category is not addressed here.

RANKINGS

Category	Supporting Research and Evidence
IA	Strongly recommended for implementation and supported by well-designed experimental, clinical, or epidemiologic studies
IB	Strongly recommended for implementation and supported by some experimental, clinical, or epidemiologic studies and strong theoretic rationale
II	Suggested for implementation and supported by suggestive clinical or epidemiologic studies or theoretic rationale

RECOMMENDATIONS

Preoperative—partial and modified

PREPARATION OF THE PATIENT

Category IA

- When possible, identify and treat infections remote to the surgical site before elective operation; postpone surgery until resolved. Do not remove hair from operative site unless necessary to facilitate surgery. If hair is removed, do immediately before surgery, preferably with electric clippers.

Category IB

- Adequately control serum blood glucose in diabetics and particularly avoid hyperglycemia perioperatively.
- Encourage cessation of tobacco use (cigarettes, cigars, pipes, chewing/dipping) 30 days before surgery.
- Do not withhold necessary blood products from surgical patients to prevent SSIs.
- Require patients to shower or bathe the night before operative procedure.
- Wash incision site to remove gross contamination before performing antiseptic skin preparation.

Category II

- Prepare skin in concentric circles from incision site.
- Keep preoperative stay in hospital as short as possible.

SURGICAL TEAM MEMBERS

Category 1B

- Keep nails short and do not wear artificial nails.
- Perform a preoperative surgical scrub/surgical hand antisepsis (hands and forearms up to the elbows) for at least 2 to 5 minutes using an appropriate antiseptic. After performing the surgical scrub/surgical hand antisepsis, keep the hands up and away from the body. Dry hands with a sterile towel, and don a sterile gown and gloves.
- Educate and encourage surgical personnel who have signs and symptoms of transmissible infections to report conditions promptly to supervisory personnel.
- Develop well-defined policies concerning patient care responsibilities when personnel have potentially transmissible infectious conditions.
- Do not routinely exclude surgical personnel who are colonized with organisms such as *S. aureus* or group A streptococcus, unless such personnel have been linked epidemiologically to dissemination of the organism in the healthcare setting.

Category II

- Clean underneath each fingernail before performing the first surgical scrub of the day.
- Do not wear hand or arm jewelry.

POSTOPERATIVE INCISION CARE

Category IB

- Protect with a sterile dressing for 24 to 48 hours postoperatively incisions that have been closed primarily.
- Wash hands before and after dressing changes and any contact with the surgical site.

Category II

- When an incision dressing must be changed, use sterile technique.
- Educate the family regarding proper incision care, symptoms of SSI, and the need to report such symptoms.

Modified from Mangram AJ et al: *Special report: guidelines for prevention of surgical site infection,* 1999, National Centers for Infectious Diseases, Hospital Infections Programs, available at www.cdc.gov/ncidod/dhqp/pdf/guidelines/SSI.pdf. Accessed February 9, 2009.

Negative Pressure Wound Therapy

Also known as vacuum-assisted closure (VAC), negative pressure wound therapy (NPWT) is used for difficult-to-manage wounds that do not respond to traditional wound care methods. This treatment may be associated with health cost savings (Research Highlight, p. 261). Negative pressure wound therapy works by using a device to apply constant controlled negative pressure to a wound that is filled with a drainage sponge and sealed with an occlusive dressing. The VAC system has three main mechanisms of action that promote wound healing. First, negative pressure results in mechanical tension on the tissues, causing the development of new blood vessels, mitosis, and dilation of the arterioles; at the same time, pressure produces a centripetal force that helps to pull the wound edges together. Second, VAC therapy promotes evacuation of excess wound fluid, such as the interstitial fluid that accumulates in a wound and prevents the circulatory and lymph systems from delivering nutrients and oxygen. Third, negative pressure reduces bacterial colonization in the wound bed. Stagnant exudates are eliminated, stunting bacterial growth and proliferation (Thompson and Marks, 2007). VAC therapy may be used for acute and traumatic wounds, subacute wounds, pressure ulcers, chronic open wounds, meshed skin grafts, and skin flaps. The therapy is

RESEARCH HIGHLIGHT

Vacuum-Assisted Wound Care and Economics

The cost of managing chronic wounds, particularly wounds resulting from complications related to diabetes, is staggering and remains a challenge for practitioners as they try to balance the patient's needs with available resources and hospital utilization. This randomized study compared wound treatment using either negative pressure wound therapy or moist wound therapy to determine the direct economic costs and resource utilization for patients with diabetic foot wounds.

Patients with partial foot amputation wounds up to the transmetatarsal level were enrolled into this 16-week, multicenter randomized clinical trial. A total of 162 patients participated in the study; 77 were randomized to the group receiving negative pressure wound therapy using a vacuum-assisted closure device and 85 patients received moist wound therapy using alginates, hydrocolloids, foams, or hydrogels. Each group received no less than three dressing changes a week. The wounds were treated until healed or until completion of the study period (112 days).

The researchers calculated resource utilization and direct costs using data from patient records and Milliman's Health Cost Guidelines. Costs included inpatient care, antimicrobial agents, outpatient visits, surgical procedures, and dressing supplies. The average cost of total direct care per patient treated for 8 weeks or longer was $27,270 in the negative pressure wound therapy group and $36,096 in the moist wound therapy group.

The study substantiated the hypothesis that the treatment of complex diabetic foot wounds is a major factor contributing to healthcare costs. Negative pressure wound therapy appears to be a comparatively cost-effective means of managing diabetic foot wounds.

Modified from Apelqvist J et al: Resource utilization and economic costs of care based on a randomized trial of vacuum assisted closure therapy in the treatment of diabetic foot wounds, *Am J Surg* 195:782-788, 2008.

FIGURE 8-5 The VAC pump.

contraindicated if blood vessels, nerves, bones, or organs are exposed and in the presence of necrotic tissue with eschar, a malignancy in the wound edges, untreated osteomyelitis, peripheral vascular disease, or fistulas to organs or body cavities (Bonham, 2009).

The negative pressure unit may be applied in the OR after wound debridement. All nonviable tissue must first be removed to reduce bacterial load in the wound bed. The skin area around the wound is dried and specialized reticulated foam is cut to fit the wound bed, including all tunnels and tracks. The surgeon must be careful not to overfill the wound with the sponge because this could cause further mechanical trauma. When the sponge is in place, the surgeon covers the entire sponge, wound bed, and surrounding skin with a transparent occlusive drape, taking care to seal the edges completely. A 2-cm or greater edge of intact periwound skin must be available to ensure an airtight seal of the dressing. A 2-cm cut is made through the occlusive dressing into the sponge for insertion of the drainage tube, which has side and end ports. The tubing is connected to a VAC pump (Figure 8-5). A portable, battery-operated unit also is available for more ambulatory patients. A canister collects the fluid and exudate. The pump cycle may be used on a continuous or intermittent setting. For best results, the patient must use the unit at least 22 hours a day (Thompson and Marks, 2007).

Hydrotherapy and Hydrosurgery

Traditionally hydrotherapy is undertaken via immersion in a whirlpool tank or tub. The mechanism of agitated water and injected air is thought to dilute bacterial loads and remove debris, while increasing circulation to the area. Because immersion in a tank is not practical from an intraoperative perspective, the hydrotherapy method most frequently used in the OR is pulsatile lavage. Manufacturers provide a variety of systems to deliver pulsatile lavage. Most systems consist of a motor that creates pressure within a tubing set to allow the delivery of fluid at 10 to 15 psi through a handpiece to the wound bed. The handpiece is equipped with a splash shield to help concentrate the spray and minimize droplet aerosolization of the irrigant. While the system is delivering the fluid, it simultaneously suctions it to remove debris and bacteria. Standard Precautions must be observed by all healthcare team members while using pulsatile lavage and the patient should be protected from aerosolization.

Hydrosurgery is a form of wound debridement that utilizes a powered handpiece system with narrow nozzle through which pressurized saline (up to 15,000 pounds psi) is used to excise necrotic tissue. The highly pressurized force creates a suction effect that allows the surgeon to remove devitalized tissue through the handpiece while preserving the healthy tissue (Knox et al, 2007; Stojadinovic et al, 2008) (Research Highlight, p. 262).

Skin Substitutes

A more recent technology for the treatment of wounds is the use of an engineered skin substitute. The skin substitute stimulates wound epithelialization and is capable of producing growth factors. The skin substitute may be used in lieu of a split-thickness skin graft for wound coverage. Skin substitutes are not permanent solutions in most cases, but are a bridge to permanent closure with skin grafts or granulation tissue. Skin substitutes are formed by placing human cells

RESEARCH HIGHLIGHT

Hydrosurgical Wound Debridement

Surgeons use many techniques to manage wounds and to prepare wound beds for healing or closure, including the use of pressurized fluid delivered via a bulb syringe or pulsed lavage. These hydrosurgery methods have limitations in terms of effectiveness of tissue removal and increased exposure of the patient and surgical team to droplet aerosolization or splashing from irrigant use. Newer hydrosurgery technology allows surgeons to remove devitalized tissue via the Versajet™, a commercially available system that pressurizes an irrigant via a disposable handpiece. As the irrigant is forced through the handpiece, a localized vacuum is created and the dissected tissue is suctioned.

Surgeons used the Versajet hydrosurgery system to prepare wound beds in 16 patients ages 35 to 80 years with a variety of wounds (e.g., necrotic, burns, traumatic, diabetic). The authors reported that the system was more selective in tissue removal and allowed them to perform a single wound debridement in many cases instead of multiple debridement sessions using traditional sharp dissection. Although a comparative analysis was not conducted, the authors stated anecdotally that the speed of the system over traditional methods saved operating time, and they estimated the time per debridement procedure was approximately 15 minutes. Other advantages included decreased bleeding (which decreased the need for electrocoagulation and thermal tissue damage), improved wound visibility, decreased tissue edema, removal of tissue in layers, and subjective patient reports of decreased pain. Formalized studies remain necessary to substantiate the authors' findings.

Modified from Pascone M et al: Use of a novel hydrosurgery device in surgical debridement of difficult-to-heal wounds, *Wounds* 20(5):139-146, 2008.

onto matrices that are collagen or synthetic based. As the cells grow and divide, they secrete growth factors and other useful substances to help build a foundation for healing. The substitutes are formed into a variety of shapes and sizes to facilitate wound coverage. They also may be used to cover donor sites from skin graft harvesting. Table 8-1 summarizes the actions and uses for some commonly available commercial skin substitutes. Advantages to using skin substitutes include ready commercial availability, effective wound contracture management, decreased risk of donor area morbidity, provision of long-term coverage of the wound, and compatibility with autologous tissues (Evans, 2007).

Growth Factors

Growth factors are naturally occurring proteins (cytokines and peptides) that are signaling molecules that stimulate cycles of mitosis of fibroblasts and epidermal cells, smooth muscle cells, and vascular endothelial cells. Human or recombinant growth factors may be applied to wounds in the OR, but are more typically administered in the clinic setting. Growth factors initiate wound healing by accelerating the formation of granulation tissue and work most effectively in the proliferative phase of wound healing. They improve the cellular or molecular environment of the wound and signal target cells to begin tissue repair. Growth factors generally are categorized by their source (i.e., if obtained from platelets, they are designated as platelet-derived growth factors [PDGFs]; from the epidermis, epidermal growth factor [EGF]). To obtain PDGFs, typically 50 to 200 ml of venous blood is withdrawn. The platelets are separated and activated with thrombin to make a gel that is applied to a clean wound bed. The wound is covered with a nonadherent gauze dressing that remains in place for 12 hours (Panuncialman and Falanga, 2007).

TABLE 8-1

Skin Substitutes

Name	Description	Use/Application
Biobrane	Porcine collagen-coated nylon mesh is bonded to a silicone rubber membrane.	Donor sites and partial-thickness wounds
Dermagraft	Single layer; contains cultured fibroblasts on cultured synthetic matrix. Provides cells and growth factors to wound.	Approved only for use in diabetic foot ulcers
TransCyte	Two-layer product. Outside layer is semipermeable and synthetic, allowing fluid and gas exchange and promoting a moist healing environment. Inner layer is a bioengineered cell matrix that adheres quickly to wound surfaces.	Superficial to mid–partial-thickness burns, temporary coverage of excised burns
Apligraf	Living, two-layer product. Inside layer combines bovine type I collagen with human fibroblasts to produce matrix proteins. Outside layer stimulates epidermal cells to replicate.	Widely used for wounds of ankle and foot; also used to treat donor sites and surgical excisional wounds
AlloDerm	Cadaver-donated product is processed to remove all epidermal and dermal cells while leaving cellular matrix intact.	Can be used on large areas; comes in large sheets
Oasis	Made from porcine small intestinal submucosa. Consists of naturally occurring growth factors and collagen.	Superficial burns, donor sites
Integra	Two-layer dressing consisting of dermal layer and epidermal layer. Inner, dermal layer is composed of bovine tendon collagen and synthetic chondroitin 6-sulfate. As healing progresses, inner layer degrades. Outer layer is a synthetic material (silicone) that serves to control moisture loss from the wound.	Useful in burn coverage

Modified from www.burnsurgery.org. Accessed January 4, 2009; Tenenhaus M, Rennekampff HO: Burn surgery, *Clin Plast Surg* 34(4):697-715, 2007.

DRESSINGS

Application of surgical dressings is often the responsibility of the perioperative nurse (History box). The dressing may serve one or more of the following purposes:

- Cushioning and protection of the wound from trauma and gross contamination
- Absorption of drainage
- Debridement of the wound
- Support, splinting, or immobilization of the body part and incisional area
- Assistance in hemostasis and minimization of edema and dead space, as in a pressure dressing
- Promotion of the patient's physical comfort and aesthetic appearance
- Maintenance of a moist environment and prevention of cell dehydration
- Application of medications

Dressings are selected based on the characteristics of the surgical site, depth, and area, and the patient's overall condition (Table 8-2). Questions to ask when choosing a dressing are as follows:

- What does the wound need?
- What is the purpose of the product?
- How well does the product function?
- What does the patient need?
- What is available?
- What is practical?

Dressings can be grouped into two main categories: primary and secondary dressings. *Primary* dressings are placed directly over or in the wound. A variety of primary dressing materials are available on the market today. The function of these dressings is to absorb drainage and then wick it away from the wound edge. Cotton gauze or synthetic dressings may be used for this purpose. The layer of primary dressing directly contacting the wound should be nonadherent, unless debridement is desired.

Secondary dressings are placed directly over the primary dressing. These function to absorb excessive drainage, provide hemostasis by compression, and protect the wound from further trauma. These functions usually are accomplished with a bulky dressing, such as an abdominal pad. These pads have a cotton filling that provides extra absorbency.

Dressings may be secured with a variety of products, including tape, Elastoplast®, ACE bandages, or soft roll products. Tape is available with a variety of backing materials (cloth, paper, taffeta, plastic) and with regular or nonallergenic adhesive. The strength and elasticity required, patient allergies, the condition of the patient's skin, and anticipated frequency of dressing change determine which type is selected. When applying tape to the dressing, the perioperative nurse should apply pressure evenly from both sides of the tape and away from the direction of the incision. Applying tape with excessive pressure may result in stretching and trauma to the skin. The tape should cover the edges of the dressing and be placed at right angles to the direction of motion when applied over a joint. When frequent dressing changes are anticipated, Montgomery straps can be selected to secure the dressing (Figure 8-6). When compression of the wound for hemostasis or reduction of edema is desired, a polyurethane dressing, elastic tape, or elastic bandage may be used to secure the secondary dressing.

HISTORY

A Historical Look at Dressing Materials

One of the duties of the perioperative nurse in the early 1900s was to manufacture, sterilize, and maintain bandages and drains. Typical classifications of bandages were roller bandages, compound bandages (e.g., many-tailed bandages and slings), immobilizing bandages (e.g., gauze rolls impregnated with plaster, paraffin, or starch), and pressure bandages.

Roller bandages were made from muslin, crinoline, flannel fabric, or gauze. Pressure and occlusive bandages were made from India-rubber cloth. To make roller bandages from muslin, crinoline, or flannel, the nurse obtained 4 to 6 yards of uncut fabric and washed it first in a hot saline solution. When the fabric dried, it was cut to the desired width and rolled by hand or on a bandage-rolling machine operated by a foot treadle. An expedited method of making multiple roller bandages was to roll the entire length of fabric without cutting it into individual strips and place it into a carpenter's miter box, later cutting the desired width with a bread knife. Roller bandages were steam sterilized and wrapped in paraffin-coated paper. This paper was made by spreading paper over a flat surface, pouring wax on it, and ironing it evenly with a flat iron. Compound dressings (e.g., the scultetus binder) were cut and sewn by hand. The nurse made immobilizing bandages by manually applying plaster of paris to crinoline strips and placing the rolled bandage in an airtight metal container. India-rubber cloth and other rubber goods were maintained in drawers dusted with powdered sulfur. To prepare drains, the nurse obtained the desired length and diameter of tubing from the rubber goods drawer, scrubbed the drain in soap and water, rinsed the drain, and then boiled the drainage tube in a solution of 1% carbonate of soda for 1 hour. The drain was removed and sealed in a jar containing a solution of normal saline and carbolic acid. The solution in the jars was changed once a week. Any fenestrae or other modifications were made at the time of use. Cigarette drains were made by impregnating four 9-inch lengths of lamp wicking with antiseptics, such as iodoform powder, zinc oxide powder, carbolic crystals, resin, or castor oil, and enclosing the bundle in green silk or rubber tissue stitched in place.

To apply muslin bandages, the nurse saturated the bandage in warm water to enhance the patient's comfort and wound the bandage in a circular, figure-of-eight, or spiral fashion to cover the affected area. Muslin roller gauze was used to bandage all parts of the body. When the bandage was complete, the nurse secured it by sewing it closed, fastening it with safety pins, or knotting the tails. Removal of the bandage was accomplished by unrolling the muslin instead of cutting it, to facilitate disinfection and reuse.

Modified from Fowler FS: *The operating room and the patient,* ed 3, Philadelphia, 1913; Saunders, Witkowski JA, Parish LC: Occlusive therapy in historical perspective, *Int J Dermatol* 37:555-558, 1998.

Immobilization is accomplished with the addition of soft padding, elastic bandages, splints, and casting materials (splints and casts are discussed in greater detail in Chapter 19).

In some situations, the wound is not dressed at all. An undressed wound that heals by exposure to air has the following advantages: (1) allows for optimal observation of the incisional area, (2) aids bathing, (3) prevents possible adhesive-tape reactions, (4) increases comfort and maneuverability for many patients, and (5) seems to minimize adverse responses by the patient to the operation.

TABLE 8-2

Comparing Wound Dressings

Products*	Advantages	Disadvantages	Nursing Considerations
COTTON MESH GAUZE	Low cost, readily available	Woven forms may leave lint in wound	Can be used as wet-to-dry dressing for wound debridement and granulation
Woven and nonwoven	Wicks away moisture	May dry out	Frequent dressing changes may be needed if gauze dries out
	Can be used for mechanical debridement	Nonwoven not as effective as woven for debridement	May be used with saline and amorphous gels to keep moist
NONADHERENT DRESSING	Less traumatic for patient	Poor absorption of fluids	*Nonimpregnated* can be used as primary or secondary dressing
Nonimpregnated: Telfa		Impregnated form cannot be used as primary dressing	Useful for donor sites, skin grafts
Impregnated: Adaptic, Scarlet Red, Vaseline Gauze, Xeroform		Impregnated form may cause maceration if left on wound for prolonged period	
TRANSPARENT FILMS	Resistant to shearing and friction	Cannot absorb exudate, which may lead to maceration	May wrinkle on application
Bioclusive, Opsite, Tegaderm	Conform well to irregular surfaces Wound is easily monitored through film May be more cost-effective because of decreased frequency of dressing change	Exudate may leak through seal	Use with caution on fragile skin
HYDROCOLLOID	Insulates and cushions	May melt and leave residue in wound	Should not be used in presence of infection because of occlusive properties
Comfeel, Sorbex, DuoDerm, Tegasorb	Available in a variety of sizes and forms	May bunch or wrinkle at edges	Need 1- to 2-in. border of intact skin beyond wound to seal edge of dressing
	Useful on all stages of wounds	May not adhere well to irregular shapes or contours	Can be used as a primary or secondary dressing
	Adheres in presence of moisture	May be bulky	May react with wound proteins and develop an odor that can be mistaken for infection
HYDROGEL	Can be used to fill shallow wounds and cavities	Excessive application can lead to maceration	Should be applied to wound surface only
Carrasyn, Solosite Gel, Tegagel, Vigilon, Nu-gel, Curagel	Cooling, soothing action may decrease painMay be used to rehydrate wounds	May be difficult to keep in shallow wounds	Viscosity varies among products Compatible with a variety of medications, so can be used as a carrier for antibiotics
ALGINATES	Highly absorbent	May cause burning sensation for patient	Available in pastes, pads, ropes, powders, starches
Algiderm, Algosteril, Curasorb, SeaSorb, Kaltostat, Sorbsan	Useful for increased levels of exudates	Requires secondary dressing	Product swells, so apply lightly in cavities and undermined areas
	Moisture retentive	Easily dislodged by mechanical force	Saturate with saline for removal if dried
FOAM	Highly absorbent	Contraindicated for desiccated wounds	Dressing should be 2-3 cm larger than wound
Lyofoam, Curafoam, Allevyn, Flexzan, BioPatch, VigiFOAM	Helps contain exudates	Leakage may occur if not covered with waterproof protection	Use with packing in undermining, tunneling wounds

TABLE 8-2—cont'd

Comparing Wound Dressings

Products*	Advantages	Disadvantages	Nursing Considerations
FOAM, cont'd	Can be left in place for 7 days Comfort for patient		Available as pads, sheets, or rolls
SILICONE	Easy to apply, reusable	May adhere to itself	May be used to reduce pain when wound vacuum system is used
Cica Care Adhesive Silicone Gel Sheet, Mepiform, Oleeva	Variety of sizes, promotes scar reduction	Can be difficult to apply	Marketed to consumers as a way to reduce scar formation
COLLAGEN	May accelerate wound repair	May have unpleasant odor	Requires a secondary dressing
Fibracol Plus, Promogran Cellerate, Biostep, Catrix, ColActive, Collieva, Biopad	Effective in recalcitrant wounds		Available in gels, pastes, pads, powder Source is equine, bovine, porcine, or avian collagen
COMPOSITES	Thin, nonadherent attached adhesive	Not recommended for heavily draining wounds	May be used as primary or secondary dressing
Alldress, Primapore, OpSite Post-Op, DermaSIL			One-hand application in some cases Use with caution with fragile skin

*NOTE: The products included here are representative of what is available and are not meant to be inclusive.
Modified from Brett D: A review of collagen and collagen-based wound dressings, *Wounds* 20(12), 2008, available at www.medscape.com/viewarticle/586468. Accessed February 13, 2009; Morin RJ, Tomaselli NL: Interactive dressings and topical agents, *Clin Plast Surg* 34(4):643-658, 2007; Rolstad BS, Ovington LG: Principles of wound management. In Bryant RA, Nix DP, editors: *Acute and chronic wounds: current management concepts,* ed 3, St Louis, 2007, Mosby.

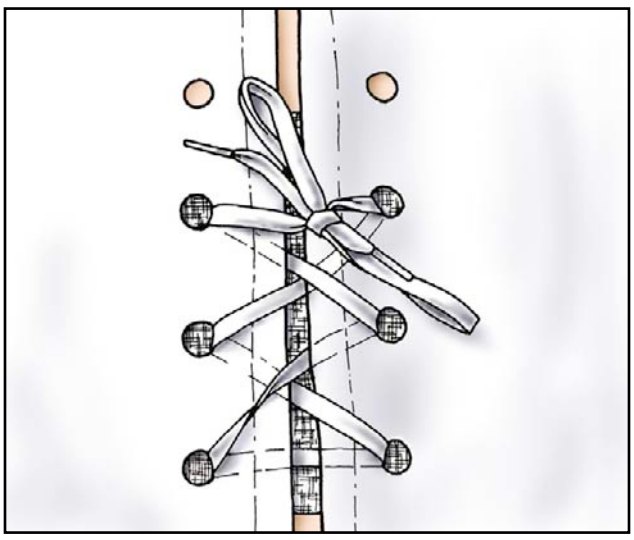


FIGURE 8-6 Montgomery straps.

DRAINS

Drains control ecchymosis and provide exits through which air and fluids, such as serum, blood, lymph, intestinal secretions, bile, and pus, can be evacuated from the operative site. Drains also may be used to prevent the development of deep wound infections. They usually are inserted at the time of surgery, primarily through a separate small incision known as a *stab wound,* close to the operative site. Drains may or may not be sutured to the skin.

In some instances (e.g., chest, common bile duct, bladder), drainage is directly through the lumen of the tube (as with a Foley retention catheter) or via perforations or fenestrations in the tubing into a closed drainage system. In other instances (e.g., peritoneal cavity or skin wound), drainage of pus or blood is primarily along the outside surface of the drain by capillary action and gravity (as with the simple Penrose drain) into a dressing. The selection of a simple versus a closed drainage system depends on the needs of the site to be drained, patient activity, and overall healing capability. Many types of drains are available. The most common are made of latex, polyvinyl chloride (PVC), or silicone (Figure 8-7). Particular care should be taken to ensure that the patient is not allergic to latex when considering any latex drain. For many wounds, a portable, self-contained, closed wound suction unit is selected. These units create a negative pressure in a reservoir attached to the drain. Fluid is gently drawn out of the wound and collected in the reservoir.

The perioperative nurse must document clearly on the operative record the location and type of drain and ensure the drain is working properly before the patient leaves the OR. This information is important to nurses caring for the patient in the postanesthesia and postoperative nursing units. Some wounds yield significant drainage and must be monitored closely during the postoperative course. A disadvantage of wound drains is that they create a portal for entry and exit of infectious microorganisms. Extreme care must be taken in emptying drain reservoirs to avoid contamination. Closed autologous drains allow for collection of blood from a surgical wound and the return of that blood to the patient; this minimizes the need for transfusion of blood from outside donors, reducing the risk of bloodborne pathogen transmission.

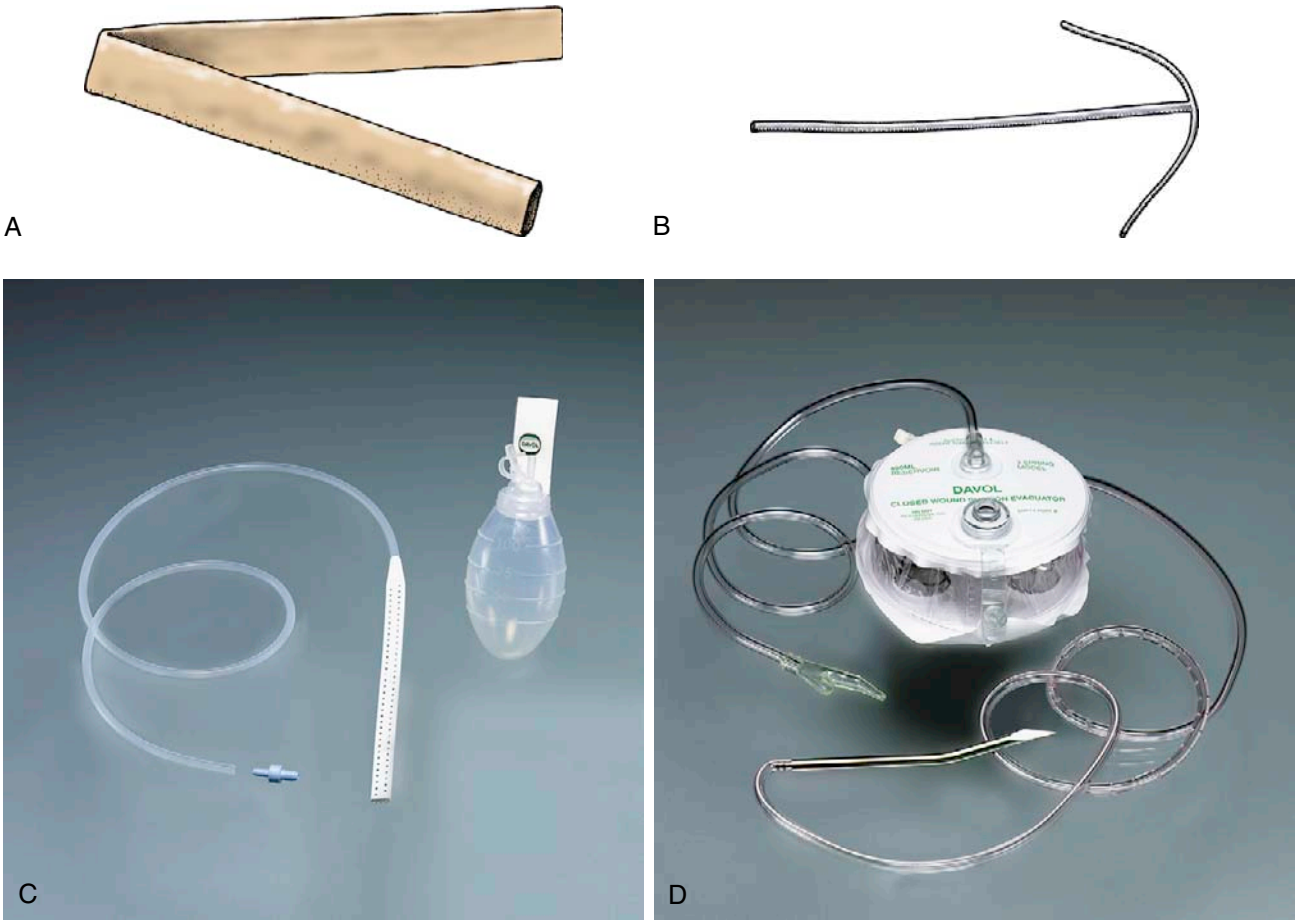


FIGURE 8-7 Drains are available in a variety of styles. Pictured are Penrose (**A**) and T-tube (**B**), which drain by gravity, and Jackson Pratt (**C**) and Hemovac (**D**), which represent closed drainage systems.

REFERENCES

Association of periOperative Registered Nurses (AORN): *Perioperative standards and recommended practices*. Denver, 2009, The Association.

Barnett TE: The not-so-hidden costs of surgical site infections, *AORN J* 86:249–257, 2007.

Beaver, M: CMS reimbursement changes put spotlight on prevention of catheter-related infections, Infection Control Today, 2008, available at www.infectioncontroltoday.com/articles/CMS-Regulations-Catheter-Infections.html. Accessed January 12, 2009.

Bonham PA: Negative pressure wound therapy, *Advance for Nurses* 11(4):17–19, 2009.

Ethridge EJ et al: Wound healing. In Townsend CM et al, editors: *Sabiston textbook of surgery*, ed 18, Philadelphia, 2008, Saunders.

Evans J: Massive tissue loss: burns. In Bryant RA, Nix DP, editors: *Acute and chronic wounds: current management concepts*, ed 3, St Louis, 2007, Mosby.

Frantz RA et al: Devices and technology in wound care, In Bryant RA, Nix DP, editors: *Acute and chronic wounds: current management concepts*, ed 3, St Louis, 2007, Mosby.

Knox KR et al: Surgical wound bed preparation of chronic and acute wounds, *Clin Plast Surg* 34:633–641, 2007.

Mangram AJ et al: Special report: guidelines for prevention of surgical site infection, 1999, National Centers for Infectious Diseases, Hospital Infections Programs, available at: www.cdc.gov/ncidod/dhqp/Pdf/guidelines/ssi.Pdf. Accessed January 3, 2009.

Panuncialman J, Falanga V: The science of wound bed preparation, *Clin Plast Surg* 34:621–632, 2007.

Ramundo J: Wound debridement. In Bryant RA, Nix DP, editors: *Acute and chronic wounds: current management concepts*, ed 3, St Louis, 2007, Mosby.

Stojadinovic A et al: Topical advances in wound care, *Gynecol Oncol* 111:S70–S80, 2008.

Thompson JT, Marks MW: Negative pressure wound therapy, *Clin Plast Surg* 34:673–684, 2007.

CHAPTER 9

Postoperative Patient Care and Pain Management

JAN ODOM-FORREN

The postoperative phase of care begins as soon as the surgical procedure concludes and the patient is transferred to the postanesthesia care unit (PACU). The PACU, in the past, was called the *recovery room* or *postanesthesia room*. In 1863 Florence Nightingale first described a postanesthesia area this way: "It is not uncommon, in small country hospitals, to have a recess or small room leading from the operating theater in which the patients remain until they have recovered, or at least recovered from the immediate effects of the operation" (History box).

An assigned area for the care of the postoperative patient is a relatively recent addition to surgical patient care. Although surgical procedures have been performed for thousands of years, and general anesthesia has been available for almost 150 years, PACUs became common only in the past 30 to 40 years. A few recovery rooms were opened in the 1920s and 1930s. In the 1940s numerous PACUs opened because of the shortage of nurses during the war years and the need to centralize patients, equipment, and personnel for postoperative care. Hospitals soon realized that use of the PACU decreased patient morbidity and mortality and shortened the stays of some patients (Ruth et al, 1947). Many hospitals opened PACUs after this discovery was reported.

PACUs have since flourished. Technologic innovation has profoundly affected PACUs, as in other critical care areas. The complexity of anesthesia management demands specially trained nurses who have expertise in the prompt recognition and management of postoperative complications. Most patients who receive general anesthesia, major regional anesthesia, or monitored anesthesia care are transferred to the PACU. PACU is considered postanesthesia phase I—where the patient transitions to phase II (preparation for discharge home [Ambulatory Surgery Considerations]), an inpatient setting, or a critical care unit (ICU or CCU) (ASPAN, 2009a).

PACUs should be adjacent to the surgical suite with easy access for patient transport. The patient's status should be assessed for needs during transfer (e.g., oxygen, manual positive-pressure ventilation device, a bed instead of a stretcher).

A perioperative nurse accompanies the patient to the PACU with an anesthesia provider and gives a hand-off report on the status of the patient to a perianesthesia nurse. A PACU nurse assumes care of the patient after initial assessment of the patient and report from the transferring team.

PERIANESTHESIA CONSIDERATIONS

Assessment

Admission to the PACU. Initial assessment of the postoperative patient begins with an immediate determination of airway and circulatory adequacy. The airway is assessed for patency, humidified oxygen applied, and respirations counted. Pulse oximetry is initiated on all patients, and the quality of breath sounds determined. The PACU nurse connects the patient to the cardiac monitor, and evaluates rate and rhythm. Blood pressure is measured by means of a manual cuff or an automatic cuff (e.g., a Dinamap). If the patient has an arterial line, the PACU nurse connects it to the monitor.

After the PACU nurse assesses the *ABCs* (*a*irway, *b*reathing, *c*irculation), the perioperative nurse and anesthesia provider give a comprehensive hand-off report. The 2009 Joint Commission (TJC, 2009) *National Patient Safety Goals* (NPSGs) emphasize a standardized approach to hand-off communication that includes the opportunity to ask and respond to questions (Risk Reduction Strategies). Standardization of how information is communicated assures that the information will be accurate and complete. The perioperative nurse should collaborate, adding and verifying important patient information. Box 9-1 includes suggestions on what each surgical team member should report.

The American Society of PeriAnesthesia Nurses (ASPAN) (2009a) recommends that the hand-off report contain the following elements:

- Relevant preoperative information, such as vital signs and temperature; radiologic findings; laboratory values; oxygen saturation; allergies (including latex); medication use/last dose; NPO status; disabilities; substance abuse; mobility limitations; prostheses; sensory limitations (including hearing and visual aids); and, for pediatric patients, birth history, developmental stages, gestational age, and parent/child interactions
- Anesthesia technique and agents administered
- Length of time anesthesia was administered and time reversal agents were given
- Type of operative or other invasive procedures performed
- Estimated fluid or blood loss, and replacement therapy
- Complications occurring during anesthesia, treatment initiated, and patient responses
- Emotional status on arrival in the OR or procedure room
- Pain and comfort management interventions and plans

HISTORY

The Evolution of the PACU

Separate care for postsurgical patients can be dated to 1751, when New Castle Infirmary, in New Castle, England, reserved rooms for dangerously ill or major surgery patients. In 1863 Florence Nightingale suggested separate rooms for patients to recover from the immediate effects of anesthesia. During the twentieth century, the complexity of surgeries increased in direct relation to technical discoveries. The number of recovery units gradually grew, especially after their value became clear. The Anesthesia Study Commission of the Philadelphia County Medical Society reported in 1947 that one third of preventable postsurgical deaths during an 11-year period could have been prevented by improved postoperative nursing care. In 1949 the Operating Room Committee for New York Hospital noted that adequate recovery room service was necessary for any hospital that provided surgical services. By the 1970s "recovery rooms" were managing routine postanesthesia patients as well as critically ill postanesthesia patients receiving respiratory and circulatory support. Today, recovery rooms are known as *postanesthesia care units (PACUs)* and sometimes, because of space constraints and cost containment, PACU nurses also manage the care of overflow intensive care unit/telemetry patients or provide space for procedures such as pain management or insertion of central lines.

Modified from Odom-Forren J, Clifford T: The evolution of perianesthesia nursing. In Schick L, Windle P, editors: *Perianesthesia nursing core curriculum: preoperative, phase I and phase II PACU nursing,* St Louis, 2009, Saunders.

AMBULATORY SURGERY CONSIDERATIONS

Important Education Information for Patients Who Are Discharged from Phase II Recovery to Home

- Anesthesia
  - Advise patient of common side effects: dizziness and drowsiness, have assistance if needed; sore throat; post discharge nausea and vomiting.
  - For the next 24 hours the patient should not drive or operate machinery, drink alcohol, or sign important papers, and a responsible adult should stay with the patient.
- Activity limitations
  - Advise patient to go home and rest for next 24 hours. Inform patient of any limits to activity because of procedure (e.g., no sexual activity for 4 weeks, no lifting of objects that weigh more than 10 pounds).
- Diet
  - Instruct patient how to progress to regular diet, or give instructions to patient detailing specific diet required because of procedure.
- Safety concerns
  - Review preparation of home for patient return (e.g., removal of rugs that increase fall risk, sleeping area close to bathroom).
- Medications
  - Discuss new take-home medications or prescriptions. Document last dose of medication on patient's written instructions if given before discharge.
  - Discuss resumption of home medications. Physician should have noted which home medications the patient is to continue after discharge.
  - Instruct the patient to take the medication with food (unless contraindicated) to decrease stomach irritation.
  - Discuss the use of acetaminophen or ibuprofen if the patient has no pain medication ordered (unless contraindicated).
  - Advise patient not to take acetaminophen if taking pain medications that include acetaminophen as an ingredient.
- Surgical procedure
  - Discuss any information that pertains to specific procedure (e.g., when to remove dressing, when to resume showers or baths, ice at site, weight-bearing restrictions).
- Bowel habits
  - Increase dietary fiber and fluids.
  - Use stool softener if needed.
- When to call the healthcare provider
  - Fever greater than 101° F orally
  - Pain that becomes worse or is not relieved by pain medication
  - Bleeding that is unexpected
  - Warmth, redness, or swelling at the operative site
  - Evidence of pus
  - Unable to eat or drink by day after discharge
  - Persistent nausea and vomiting
  - Unable to void
- Follow-up care
  - Instruct patient about next appointment with physician or ascertain that appointment is already scheduled.
  - Give patient telephone number for physician's office.
  - If applicable, give patient telephone number of ambulatory surgery center.
- Home procedures
  - If patient requires procedures at home such as dressing change or emptying drainage reservoir, ascertain that responsible adult has received instructions and given a return demonstration of action.
- Written instructions
  - All discharge instructions should be in writing and given to the patient, including all the pertinent information included above, specific information about any new medication, and a list of home medications that physician requests be continued or discontinued.

The patient's American Society of Anesthesiologists (ASA) physical classification status (see Chapter 4) also should be provided during the hand-off report. Useful information that the perioperative nurse can also provide includes airway status and presence of tubes, drains, catheters, and intravascular lines. Any postoperative orders to be initiated in the PACU are discussed at this time.

The anesthesia provider should not leave the patient until the PACU nurse accepts responsibility for the patient's care. Standard III-3 of the ASA's *Standards for Postanesthesia Care*

RISK REDUCTION STRATEGIES

Patient Hand-Off

The *2009 National Patient Safety Goals (NPSGs)* from The Joint Commission (TJC) identify "Improve Communication" as Goal 2. The goal addresses specific ways of handling verbal or telephone orders including "reading back" the complete order or test result. Goal 2 also requires that each healthcare facility have in place a standardized list of abbreviations, acronyms, symbols, and dose designations that are not approved for use in the facility. Important to the PACU is that the organization implement a standardization approach to hand-off communications, including an opportunity to ask and respond to questions (TJC, 2009; Saufl, 2009). Ineffective communication is the most frequently cited root cause for sentinel events (TJC, 2009). Communication must be timely, accurate, complete, unambiguous, and understood by the recipient to be effective and reduce risk to the patient.

Any patient hand-off from the surgical team (anesthesia provider, surgeon, perioperative nurse) to the PACU nurse should include the following:

1. Interactive communication that allows the PACU nurse an opportunity to question the person giving the report.
2. Up-to-date information regarding the patient's condition, care, treatment, medications, services, and any recent or anticipated changes.
   a. Consider a policy that specifies information required in each report based on current standards and guidelines.
3. An opportunity for the PACU nurse to review relevant patient historical data, which may include previous care, treatment, and services.
   a. Anesthesia provider is not to leave the bedside until the PACU nurse accepts responsibility for the patient's care.
4. Interruptions during hand-offs are limited to minimize the possibility that information fails to be conveyed or is forgotten.
   a. Surgical team should not answer pagers, telephones, or otherwise cause interruption or distraction during the hand-off.
   b. The PACU nurse will limit interruptions or distractions during hand-off to emergencies.
   c. The PACU environment should be conducive and supportive of uninterrupted time during hand-off.
      (i) Consider adding a signal in the PACU to alert other nurses that a hand-off is in progress.

Adapted from The Joint Commission: *2009 National Patient Safety Goals Hospital Program,* available at www.jointcommission.org/patientsafety/nationalpatientsafetygoals/09_hap_npsgs. Accessed July 9, 2009; Saufl NM: 2009 National Patient Safety Goals, *J Perianesth Nurs* 24:114-118, 2009; Martin LB: Enhanced communication protects patients, *Breathline* 28(1):13, Jan/Feb 2008.

(ASA, 2004) states, "the member of the anesthesia care team shall remain in the PACU until the PACU nurse accepts responsibility for the nursing care of the patient."

Initial Assessment. After the immediate assessment of the ABCs and completion of the hand-off report, the PACU nurse begins a more thorough postanesthesia assessment. The assessment is performed quickly and is specific, in part, to the type of operative procedure. Recommended elements of an initial assessment in the PACU are presented in Box 9-2.

BOX 9-1

Suggestions on Content for Hand-Off Report from Anesthesia Provider and Perioperative Nurse

ANESTHESIA PROVIDER MAY REPORT:

- Patient name, allergies, surgical procedures performed
- Pertinent medical and/or surgical histories
- Current medications
- Anesthetic delivered
- Medications administered
- Regional anesthetic used
- Intraoperative course (anesthesia-related)
- Lines, fluids, losses; the anesthesia provider may include estimated blood loss (EBL) in the hand-off report to the PACU nurse. In some institutions, a surgical Apgar score is calculated at the end of the surgical procedure from the EBL, lowest mean arterial pressure (expressed in mm Hg), and lowest heart rate rhythm recorded on the anesthesia record during the procedure. The score may be used to identify patients with a higher likelihood of developing complications after surgery (Regenbogen et al, 2009).
- Pain management
- PACU orders
- Questions and answers

PERIOPERATIVE NURSE MAY REPORT:

- Identity of patient
- Preoperative diagnosis
- Procedure performed
- Location of incision(s), dressings, drains, catheters, tubes, packing, stomas
- Surgical complications
- Allergies and reactions
- Medications, fluids, irrigations delivered by surgeon or RN
- Positioning during surgery
- Communication of other pertinent issues:
  - Location/presence of family or others
  - Special requests verbalized by the patient preoperatively
  - Special devices
  - Patient deficits
- Questions and answers

Modified from Chard R: Care of postoperative patients. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* St Louis, 2010, Saunders; Sullivan EE: Handoff communication, *J Perianesth Nurs* 22:275-279, 2007; Drain CB, Odom-Forren J: *Perianesthesia nursing: a critical care approach,* St Louis, 2009, Saunders.

Some PACUs use a head-to-toe assessment to organize the data obtained (Figure 9-1). Other PACUs take a major body systems' approach (Figure 9-2). In any case, the PACU nurse assesses admitting vital signs and the ABCs, beginning with the respiratory system. Respiratory assessment comprises rate, rhythm, auscultation of breath sounds for ventilatory adequacy, and oxygen saturation level. Any artificial airway and type of oxygen delivery system are noted.

The PACU nurse next assesses the cardiovascular system by monitoring heart rate and rhythm. The patient's initial blood pressure is compared with one or more preoperative readings. Body temperature is obtained, skin condition examined, and peripheral pulses checked, if indicated. Next, the PACU nurse assesses neurologic function by asking questions such as the following: Has the patient reacted (awakened from anesthesia)? Can the patient follow commands? Is the patient oriented, at least to name and hospital? Can the patient move all extremities

BOX 9-2

Initial Assessment in the PACU

Initial assessment in the PACU includes documentation of the following:

1. Integration of data received at hand-off report for transfer of care
2. Vital signs
   a. Respiratory status—airway patent, breath sounds, type of artificial airway, mechanical ventilator settings, oxygen saturation, and $ETCO_2$ monitoring if indicated
   b. Blood pressure—cuff or arterial line
   c. Pulse—apical, peripheral
   d. Cardiac monitor, rhythm documented
   e. Temperature/route
   f. Hemodynamic pressure reading if indicated (central venous, arterial blood, pulmonary artery wedge, and intracranial pressure)
3. Pain/comfort assessment (including emotional comfort)
4. Neurologic function including level of consciousness
5. Position of patient
6. Condition and color of skin
7. Patient safety needs
8. Neurovascular—peripheral pulses and sensation of extremity or extremities as applicable
9. Condition of dressings or suture line, drains, tubes, receptacles
10. Amount and type of drainage
11. Muscular response and strength/mobility status
12. Pupillary response as indicated
13. Fluid therapy—location of lines, condition of intravenous site, and security and amount of solution infusing (including blood)
14. Postanesthesia scoring system if used
15. Procedure-specific assessment

Modified from American Society of PeriAnesthesia Nurses: *2008-2010 Standards of perianesthesia nursing practice,* Cherry Hill, NJ, 2009, The Society.

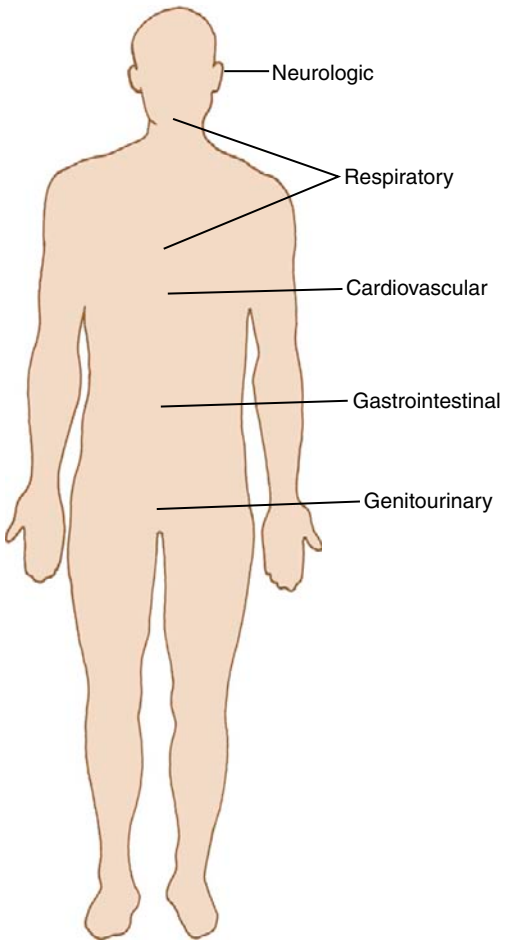


FIGURE 9-1 Head-to-toe assessment.

and lift the head? Are there deviations from preoperative neurologic functioning? Some operative procedures require a more detailed assessment.

To assess renal function, the PACU nurse measures intake and output. Total intraoperative fluid intake and estimated blood loss are reviewed. IV lines, infusions, and irrigation solutions are noted and recorded. Any drains or catheters are listed; their output is noted for color, amount, and consistency.

The surgical site is checked, noting any drainage on the bandage, including amount and color. The area around the incision is inspected so that any future changes may be compared. Patients undergoing vaginal hysterectomy require that the abdomen be assessed for firmness. A rigid abdomen may indicate hemorrhage. Comparing firmness of the abdomen on admission and later findings of a rigid abdomen can lead to important comparisons. The patient is also assessed for signs or symptoms of pain or discomfort and nausea, and medicated appropriately.

Information obtained from the admission assessment is documented in the PACU record (Figure 9-3).

Nursing Diagnosis

Common nursing diagnoses related to the care of postanesthesia patients include the following:

- Ineffective Breathing Pattern
- Decreased Cardiac Output
- Ineffective Thermoregulation
- Acute Pain

Outcome Identification

Outcomes identified for the selected nursing diagnoses can be stated as follows:

- The patient will demonstrate adequate ventilation, perfusion, and expansion of the lungs on discharge from the PACU.
- The patient will achieve and maintain adequate cardiac output on discharge from the PACU.
- The patient will attain a normal body temperature (96.8° to 100.4° F) (36° to 38° C) on discharge from the PACU.
- The patient will demonstrate appropriate cognitive function on discharge from the PACU.
- The patient will exhibit 4 or less on a numeric pain rating scale of 0 to 10 (or a pain/comfort level established by the patient as "acceptable") on discharge from the PACU.

Planning

When nursing diagnoses and desired outcomes are identified for the postoperative patient, a plan of care is designed that considers specific patient needs. Some nursing diagnoses are appropriate for all postanesthesia patients. A Sample Plan of Care for a postanesthesia patient follows on p. 271.

SAMPLE PLAN OF CARE

Immediate Postoperative Patient Care in the PACU

NURSING DIAGNOSIS

Ineffective Breathing Pattern related to medications associated with anesthesia, type of surgical procedure, pain, tracheobronchial obstruction

OUTCOME

The patient will maintain ventilation, perfusion, and adequate expansion of lungs on discharge from the PACU as evidenced by regular respiratory rate and pattern, bilateral breath sounds clear and equal, blood pressure and pulse within preoperative range, oxygen saturation at least 92% or equal to preoperative status, patent airway, and control of pain.

INTERVENTIONS

- Assess respiratory status on admission to the PACU and at intervals until discharge.
- Determine level of consciousness (to assess for need to reverse opioid, benzodiazepine, or muscle relaxant).
- Administer humidified oxygen; assess need for continued oxygen after discharge.
- Elevate head of bed (if not contraindicated).
- Encourage patient to take deep breaths or sustained maximal inspiration.
- Determine need for chin tilt or jaw thrust if patient is nonreactive without patent airway. Insert artificial airway if needed. Call anesthesia provider for further assistance.
- Assess patient for level of comfort. Administer pain medication as needed, per order or protocol.

NURSING DIAGNOSIS

Decreased Cardiac Output related to anesthetic agents and other medications, fluid or blood loss or replacement, peripheral pooling of blood, alteration in preload or afterload, alterations in rate or rhythm

OUTCOME

The patient will maintain adequate cardiac output on discharge from the PACU as evidenced by blood pressure within preoperative range, skin warm and dry, oriented to person and place, and pulse strong and regular.

INTERVENTIONS

- Monitor vital signs, electrocardiogram, and central venous pressure, with or without pulmonary artery catheter.
- Assess level of consciousness to determine effect of medication still in circulation.
- Monitor and record drainage from surgical site.
- Monitor and record intake and output.
- Administer fluid or blood products if indicated.
- If hypotensive, elevate legs unless contraindicated; increase rate of fluid administration.
- Maintain patency of intravenous lines.
- Administer medication if needed to improve depressed myocardial contractility, increase cardiac output, and promote diuresis.
- Administer vasodilators, vasoconstrictors, or antidysrhythmics as ordered.
- Warm patient to temperature 36° C (96.8° F).
- Administer humidified oxygen.

NURSING DIAGNOSIS

Ineffective Thermoregulation related to surgical procedure: anesthetic agents, length of surgery, age of patient, environment, irrigation, type of surgery, or genetic predisposition to malignant hyperthermia

OUTCOME

The patient will maintain normothermia, a core temperature of 36° to 38° C (96.8° to 100.4° F), on discharge from the PACU.

INTERVENTIONS

- Measure body temperature on admission; document temperature and route of measurement.
- Assess peripheral circulation.
- Monitor vital signs and oxygen saturation.
- Observe for shivering.
- Initiate measures to warm patient if hypothermic: place warmed blankets on patient's body and head; use forced-air warming device to rewarm patient.
- Initiate appropriate measures for malignant hyperthermia, if indicated (see Chapter 4).
- Maintain ongoing temperature monitoring until discharge.

NURSING DIAGNOSIS

Acute Pain related to operative or other invasive procedures

OUTCOME

The patient will exhibit a decreased level of pain or pain at a tolerable level on discharge from the PACU.

INTERVENTIONS

- Assess for subjective signs of pain: patient reports to the PACU nurse that he or she is in pain; patient is given a visual analogue or numeric scale to rate pain level.
- Assess for objective signs of pain: protective guarding behavior, moaning, crying, whimpering, restlessness, irritability, diaphoresis, dilated pupils, facial expression of pain, changes in vital signs (blood pressure, respiratory rate, or pulse).
- Refer to agency protocol for assessing and treating pain based on patient's pain rating.
- Monitor for pain relief and adverse reactions (respiratory depression, oversedation), and document.
- Administer pain medication as prescribed: titrate intravenous doses; initiate patient-controlled analgesia or continuous epidural analgesia (this may be patient-controlled epidural analgesia).
- If epidural analgesia is used, assess for numbness, leg weakness, pruritus, and respiratory depression. Document findings and notify physician if findings are positive.
- If patient is intubated but conscious, collaborate in pain rating scale by pointing to a number or face and having patient indicate *yes* or *no.* If patient is unconscious, be especially attentive to signs such as grimacing.
- Initiate alternate methods of pain relief: transcutaneous electrical nerve stimulation (TENS), music, massage, relaxation, guided imagery.
- Reposition patient for comfort if not contraindicated.
- Assess causes of pain (e.g., surgical site versus chest pain).
- Document medications administered, dose, route, time, and effectiveness of pain relief.

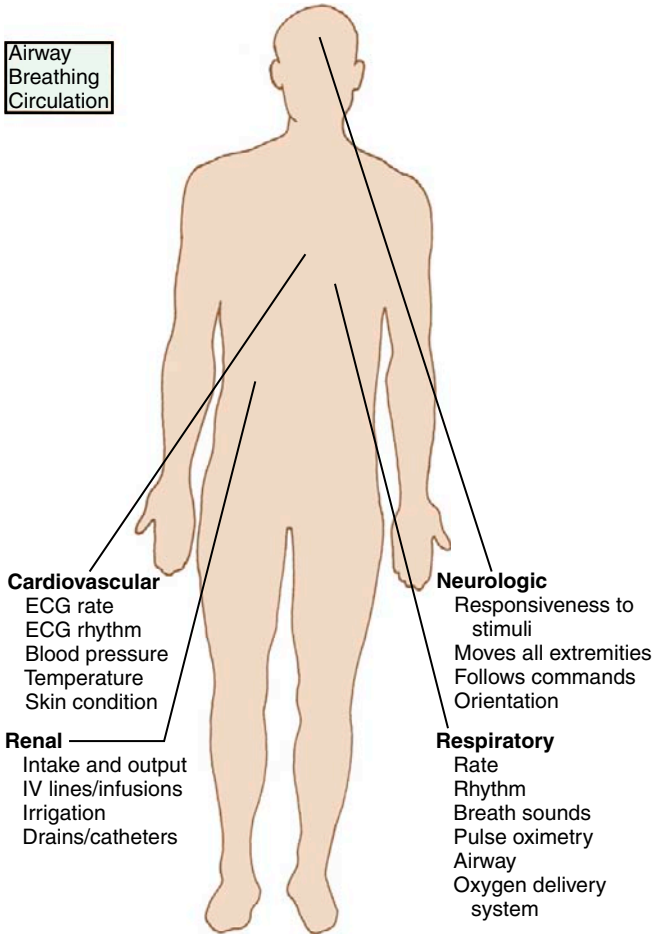


FIGURE 9-2 PACU major body systems' assessment. *ECG,* electrocardiogram; *IV,* intravenous.

Implementation

Dangerous and life-threatening changes can occur rapidly during postanesthesia care. The following complications are pertinent to the care of all patients during the immediate postoperative period. Prompt recognition and immediate intervention are imperative for the well-being of PACU patients.

Postoperative Complications

RESPIRATORY

Airway Obstruction. The first priority in the care of the postanesthesia patient is to establish a patent airway. A common cause of airway obstruction is the tongue, which is relaxed because of anesthetic agents and muscle relaxants used during surgery (Figure 9-4). The patient may present with snoring, little or no air movement on auscultation of the lungs, retraction of intercostal muscles, asynchronous movements of the chest and abdomen, and a decreased oxygen saturation level. The nursing action taken may be simple, such as stimulating the patient to take deep breaths, positioning the patient on the side, or providing supplemental oxygen. If the patient is still unresponsive, the nurse may need to open the airway with a chin tilt or jaw thrust. A chin tilt is accomplished by lifting the chin with one hand while tilting the forehead back with the other. A jaw thrust is accomplished by displacing the temporomandibular joint forward bilaterally. The patient also can be repositioned on the right side. This position is called the recovery position. Placing the patient in this position allows the tongue to move forward and the airway to remain open.

If these actions do not open the airway, an artificial airway may need to be inserted. An oral or nasal airway may be used. An oral airway is indicated for use with an unresponsive patient (Figure 9-5). A nasal airway, better tolerated by an awake patient, is indicated for patients who are arousable.

Hemorrhage after neck surgery or carotid endarterectomy also can cause acute obstruction of the airway. The PACU nurse should assess such patients carefully for bleeding. In situations such as apnea, intubation with ventilation may be required. If intubation is impossible, the patient may require a tracheostomy, although this rarely is needed. The need for airway support is a common complication in the PACU (Tarrac, 2006).

Laryngospasm. A serious PACU complication is laryngospasm, usually the result of an irritable airway. The muscles of the larynx contract and partially or completely obstruct the airway; the patient can become hypoxemic quickly. Nursing actions include removing the irritating stimulus, suctioning secretions that may be triggering a glottic response, hyperextending the patient's neck, oxygenating the patient, and possibly administering an aerosol with racemic (optically inactive) epinephrine. An awake patient experiencing a laryngospasm will be terrified and need reassurance and a calm demeanor from nurses and physicians. Other treatment suggested for the patient includes application of pressure in the depression just posterior to the condyle of the mandible and administration of IV doxapram (Ahmed, 2004). In many cases, positive-pressure ventilation must be delivered by mask and bag. If symptoms last longer than 1 minute and are unrelieved by positive pressure, administration of a muscle relaxant, such as succinylcholine, is required to relax the muscles of the larynx. Reintubation is undesirable and used only as a last resort.

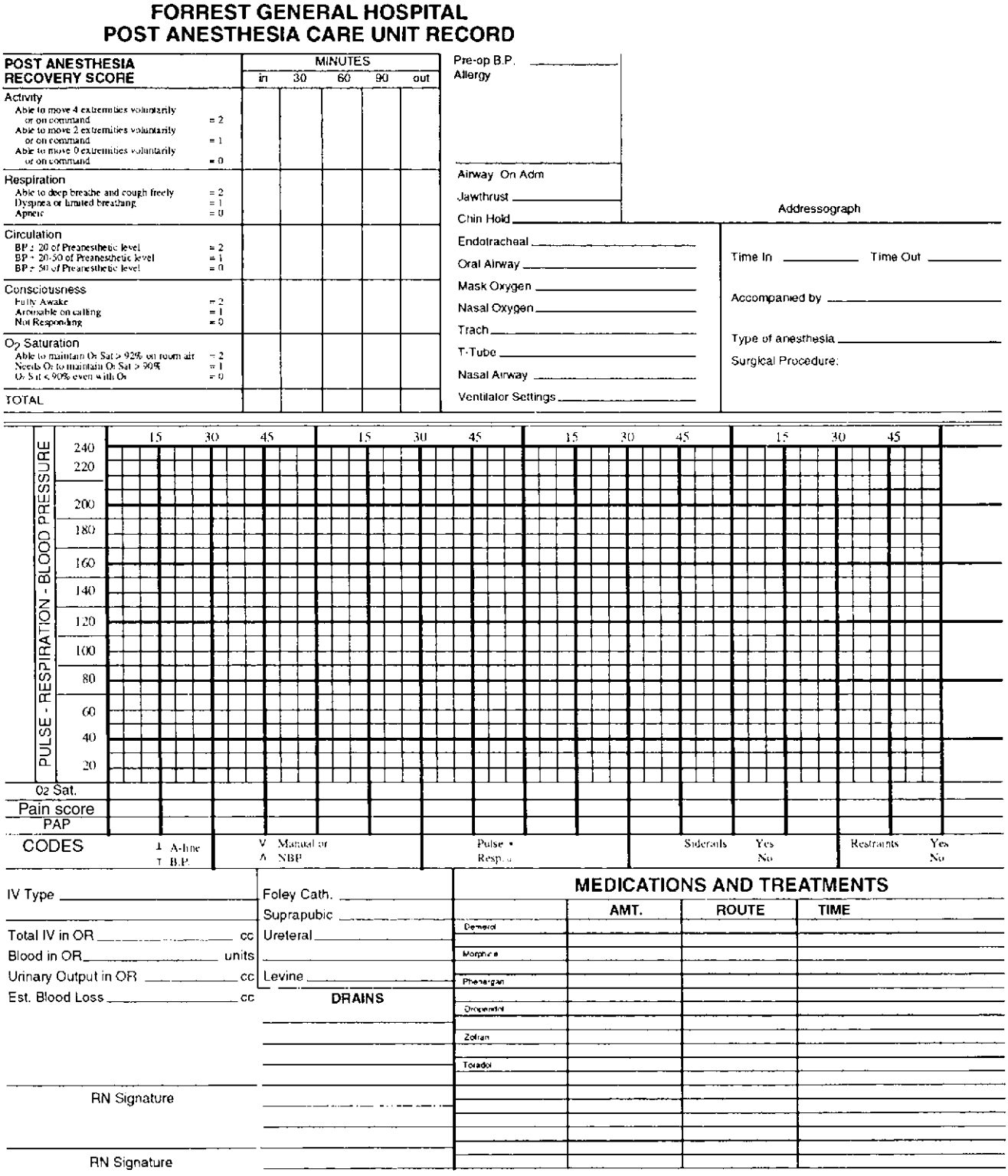
Bronchospasm. Bronchospasm is a lower airway obstruction caused by spasms of the bronchial tubes. These spasms can cause complete airway closure because of lack of cartilaginous support in the bronchioles. The patient presents with wheezing, dyspnea, use of accessory muscles, and tachypnea (Odom-Forren et al, 2010). Bronchospasm can result from aspiration, pharyngeal suctioning, or histamine release secondary to allergic response or related to medication use. Inhaled bronchodilators are the first choice of therapy for these patients, followed by intravenous aminophylline. Both IV and inhaled lidocaine can ease bronchospasm induced by histamine (Benca, 2007). If bronchospasm becomes life-threatening, epinephrine may be administered. Steroids, such as methylprednisolone, also may be administered if the underlying cause is inflammatory disease (e.g., asthma).

When obstruction occurs, the partial pressure of arterial carbon dioxide ($PaCO_2$) increases 6 mm Hg in the first minute of total obstruction and 3 to 4 mm Hg each minute thereafter (Nicholau, 2009). It is imperative that the PACU nurse make a quick assessment, rapidly intervene with airway assistance, and call for help to the anesthesia provider.

CARDIOVASCULAR. Cardiovascular system instability is a frequent finding after surgery because many anesthetic agents exert a depressive effect on the heart and vascular system. Common problems include hypotension, hypertension, and dysrhythmias. In one study of complications in the PACU, 13% were a result of tachycardia, 10.5% a result of hypertension, and 6.5% a result of hypotension (Tarrac, 2006).

Hypotension. Hypotension has been defined as a blood pressure reading that is 20% less than baseline or preoperative blood pressure measurement; it indicates either relative or absolute hypovolemia (O'Brien, 2009). Clinical signs of hypotension include a rapid, thready pulse; disorientation; restlessness; oliguria; and cold, pale skin. As hypovolemia is the most common cause of postoperative hypotension, the initial intervention is to administer IV fluids (physiologic saline or lactated Ringer's solution) at a maximum rate while making a specific diagnosis.

Cardiac output and vascular resistance determine blood pressure. Hypotension may be caused by cardiac dysfunction (such as myocardial infarction, tamponade, embolism, ischemia,



FORREST GENERAL HOSPITAL
POST ANESTHESIA CARE UNIT RECORD

POST ANESTHESIA RECOVERY SCORE	MINUTES in	30	60	90	out
Activity: Able to move 4 extremities voluntarily or on command = 2; Able to move 2 extremities voluntarily or on command = 1; Able to move 0 extremities voluntarily or on command = 0					
Respiration: Able to deep breathe and cough freely = 2; Dyspnea or limited breathing = 1; Apneic = 0					
Circulation: BP ± 20 of Preanesthetic level = 2; BP ± 20-50 of Preanesthetic level = 1; BP ± 50 of Preanesthetic level = 0					
Consciousness: Fully Awake = 2; Arousable on calling = 1; Not Responding = 0					
O_2 Saturation: Able to maintain O_2 Sat > 92% on room air = 2; Needs O_2 to maintain O_2 Sat > 90% = 1; O_2 Sat < 90% even with O_2 = 0					
TOTAL					

Pre-op B.P. _____
Allergy

Airway On Adm
Jawthrust _____
Chin Hold _____
Endotracheal _____
Oral Airway _____
Mask Oxygen _____
Nasal Oxygen _____
Trach _____
T-Tube _____
Nasal Airway _____
Ventilator Settings _____

Addressograph

Time In _____ Time Out _____
Accompanied by _____
Type of anesthesia _____
Surgical Procedure:

PULSE - RESPIRATION - BLOOD PRESSURE
240 220 200 180 160 140 120 100 80 60 40 20
15 30 45 15 30 45 15 30 45 15 30 45
O2 Sat.
Pain score
PAP
CODES ⊥ A-line ⊤ B.P. V Manual or Δ NBP Pulse • Resp. ○ Siderails Yes No Restraints Yes No

IV Type _____
Total IV in OR _____ cc
Blood in OR _____ units
Urinary Output in OR _____ cc
Est. Blood Loss _____ cc

Foley Cath. _____
Suprapubic _____
Ureteral _____
Levine _____

DRAINS

MEDICATIONS AND TREATMENTS

	AMT.	ROUTE	TIME
Demerol			
Morphine			
Phenergan			
Droperidol			
Zofran			
Toradol			

RN Signature

RN Signature

FIGURE 9-3 PACU record.

Continued

FORREST GENERAL HOSPITAL

DATE	TIME	DESCRIPTIVE NOTES (SIGN EACH ENTRY)

Report to Family: Time:	GU IRRIGANT	FOLEY OUTPUT
	TOTAL INFUSED:	TOTAL OUTPUT:

PACU DISCHARGE SUMMARY

VITAL SIGNS ON DISCHARGE	PACU OUTCOME	COMFORT LEVEL
B/P: P: R: T: OXIMETER: PAR SCORE:	UNEVENTFUL ☐ COMPLICATIONS ☐	PAIN FREE ☐ PAIN CONTROLLED ☐ SLEEPING BUT C/O PAIN WHEN AWAKEN ☐ PAIN SCORE _____

REPORT TO: TIME:	SKIN CONDITION WARM COOL DRY MOIST	COLOR PINK PALE JAUNDICED DUSKY

DRESSINGS / SURGICAL SITE / PUNCTURE SITE

X-RAYS TAKEN IN PACU	LABS DRAWN IN PACU	O_2 ORDERED YES NO _____ L/MIN PER _____ O_2 TRANSPORT YES NO

TOTAL IV IN PACU	TOTAL OUTPUT IN PACU		
	URINARY	LEVINE	DRAINS
TOTAL BLOOD IN PACU			
TOTAL PO INTAKE IN PACU	IV SITE: _____ cc LTC		

ORDERS FAXED TO PHARMACY YES NO	EQUIPMENT ORDERED	TRANSPORT BY: AMBASSADOR RN LPN TECHNICIAN

DIAGNOSIS (Circle number of any diagnosis made)	GOAL	Goal Achieved YES	NO
1 Alteration in neurological status			
2 Alteration in comfort level			
3 Alteration in emotional status			
4 Alteration in circulation			
5 Alteration in fluid volume			
6 Alteration in mobility			
7 Alteration in respiratory function			
8 Alteration in skin integrity			
9 Alteration in temperature			
10 Alteration in elimination			
11 Alteration in gastrointestinal function			
12 Alteration from injury			
13 Alteration in bleeding			
14 Other			

RHYTHM STRIPS

FIGURE 9-3, cont'd PACU record.

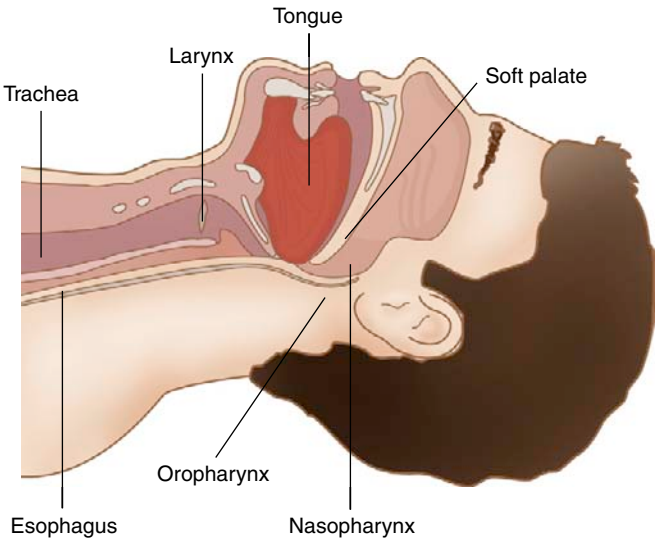


FIGURE 9-4 Obstruction of airway by tongue.

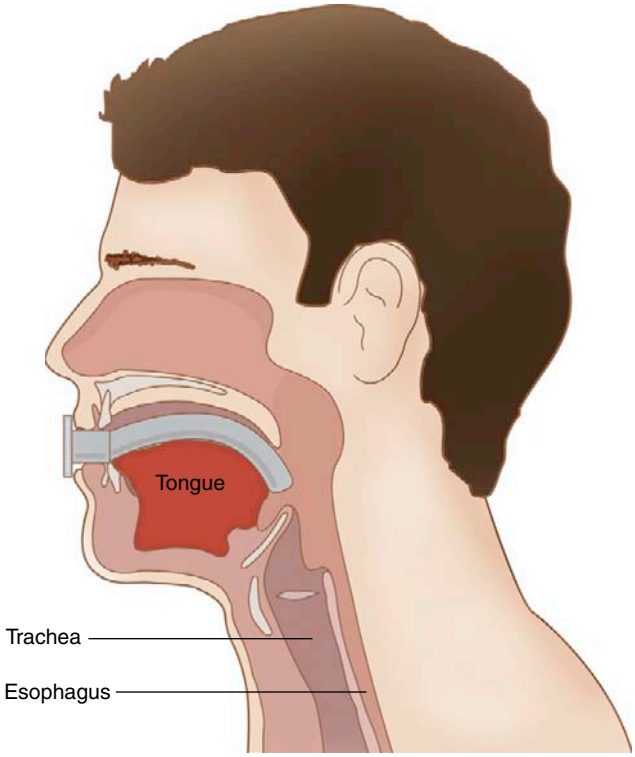


FIGURE 9-5 Oropharyngeal airway in place.

dysrhythmias, congestive heart failure, valvular dysfunction) or by medications (including anesthetic agents). In such cases, the heart no longer pumps effectively. Hemodynamic monitoring, supplemental oxygen, and cardiac stimulants are used as needed.

Hypovolemia. Hypovolemia reduces cardiac output and may be caused by hemorrhage, dehydration (inadequate fluid replacement), or increased positive end-expiratory pressure (PEEP). Fluid or blood replacement is used to treat hypovolemia. If the patient is hemorrhaging at the surgical site, a return to the OR is indicated.

Decreased vascular resistance, which causes relative hypovolemia (interference with venous return to the heart), can be related to medications, general and regional anesthesia, or anaphylaxis (Odom-Forren et al, 2010). Vasodilation can be treated with fluids, vasopressors, or elevation of the patient's legs. Anaphylactic reactions are treated with epinephrine, antihistamines, and additional fluids.

Hypertension. The normal ranges for systolic and diastolic blood pressures are generally accepted as 100 to 140 mm Hg and 60 to 95 mm Hg, respectively, although these ranges vary. Hypertension has been defined as a 20% to 30% increase above baseline blood pressure measurement (O'Brien, 2009; Odom-Forren et al, 2010). Hypertension is among the most common postoperative complications and often occurs early in the recovery phase. Blood pressure must be verified, and rapidity of the change must be noted. Clinical signs and symptoms are the most important indicators of the severity of the hypertension. Headache, mental status changes, and substernal pain are all indicators of end-organ damage. Hypertension may be caused by volume overload or pulmonary edema, which causes an increase in the cardiac output. In this case, the patient is given diuretics, placed on fluid restriction, and hemodynamically monitored. The patient with a history of cardiac disease is more at risk for adverse results.

Asymptomatic hypertension commonly occurs in the PACU and is usually considered harmless. The solution usually is determined by the cause. Pain is one of the most common causes of hypertension. Other causes of hypertension are anxiety, reflex vasoconstriction from hypothermia, hypoxemia, hypercapnia, and viscus distention, all of which cause increased vascular resistance. Patients in pain are medicated, and patients with hypothermia are warmed. Patients are oxygenated and ventilated if necessary to improve hypoxemia or hypercapnia. Patients are encouraged to void or are catheterized to empty a full bladder.

Antihypertensive drugs are used as necessary to control blood pressure. Preexisting hypertension is common in patients who have hypertension immediately after surgery. Patients should resume taking prescribed preoperative antihypertensives as soon as possible after surgery. Ambulatory surgery patients and inpatients usually are directed to take their prescribed antihypertensives on the day of surgery.

Dysrhythmias. Most dysrhythmias seen in the PACU have an underlying cause that is unrelated to myocardial injury (Odom-Forren et al, 2010). A common dysrhythmia after surgery is sinus tachycardia (rate >100 beats/min in an adult). Frequent causes include pain, hypoxemia, hypovolemia, increased temperature, and anxiety. The underlying cause is treated. Propranolol, metoprolol, or esmolol may be given. Sinus bradycardia (heart rate <60 beats/min in an adult) also is a common dysrhythmia in the PACU. Causes include hypoxemia, hypothermia, high spinal anesthesia, vagal stimulation, and some medications commonly given during or after surgery. The underlying cause is treated. Atropine is the drug of choice to increase heart rate, and usually no other treatment is required. Temporary or permanent pacemakers sometimes may be required.

Premature ventricular contractions (PVCs) are represented by wide, bizarre-looking QRS complexes. The most common causes in the postoperative period are hypoxemia and hypokalemia. These underlying conditions should be treated. Often, if cardiac disease or hypotension is not present, PVCs do not require medication. Treatment of dysrhythmias begins with determining and removing any source of the problem. Antidysrhythmic drugs, resuscitation equipment, and monitoring equipment should be immediately available.

THERMOREGULATION AND TEMPERATURE ABNORMALITIES

Hypothermia. Postoperative hypothermia, defined as a temperature less than 36° C (96.8° F) (ASPAN, 2009b), continues to be a widespread PACU problem. Often hypothermia is not life-threatening; it does, however, cause physiologic stress. Hypothermia can prolong recovery time and contribute to postoperative morbidity (Wong et al, 2007). Especially vulnerable to the effects of hypothermia are the elderly and children 2 years old or younger. Macario and Dexter (2002) determined that there are four major risk factors for hypothermia; this includes three patient populations—neonates less than 1 month of age, burn patients, and patients whose surgery included general anesthesia with neuraxial anesthesia—along with the low ambient temperature of the OR. Other risk factors include female gender, extreme age, length and type of surgical procedure, cachexia, significant fluid shift, and use of cold irrigants (Good et al, 2006; Wagner, 2006). The prevention and management of unplanned perioperative hypothermia remain a national priority in the prevention of surgical site infection, and it has been designated as a quality measure by the Surgical Care Improvement Project (SCIP) (ASPAN, 2009b; Langham et al, 2009).

Assessment of the need for prewarming begins preoperatively. Preventive warming measures are begun for normothermic patients and active warming measures instituted for hypothermic patients (ASPAN, 2009b).

Prevention of heat loss continues in the OR. Under general anesthesia, the patient does not produce heat and depends on ambient temperature. Prevention includes increasing the ambient temperature in the OR, providing the patient with warm blankets on arrival in the OR, and using draping techniques that minimize exposure during the procedure. Heated humidifiers and fluid warmers add heat. A common device to prevent hypothermia in the OR is a forced-air warming device (Figure 9-6).

In the PACU, tremendous demands are made on the body when the patient shivers. Shivering can increase the need for oxygen by 300% to 400%. Hypothermic patients should have oxygen therapy initiated immediately on admission. For a patient with a healthy heart, there may be no harmful effects. For a patient with coronary artery disease or cardiomyopathy, however, decompensation can occur. Perioperative normothermia has been associated with reduced incidence of morbid cardiac incidents and ventricular tachycardia in patients with cardiac risk factors (Leslie and Sessler, 2003; Siew-Fong et al, 2003).

Other problems associated with hypothermia include intravascular volume loss attributable to a fluid shift from the extracellular space, probably related to vasoconstriction (Reynolds et al, 2008). As the patient begins to rewarm, vasodilation follows, and the patient can require large amounts of intravenous fluids to avoid hypovolemia. The central nervous system is depressed by hypothermia. A cold postanesthesia patient remains more anesthetized than a warm patient while recovering. Nitrogen loss and hypokalemia can cause a predisposition to wound infection (Doufas, 2003). Impaired wound healing and surgical site infection have been linked to hypothermia (Paulikas, 2008).

Hypothermia slows metabolism and alters the effects of some anesthetic drugs. Of special interest is the prolonged elimination of muscle relaxants in hypothermic patients. Clotting abnormalities can occur. Platelet activity declines, and fibrinolysis increases with hypothermia; both conditions enhance the tendency to bleed (Sessler, 2001).

FIGURE 9-6 Bair Hugger; focused thermal environment.

Rewarming is a priority in the immediate care of the postoperative patient because hypothermia may augment the risk of adverse outcomes (Sessler, 2001). Wet and cold gowns and blankets should be removed, and warm, dry gowns and blankets should be applied to the head and body. Several external rewarming techniques are available. Application of warm cotton blankets has been a PACU tradition. Warm blankets are applied every 5 to 10 minutes until the patient is normothermic. Cotton blankets gradually increase the patient's temperature. They do not actively heat patients, however, and warming can be a slow process. Forced-air warming devices have been effective in rewarming patients. They produce a thermal-focused environment that transfers heat to a patient by blowing warm air through a plastic and tissue paper blanket that covers the patient (Siew-Fong et al, 2003). Forced-air warming devices are standard hypothermia treatment in PACU settings.

Continuous fluid-circulating blankets or warm-water mattresses have shown little value in rewarming patients because the size of the surface area in contact with the heat source is limited. Radiant heat lamps depend on exposure of large areas of body surface and are of limited use to adult patients. Fluid and blood warmers are useful for large volumes of cool fluids, but not to reverse hypothermia.

Studies have explored the best method to obtain accurate temperatures in the PACU when invasive core temperature measures, pulmonary artery, distal esophagus, nasopharynx, and tympanic membrane are unavailable. Both a study comparing eight noninvasive techniques to bladder temperature (Langham et al, 2009) and another systematic review of accuracy of noninvasive core temperature measurement (Hooper and Andrews, 2006), concluded that the most accurate method for routine postoperative temperatures was electronic oral temperatures.

Hyperthermia. Hyperthermia may indicate an infectious process or sepsis, or it may indicate a hypermetabolic process—malignant hyperthermia (MH). MH is a serious emergency

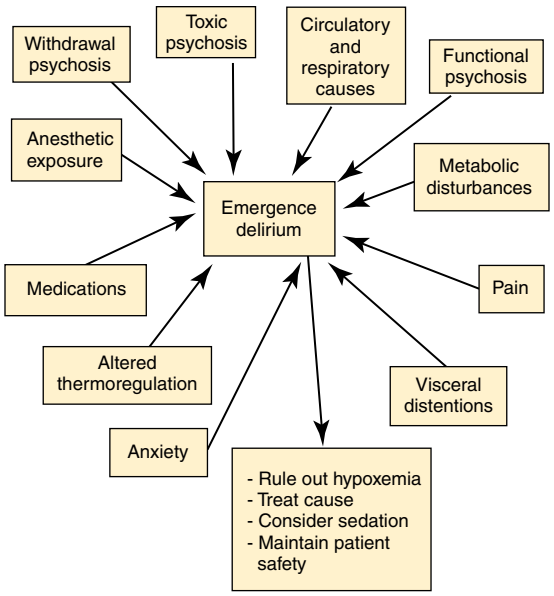


FIGURE 9-7 Emergence delirium in the PACU: contributing factors and treatment.

that is genetic in origin (Rosero et al, 2009). It is triggered by volatile anesthetic agents and the depolarizing muscle relaxant *succinylcholine*. Death may ensue unless MH is immediately recognized and treated (see Chapter 4).

DISTURBANCES IN COGNITIVE FUNCTION. PACU patients may be disoriented, drowsy, confused, or delirious. Attempts have been made to differentiate emergence delirium from agitation, with agitation defined as mild restlessness and mental distress. Delirium can be confused with agitation or the cause of agitation (Moos, 2005; Vlajkovic and Sindjelic, 2007). Causes range from residual effects of anesthetics to pain and anxiety. Hypoxemia always should be ruled out first; it remains the most common cause of postoperative agitation. Chemically dependent patients often awaken in an agitated state. Viscus distention also can contribute to agitation in a drowsy, confused patient. The PACU nurse should identify and eliminate the cause of the agitation or confusion, if possible. The patient can be engaged in short conversations and reoriented to place and person. Baseline preoperative data are important to determine the cause of agitation. Persistent changes from preoperative status require thorough assessment and possible intervention by the physician. See Figure 9-7 for a summary of contributing factors to emergence delirium and treatment options.

NAUSEA AND VOMITING. Postoperative nausea and vomiting (PONV) is a problem that affects approximately 30% of PACU patients (Odom-Forren and Moser, 2005). For patients with four risk factors, the incidence can be 70% to 80% (Apfel et al, 2002). Primary risk factors associated with PONV are female gender, nonsmoker, history of PONV or motion sickness, use of volatile anesthetics, use of nitrous oxide, postoperative use of opioids, duration of surgery, and type of surgery (Murphy et al, 2006; Gan et al, 2007). Management of nausea and vomiting begins preoperatively and continues into the intraoperative period (Evidence for Practice). Preventive therapy for patients at high risk of PONV has been effective in reducing its incidence. There is no single method to prevent or treat PONV. Many causative factors relate to anesthesia and surgery. Risk factors for PONV should be assessed preoperatively and care planned accordingly. Apfel and colleagues (1999) developed a simplified risk assessment tool, widely used today, based on four risk factors: gender, smoking status, history of PONV or motion sickness, and postoperative use of opioids. See Figure 9-8 for guidelines regarding preoperative management and prophylaxis of PONV.

Receptors that can cause nausea and vomiting when triggered are dopamine type-2, serotonin type-3, histamine type-1, muscarinic cholinergic type-1, and neurokinin type-1. Patients at risk for PONV should have either one or a combination of agents that block one or more of these receptor sites. Medications that have proven effective are ondansetron (Zofran), dolasetron (Anzemet), granisetron (Kytril), promethazine (Phenergan), prochlorperazine (Compazine), dexamethasone (Decadron), palonosetron (Aloxi), and transdermal scopolamine. Other medications that can be considered are metoclopramide (Reglan) at a dosage of at least 25 to 50 mg IV, dimenhydrinate (Dramamine), diphenhydramine (Benadryl), or droperidol (Inapsine). Droperidol has a black box warning and the patient must be monitored for QT prolongation/torsades de pointes after administration (Golembiewski and Tokumaru, 2006). If the patient

EVIDENCE FOR PRACTICE

ASPAN's Evidence-Based Clinical Practice Guideline for the Prevention and/or Management of PONV/PDNV

The lack of a multidisciplinary and multimodal treatment approach to PONV and PDNV prompted ASPAN to appoint a Strategic Work Team (SWT) that consisted of 16 multidisciplinary, multispecialty experts who were national and international academic and private practice experts. These experts reviewed and analyzed published evidence and developed a consensus regarding evidence-based, multimodal clinical practice recommendations that addressed prevention or management of PONV and PDNV. The specific aims of this group were to critique and synthesize evidence regarding the prevention and/or management of PONV/PDNV in the adult population, to develop evidence-based recommendations including traditional therapeutic management and complementary modalities, and to identify areas of needed research. The guideline includes separate algorithms for preoperative patient management, postoperative management of PONV, and management of PDNV.

Some of the evidence-based recommendations for postoperative patient management in the phase I and phase II PACU include:

- Assess for PONV on admission, discharge, and more frequently as indicated. If nausea is present, quantify the severity with a verbal descriptor scale (VDS) or visual analogue scale (VAS).
- Implement rescue interventions: verify hydration and blood pressure, select and administer appropriate rescue antiemetic. (Rescue antiemetic should affect a different receptor site than prophylactic agents already administered.)
- Include patient education on management of PDNV in all ambulatory surgery discharge education.
- Include assessment for the presence and severity of PDNV in any ambulatory surgery patient follow-up contact.

Adapted from ASPAN: ASPAN's evidence-based clinical practice guideline for the prevention and/or management of PONV/PDNV, *J Perianesth Nurs* 21:230-250, 2006.

is hypotensive with nausea and vomiting, ephedrine may be administered with additional fluid administration. PONV rescue medication administered in the PACU should be an antiemetic from a different pharmacologic class than medication given for prophylaxis (Golembiewski and Tokumaru, 2006). See Figure 9-9 for postoperative management of the patient with PONV.

Patients may also experience nausea and vomiting after discharge home from ambulatory surgery. Less research is available to direct the care of these patients, but the use of transdermal scopolamine, promethazine (suppositories or oral), or ondansetron dissolving tablets (ODTs) is supported by small studies (Odom-Forren et al, 2006). See Figure 9-10 for management of the patient with postdischarge nausea and vomiting (PDNV) (Research Highlight).

ASPIRATION. Aspiration, the passage of regurgitated material into the lungs, can occur during the perioperative period, with most aspirations occurring during tracheal intubation or extubation (Kalinowski and Kirsch, 2004). The PACU nurse must protect the airway of an unconscious or semiconscious patient to prevent aspiration of gastric contents. Prevention of aspiration postoperatively includes responding quickly to reports of nausea and vomiting, avoiding conversations that could elicit nausea and vomiting, and preventing rapid movement and head elevation of the

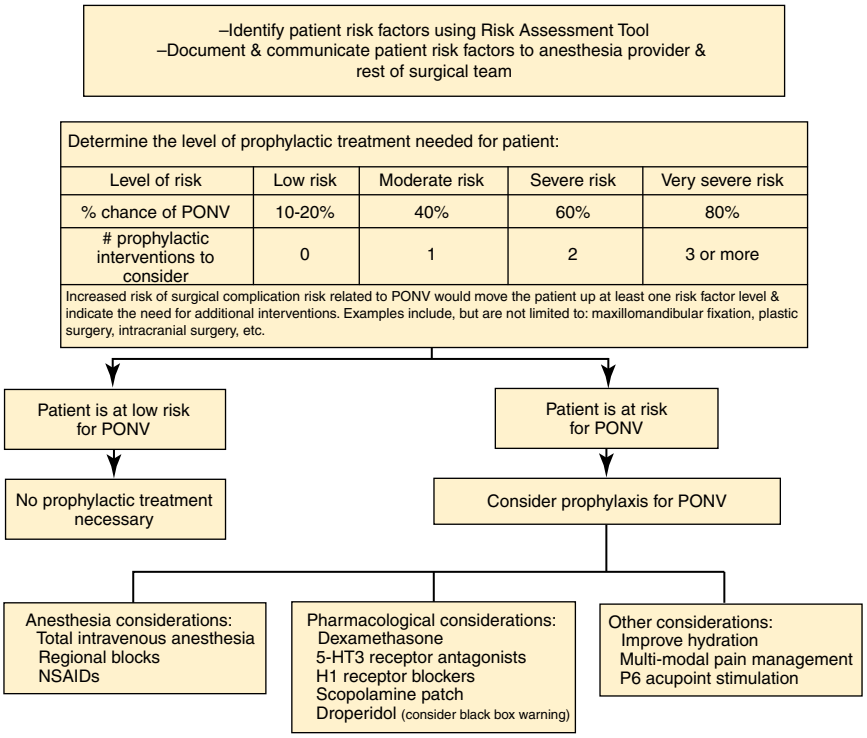


FIGURE 9-8 Preoperative patient management of PONV/PDNV.

RESEARCH HIGHLIGHT

Antiemetic Prophylaxis for Postdischarge Nausea and Vomiting (PDNV) and Impact on Functional Quality of Living during Recovery in Patients with High Emetic Risks

Pan and colleagues conducted a prospective, randomized, double-blind comparison of two prophylactic antiemetic regimens. In a sample of 64 women undergoing gynecologic ambulatory surgery, the study group was given intraoperative IV dexamethasone 8 mg and ondansetron (ODT) 4 mg, followed by a 1-mg oral disintegrating ondansetron tablet taken on discharge and each of the next two mornings. The control group only received the IV ondansetron during surgery. The patients were followed for 5 days after discharge. The reported incidence of postdischarge nausea for the study group was 20%, while it was 57% for the control group. Postdischarge vomiting occurred in 3% of the study group and 20% of the control group. Sixty percent of the control group and 33% of the study group stated that emetic symptoms negatively affected quality of life. It was concluded that the study group had a reduced incidence of PDNV and its negative impact on their quality of life. PDNV incidence is high and affects quality of life for ambulatory surgery patients for up to 5 days after surgery.

Modified from Pan P et al: Antiemetic prophylaxis for postdischarge nausea and vomiting and impact on functional quality of living during recovery in patients with high emetic risks: a prospective, randomized, double-blind comparison of two prophylactic antiemetic regimens, *Anesth Analg* 107:429-438, 2008.

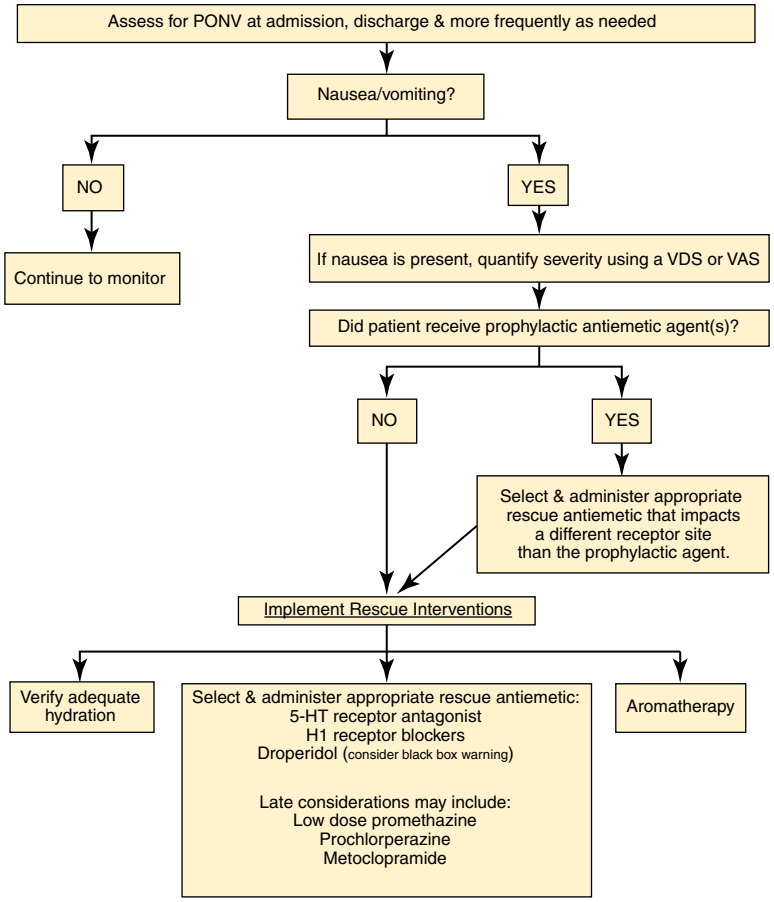


FIGURE 9-9 Postoperative patient management of PONV.

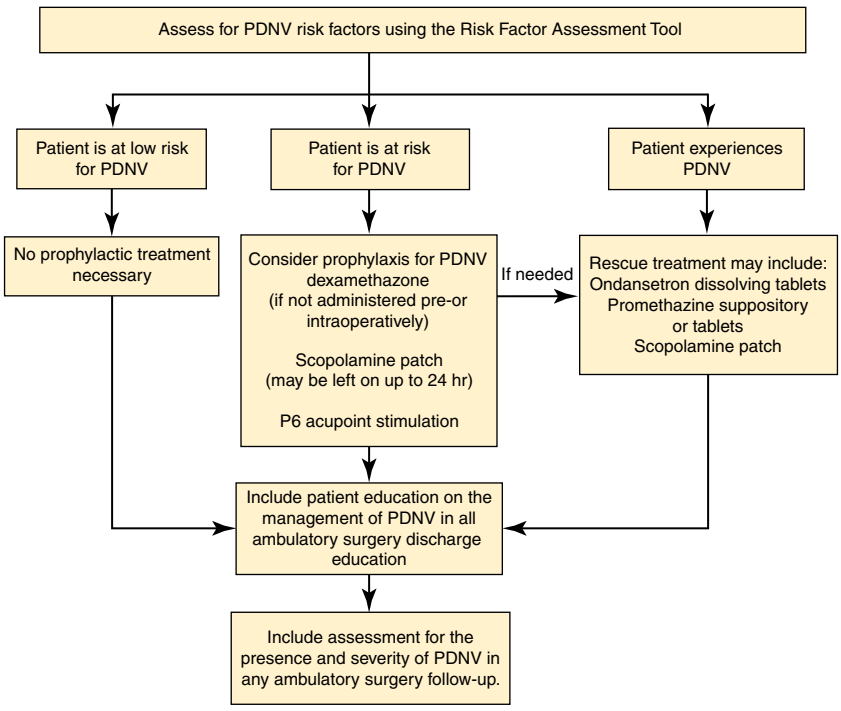


FIGURE 9-10 Management of PDNV.

TABLE 9-1

Risk Factors for Pulmonary Aspiration

General Risk Factors	Specific Risk Factors
Age (older > younger)	Emergency
Gender (female > male)	Pregnancy
Co-morbid diseases	Recent oral intake
IDDM	Opioid administration
CNS deficits	Increased gastric residual volume, as with gastrointestinal obstruction or dysfunction
Peripheral vascular disease	Obesity
Hepatobiliary or gastrointestinal diseases	Difficulty in protecting airway, as with depressed level of consciousness
Renal dysfunction	Previous esophageal dysfunction
	Head injury or neurologic dysfunction
	Lack of coordination of swallowing and respiration
	Procedures that increase intraabdominal pressure (e.g., upper abdominal surgery, straining with ETT)
	Difficult intubation/airway

CNS, central nervous system; *ETT,* endotracheal tube; *IDDM,* insulin-dependent diabetes mellitus (type 1).
Modified from Warner M: Risks and outcomes of perioperative pulmonary aspiration, *J Perianesth Nurs* 12(5):355, 1997; Schick L: *Calling 911: management of common PACU emergencies,* presented at 19th Annual ASPAN Conference, Kansas City, Mo, April 19, 2000; Kalinowski CPH, Kirsch JR: Strategies for prophylaxis and treatment for aspiration, *Best Pract Res Clin Anaesthesiol* 18(4):719-737, 2004.

patient. Nonreactive patients can be placed on their sides in the recovery position.

Volume and acidity of the aspirate determine the extent of damage to the lungs. The most severe damage seems to be in cases in which the pH is less than 2.5 or the volume greater than 25 ml (Kalinowski and Kirsch, 2004). Preoperatively, patients may receive clear, nonparticulate antacids, such as Bicitra, to raise the gastric fluid pH. Histamine (H_2)-receptor antagonists, such as cimetidine, ranitidine, or famotidine, decrease gastric acid production. Metoclopramide speeds gastric-emptying time. Aspiration does not occur in patients with normal protective reflexes. Risk factors can be divided into general and specific (Table 9-1).

Signs and symptoms of aspiration include tachypnea and hypoxemia attributable to a decrease in lung compliance. Wheezing, coughing, dyspnea, hypotension, apnea, and bradycardia may occur. Treatment focuses on promoting tissue oxygenation. Supplemental oxygen is given. Positive pressure applied by use of a mask or an endotracheal tube may be needed to maintain arterial oxygenation, and a chest x-ray may be performed. If intubated, the trachea can be suctioned. Bronchoscopy is performed if aspirated particles are large and cause an airway obstruction. Neither steroids nor antibiotics are warranted (Kalinowski and Kirsch, 2004). Tracheal secretions can be cultured, and if the results are positive, an appropriate antibiotic can be started. Bronchodilators are used as required. Recovery of the patient depends on recognition of the problem, quantity and pH of aspirate, physical condition of the patient before the event, and speed with which medical intervention begins (Kalinowski and Kirsch, 2004).

ACUTE PAIN. Pain is a subjective experience and may or may not be verbalized. Often, healthcare providers require objective signs of discomfort in addition to subjective reports of pain from the patient, which can lead to undertreatment of pain. The guiding principle in pain care is that pain is whatever the patient says it is (AHCPR, 1992; Pasero, 2009). The Agency for Health Care Policy and Research (AHCPR, now known as the Agency for Healthcare Research and Quality [AHRQ], 1992) reports that the most reliable indicator of the existence and intensity of pain is the patient's self-report. All patients should be assessed for pain severity using a verbal descriptor rating scale, numeric rating scale, or a visual analogue scale (Flaherty, 2008) (Figures 9-11 and 9-12). Approximately 80% of patients in one study experienced acute postoperative pain, with most patients experiencing moderate, severe, or extreme pain (Apfelbaum et al, 2003).

Pain management is one of the highest priorities of postanesthesia care (Buss and Melderis, 2002). Patients should be assessed for pain on admission to the PACU and at frequent intervals (Box 9-3). It is important to remember that not all patients respond to pain in the same manner, despite comparable surgical procedures. Measures of pain assessment should be correlated with the patient's self-report as the most important measure of intensity. Measures to determine pain intensity in a patient who cannot self-report include exposure to a painful procedure or underlying painful conditions; behavioral signs, such as crying or restlessness; a proxy pain rating by someone who knows the patient well; and physiologic indicators, such as elevated vital signs (Pasero, 2002a, 2009). An analgesic trial can be attempted as a final measure in the hierarchy of importance in assessing the nonverbal patient. Improvement in behaviors after the analgesic trial indicates that pain was the likely underlying cause (Pasero, 2009).

Evidence indicates that early analgesia reduces postoperative problems. Nonsteroidal antiinflammatory drugs (NSAIDs), or cyclooxygenase-type 2 (COX-2) inhibitors for patients who have experienced adverse effects from conventional NSAID use, and opiates are the analgesics of choice. Generally, they are used in combination (multimodal therapy) in the PACU (Surgical Pharmacology, p. 284 and Surgical Pharmacology, p. 285). Using NSAIDs in combination with opiates can reduce opioid requirements by 20% to 40% (Joshi, 2005). COX-2 inhibitors were developed with selective inhibition of the COX enzyme, with resulting analgesia and decreased inflammation without gastrointestinal and bleeding risks (Brophy, 2005). Until more recently, there were three COX-2 inhibitors available: celecoxib, rofecoxib, and valdecoxib. Rofecoxib and valdecoxib have been withdrawn from the U.S. market because they pose an unacceptable cardiovascular risk, leaving celecoxib as the only COX-2 inhibitor currently available in the United States. It is believed that the risk with celecoxib is small and comparable to that for traditional NSAIDs (Brophy, 2005). Parecoxib is another COX-2 inhibitor currently approved for use in Europe, but is not approved by the FDA for use in the United States.

Traditionally, pain was treated with intramuscular (IM) injections of opioids at intervals from 3 to 6 hours as needed. It is now recognized that inadequate pain relief experienced

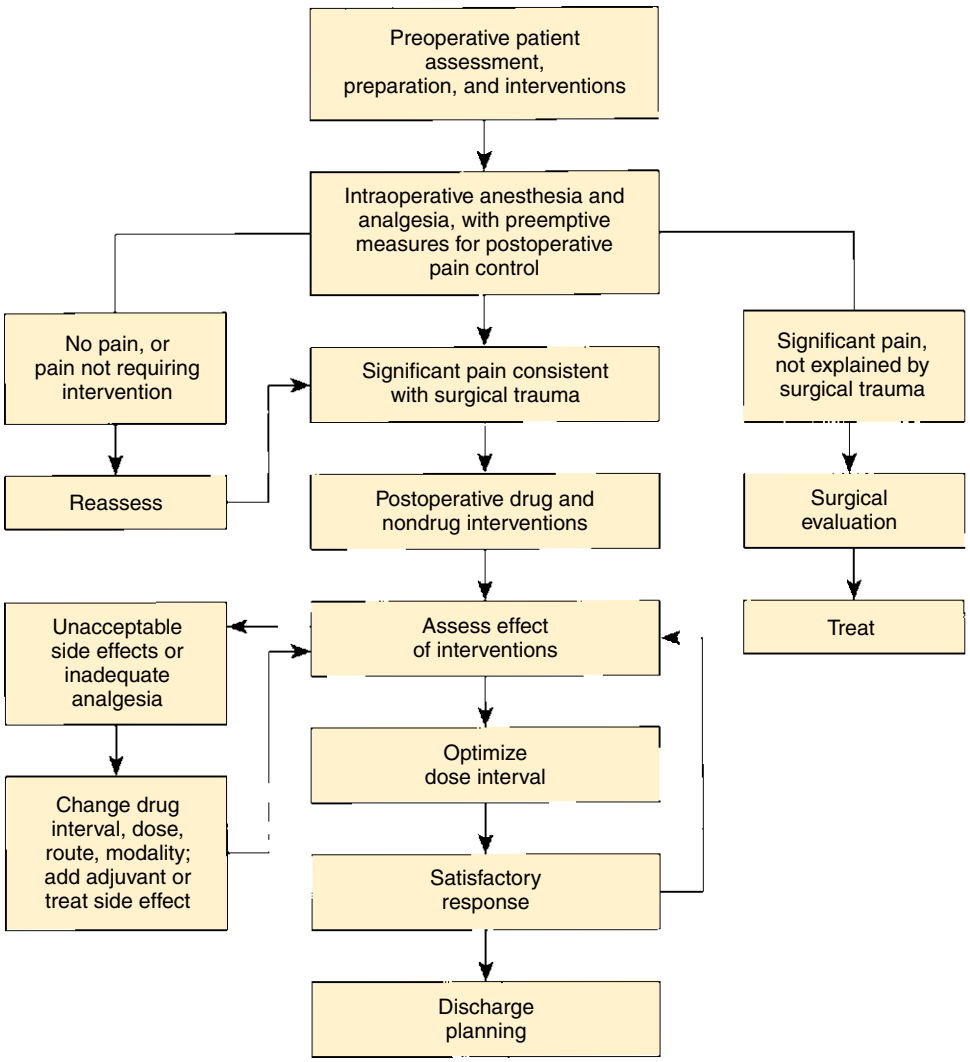


FIGURE 9-11 Acute pain management in adults.

by postoperative patients using IM injections is attributable to varying blood levels. Other methods of pain relief have since become more widespread. A common form of an opioid-delivery system is patient-controlled analgesia (PCA). PCA allows a patient to control analgesic administration. Dosage, time between doses, and the maximum dosage that can be administered are programmed into the machine. This form of analgesia also allows for a basal rate of opioids to infuse continuously, if ordered. The PCA pump also can be set to deliver continuous infusion and patient boluses. This setting allows the patient to use the bolus function to premedicate before an activity or for breakthrough pain. When PCA devices are started in the PACU, delays in preventing pain are avoided, effectiveness of the PCA device can be evaluated, and the patient's understanding and ability to use PCA can be monitored.

Other forms of postoperative pain relief may involve use of spinal analgesia, usually in the form of epidural opioid or local anesthetic administration. Patients who have had extensive procedures, including total hip or knee replacements, knee reconstruction, and major abdominal or thoracic operations, have been shown to profit from this method of pain control. Benefits of epidural analgesia for acute postoperative pain include good analgesia with minimal sedation, early ambulation and physical therapy, and excellent patient satisfaction. The FDA has approved a new extended-release epidural morphine (EREM; DepoDur) that provides pain relief for 48 hours after a single bolus injection (Pasero and McCaffery, 2005). Side effects of intrathecal administration of opioids include nausea, pruritus, urinary retention, areas of slight numbness, and respiratory depression. These side effects can be controlled by adjusting the infusion rate or by adding drugs such as diphenhydramine, ondansetron, or naloxone. Naloxone is the opioid antagonist used most frequently to reduce opioid-induced respiratory depression. It is administered slowly, never as a bolus, while the nurse observes the patient response. The patient should be able to open his or her eyes and talk to the nurse within 1 to 2 minutes of administration; naloxone is discontinued when the patient can take deep breaths on instruction and respond to physical stimulation.

Other techniques that have been shown to reduce the level of pain for the surgical patient include infiltration of the incision site with a local anesthetic in the OR before the initial

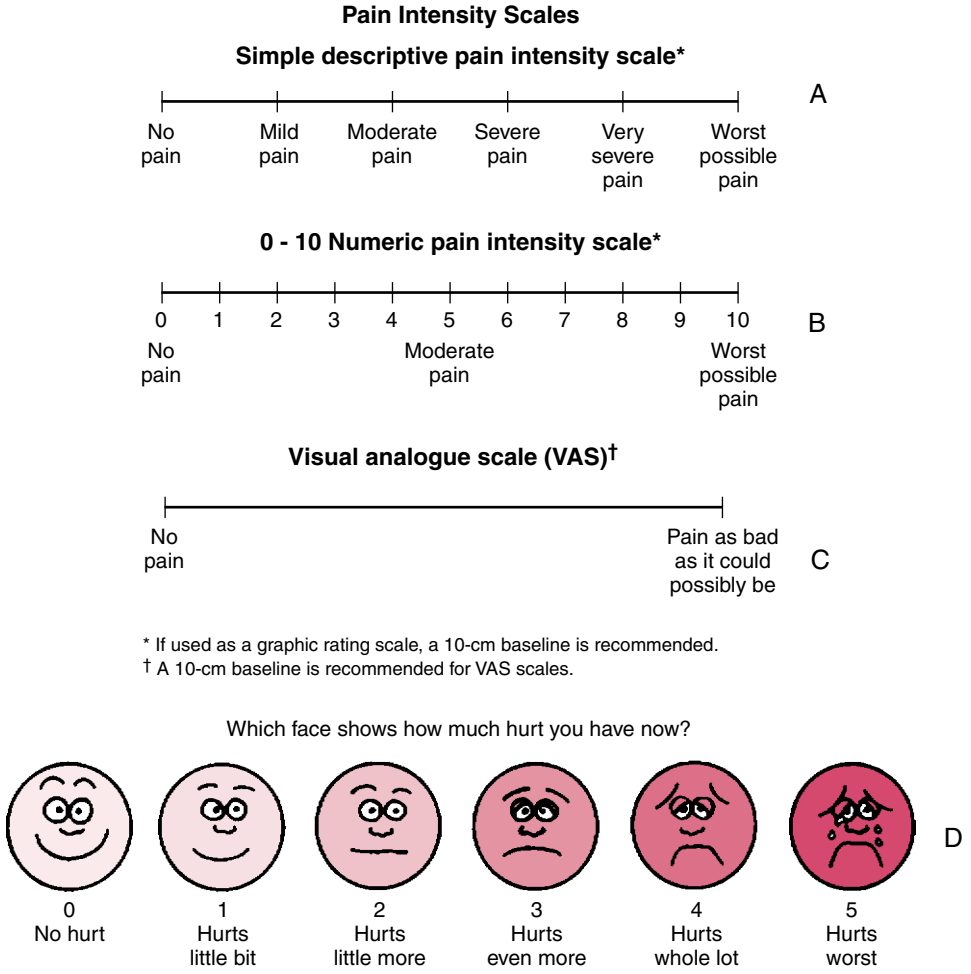


FIGURE 9-12 **A-C**, Examples of pain intensity and pain distress scales. **D**, FACES Pain Rating Scale.

incision and use of a long-acting local anesthetic at the site at the conclusion of the surgical procedure. Local anesthetics as part of a multimodal approach to pain management can contribute to a considerable decrease in opioid dosage with minimal side effects (Pasero, 2002b). One option is perineural local anesthetic infusion, in which a catheter is threaded along or into the wound. A diluted concentration of a long-acting local anesthetic is delivered to the surrounding nerves by a mechanical infusion pump for inpatients or a disposable infusion pump for ambulatory surgery patients (Banks, 2007). Thorough patient education is imperative, including removal of the catheter for patients who will be discharged home with the pump. It also is important to know the type of anesthetic the patient received during surgery and the type of local anesthetic in the pump to prevent overdose of local anesthetic. Multimodal analgesia allows a smaller dose of each component, which helps to minimize adverse effects (Viscusi, 2004).

Nonpharmacologic interventions that may be used to relieve pain include positioning for comfort, verbal reassurance, touch, applications of heat or cold, massage, and transcutaneous electrical nerve stimulation (TENS). If the patient was instructed preoperatively, other techniques that can be used are relaxation, imagery, music (Nillson, 2008), distraction, and biofeedback. Interventions that can be useful for PACU patients are preoperative education, which reduces the fear of the unknown; relaxation with deep breathing; distraction; and therapeutic massage (National Pharmaceutical Council [NPC], 2001). Nonpharmacologic interventions are designed to supplement, not substitute, pharmacologic interventions (AHRQ, 1992).

The physiologic effects of pain can be harmful for the postoperative patient. Such effects include decreased thoracic movement, increased splinting, reduced lung compliance and volume (leading to atelectasis), decreased mobility, increased risk of thromboembolism, exaggerated catecholamine response (which increases cardiac work and myocardial oxygen demand), increased risk for myocardial ischemia, impaired immune system, and delayed return of bowel and gastric function. Physiologic responses to acute pain include increased blood pressure and heart rate, dilated pupils, perspiration, increased respiratory rate, and decreased respiratory excursion (NPC, 2001; Dunwoody et al, 2008). Psychologically, the patient still in pain may display fear, helplessness, anxiety, anger, or frustration (Krenszichek, 2009). There is also an association between poorly controlled postoperative pain and the risk of developing chronic pain, which emphasizes the importance of pain control in the perioperative period (Dunwoody et al, 2008).

BOX 9-3

Pain Assessment and Reassessment

PRINCIPLES

- Pain is multidimensional. Patients experience its aspects in different ways. Comprehensive pain assessment considers the physical, sensory, behavioral, sociocultural, cognitive, affective, and spiritual dimensions of pain.
- Patients who have difficulty communicating their pain require particular attention. This includes patients who are cognitively impaired, psychotic, or severely emotionally disturbed; children; the elderly; patients who do not speak English; and patients whose level of education or cultural background differs significantly from that of the healthcare team.
- Unexpectedly intense pain, particularly if sudden or associated with altered vital signs, such as hypotension, tachycardia, or fever, should be evaluated immediately, and new diagnoses, such as wound dehiscence, infection, or deep venous thrombosis, should be considered.
- Family members should be involved when appropriate.

PAIN ASSESSMENT TOOLS

- The most reliable indicator of the existence and intensity of pain and any resultant distress is the patient's self-report.
- Self-report measurement includes numeric or verbal descriptor ratings and visual analogue scales.
- Tools should be reliable, valid, and easy for the patient and the nurse or physician to use. One may use these tools by showing a diagram to the patient to indicate the appropriate rating. One may also simply ask the patient for a verbal response: "On a scale of 0 to 10 with 0 as no pain and 10 as the worst pain possible, how would you rate your pain?" or "Please describe your pain for me, from no pain to mild, moderate, severe, or pain as bad as it could be."
- Tools must be appropriate for the patient's developmental, physical, emotional, and cognitive status.

PREOPERATIVE PREPARATION

- Discuss the patient's previous experiences with pain and beliefs about and preferences for pain assessment and management.
- Give the patient information about pain management therapies that are available and the rationale underlying their uses.
- Develop with the patient a plan for pain assessment and management.
- Select a pain assessment tool and teach the patient to use it.
- Provide the patient with education and information about pain control, including nonpharmacologic options, such as relaxation, distraction, imagery, and massage.
- Inform patients that it is easier to prevent pain than to attempt to reduce it after it is established, and that communication of unrelieved pain is essential for its relief. Emphasize the importance of a factual report of pain, avoiding stoicism or exaggeration.

POSTOPERATIVE ASSESSMENT

- Assess the patient's perceptions, along with behavioral and psychologic responses. Observations of behavior and vital signs should not be used instead of a self-report, unless the patient is unable to communicate.
- Assess and reassess pain frequently during the immediate postoperative period. Determine frequency of assessment based on the procedure performed and severity of pain. Pain should be assessed every 2 hours during the first postoperative day after major surgical procedures.
- Increase the frequency of assessment and reassessment if the pain is poorly controlled or if interventions are changing.
- Record the pain intensity and response to intervention in an easily visible and accessible place, such as a bedside flow sheet.
- Revise the management plan if the pain is poorly controlled.
- Review with the patient before discharge the interventions used and their efficacy, and provide specific discharge instructions regarding pain and its management. Have patient "teach back" or repeat instructions in his or her own words.

Modified from Acute Pain Management Guideline Panel: *Acute pain management in adults: operative procedures. Quick reference guide for clinicians,* AHCPR pub. no. 92-0019, Rockville, Md, 1992, Agency for Health Care Policy and Research, U.S. Public Health Service, U.S. Department of Health and Human Services; Flaherty E: Using pain-rating scales with older adults, *AJN* 108(6):40-47, 2008; Silkman C: Assessing the seven dimensions of pain, *AJN* 3(1):13-15, 2008.

With the advent of The Joint Commission (TJC) standards for pain management, healthcare providers had to become more knowledgeable about pain assessment and management. An excellent resource is the monograph developed by the National Pharmaceutical Council as part of a collaborative project with TJC (NPC, 2001). Patients of differing cultures respond to and communicate pain differently. A patient may believe that nonverbal communication expresses the pain to the nurse, but the nurse may not recognize the clues. Common misconceptions about pain also abound. These misconceptions must be recognized and corrected. A summary of misconceptions is listed in Table 9-2.

Buss and Melderis (2002) developed a tool to allow perianesthesia nurses to assess cognitively impaired postanesthesia patients to determine the presence of pain. This tool is limited to use in the phase I PACU but adds to the PACU nurse's ability to address acute postoperative pain. The tool, an algorithm, was developed to "assist perianesthesia nurses with the assessment and management of pain during the patient's emergence from anesthesia" (Figure 9-13). ASPAN established the first comprehensive pain and comfort guideline. The guideline addresses assessment, expected outcomes, and appropriate interventions for pain in the preoperative phase, postanesthesia phase I, and postanesthesia phases II and III (ASPAN, 2003).

The available guidelines for pain are very general and do not address procedural pain (Kehlet, 2007). However, that is changing. Procedure-specific and evidence-based pain management guidelines are now available through a web-based program called PROSPECT (Procedure Specific Postoperative Pain Management) (Pasero, 2007; PROSPECT, 2009). These clinical practice guidelines and recommendations were developed after consensus of an international group of surgeons and anesthesia care providers who have reviewed pain research and graded the evidence (Figure 9-14).

SURGICAL PHARMACOLOGY

Dosing Data for Nonopioid Analgesics

Drug	Usual Adult Dose	Usual Pediatric Dose*	Comments
ORAL			
Acetaminophen	650-975 mg q4hr	10-15 mg/kg q4hr	Acetaminophen lacks peripheral antiinflammatory activity of NSAIDs
Aspirin	650-975 mg q4hr	10-15 mg/kg q4hr†	The standard against which other NSAIDs are compared Inhibits platelet aggregation; may cause postoperative bleeding
Choline magnesium trisalicylate (Trilisate)	1000-1500 mg bid	25 mg/kg q12hr	May have minimal antiplatelet activity; also available as oral liquid
Diflunisal (Dolobid)	1000 mg initial dose followed by 500 mg q12hr	—	—
Etodolac (Lodine)	200-400 mg q6hr	—	—
Fenoprofen calcium (Nalfon)	200 mg q4-6hr	—	—
Flurbiprofen	100 mg bid, tid, qid	—	—
Ibuprofen (Motrin, others)	400 mg q4-6hr	10 mg/kg q6-8hr	Available as several brand names and generic forms; also available as oral suspension
Ketoprofen (Orudis)	25-75 mg q6-8hr	—	—
Magnesium salicylate	650 mg q4hr	—	Many brands and generic forms available
Meclofenamate sodium (Meclomen)	50 mg q4-6hr	—	—
Mefenamic acid (Ponstel)	250 mg q6hr	—	—
Naproxen (Naprosyn)	500 mg initial dose followed by 250 mg q6-8hr	5 mg/kg q12hr	Also available as oral liquid
Naproxen sodium (Anaprox)	550 mg initial dose followed by 275 mg q6-8hr	—	—
Oxaprozin	600 mg q24hr	—	Long half-life, so can be given once daily
Salsalate (Disalcid, others)	500 mg q4hr	—	May have minimal antiplatelet activity
Sodium salicylate	325-650 mg q3-4hr	—	Available in generic form from several distributors
SELECTIVE COX-2 INHIBITOR			
Celecoxib (Celebrex)	100-200 mg twice daily	—	Reduces risk of gastrointestinal side effects and renal toxicity No effects on platelet aggregation May have a higher risk of having heart attack or stroke
PARENTERAL NSAID			
Ketorolac	30 or 60 mg IM initial dose followed by 15 or 30 mg q6hr Oral dose after IM dose: 10 mg q6-8hr IV dose: 30 mg for healthy adults and 15 mg for adults >65 years	—	IM dose not to exceed 5 days. IV administration comparable to 10 mg IM morphine

NOTE: Only the above NSAIDs have Food and Drug Administration approval for use as simple analgesics, but clinical experience has been gained with other drugs as well.

*Drug recommendations are limited to NSAIDs for which pediatric dosing experience is available.

COX-2, cyclooxygenase-type 2; *NSAID,* nonsteroidal antiinflammatory drug.

†Contraindicated in presence of fever or other evidence of viral illness.

Modified from Acute Pain Management Guideline Panel: *Acute pain management in adults: operative procedures. Quick reference guide for clinicians,* AHCPR pub. no. 92-0019, Rockville, Md, 1992, Agency for Health Care Policy and Research, U.S. Public Health Service, U.S. Department of Health and Human Services.

SURGICAL PHARMACOLOGY

Dosing Data for Opioid Analgesics

Drug	Approximate Equianalgesic Oral Dose	Approximate Equianalgesic Parenteral Dose	Recommended Starting Dose (Adults >50 kg Body Weight)		Recommended Starting Dose (Children and Adults <50 kg Body Weight)*	
			Oral	*Parenteral*	*Oral*	*Parenteral*
OPIOID AGONIST						
Morphine†	30 mg q3-4hr (around-the-clock dosing) 60 mg q3-4hr (single dose or intermittent dosing)	10 mg q3-4hr	30 mg q3-4hr	10 mg q3-4hr	0.3 mg/kg q3-4hr	0.1 mg/kg q3-4hr
Codeine‡	130 mg q3-4hr	75 mg q3-4hr	60 mg q3-4hr	60 mg q2hr (IM/Sub-Q)	1 mg/kg q3-4hr§	NR
Hydromorphone† (Dilaudid)	7.5 mg q3-4hr	1.5 mg q3-4hr	6 mg q3-4hr	1.5 mg q3-4hr	0.06 mg/kg q3-4hr	0.015 mg/kg q3-4hr
Hydrocodone (in Lorcet, available as Lortab, Vicodin, others)	30 mg q3-4hr	NA	10 mg q3-4hr	NA	0.2 mg/kg q3-4hr§	NA
Levorphanol (Levo-Dromoran)	4 mg q6-8hr	2 mg q6-8hr	4 mg q6-8hr	2 mg q6-8hr	0.04 mg/kg q6-8hr	0.02 mg/kg q6-8hr
Meperidine (Demerol)	300 mg q2-3hr	100 mg q3hr	NR	100 mg q3hr	NR	0.75 mg/kg q2-3hr
Methadone (Dolophine, others)	20 mg q6-8hr	10 mg q6-8hr	20 mg q6-8hr	10 mg q6-8hr	0.2 mg/kg q6-8hr	0.1 mg/kg q6-8hr
Oxycodone (Roxicodone, also in Percocet, Percodan, Tylox, others)	30 mg q3-4hr	NA	10 mg q3-4hr	NA	0.2 mg/kg q3-4hr§	NA
Oxymorphone† (Numorphan)	NA	1 mg q3-4hr	NA	1 mg q3-4hr	NR	NR
OPIOID AGONIST—ANTAGONIST AND PARTIAL AGONIST						
Buprenorphine (Buprenex)	NA	0.3-0.4 mg q6-8hr	NA	0.4 mg q6-8hr	NA	0.004 mg/kg q6-8hr
Butorphanol (Stadol)	NA	2 mg q3-4hr	NA	2 mg q3-4hr	NA	NR
Nalbuphine (Nubain)	NA	10 mg q3-4hr	NA	10 mg q3-4hr	NA	0.1 mg/kg q3-4hr
Pentazocine (Talwin, others)	150 mg q3-4hr	60 mg q3-4hr	50 mg q4-6hr	NR	NR	NR

**CAUTION:* Doses listed for patients with body weight <50 kg cannot be used as initial starting doses in infants <6 months of age. Consult the AHCPR *Clinical practice guideline for acute pain management: operative or medical procedures and trauma* section on management of pain in neonates for recommendations.
NOTE: Published tables vary in the suggested doses that are equianalgesic to morphine. Clinical response is the criterion that must be applied for each patient; titration to clinical response is necessary. Because there is not complete cross-tolerance among these drugs, it is usually necessary to use a lower equianalgesic dose when changing drugs and to retitrate to response.
CAUTION: Recommended doses do not apply to patients with renal or hepatic insufficiency or other conditions affecting drug metabolism and kinetics.
†For morphine, hydromorphone, and oxymorphone, rectal administration is an alternate route for patients unable to take oral medications, but equianalgesic doses may differ from oral and parenteral doses because of pharmacokinetic differences.
‡*CAUTION:* Codeine doses >65 mg often are inappropriate because of diminishing incremental analgesia with increasing doses but continually increasing constipation and other side effects.
§*CAUTION:* Doses of aspirin and acetaminophen in combination opioid/NSAID preparations also must be adjusted to the patient's body weight.
NA, Not available; *NR,* not recommended.
Modified from Acute Pain Management Guideline Panel: *Acute pain management in adults: operative procedures. Quick reference guide for clinicians,* AHCPR pub. no. 92-0019, Rockville, Md, 1992, Agency for Health Care Policy and Research, U.S. Public Health Service, U.S. Department of Health and Human Services, available at www.ahrq.gov/clinic/medtep/acute.htm. Accessed December 1, 2009.

TABLE 9-2

Misconceptions about Pain

Misconception	Correction
Best judge of the existence and severity of patient pain is the physician or nurse caring for the patient.	The patient is the authority about his or her pain. The patient's self-report is the most reliable indicator of the existence and intensity of pain.
Clinician must believe what the patient says about pain.	The clinician must accept and respect the patient's self-report of pain and proceed with an appropriate assessment and treatment. The clinician is entitled to a personal opinion but should not allow it to guide practice.
Patients should not receive analgesics until the cause of pain is diagnosed.	Symptomatic relief of pain should be provided while the investigation of cause proceeds.
Visible signs, either physiologic or behavioral, accompany pain and can be used to verify its existence and severity.	Even with severe pain, periods of physiologic and behavioral adaptation occur, leading to periods of minimal or no signs of pain.
Pain never killed anyone.	Unrelieved pain may be dangerous and is unacceptable. Postoperative pain can delay healing and contribute to complications that can be life-threatening. Acute pain warns of actual or potential tissue damage and resolves when healing has occurred. Unrelieved postoperative pain is a complication or risk, not an acceptable consequence of surgery.
If the patient requires higher doses of opioids than other patients, "he's hitting the PCA button too often."	There is no set dose of opioid that is effective for all patients. Even an opioid-naïve patient may require 6× more opioid than another patient. A patient who is opioid-tolerant may require 100× the opioid of an opioid-naïve patient.

Modified from Canobbio MM: *Mosby's handbook of patient teaching,* ed 3, St Louis, 2006, Mosby; McCaffery M, Pasero C: *Pain clinical manual,* ed 2, St Louis, 1999, Mosby; Pasero C: Challenges in pain assessment, *JOPAN* 24(1):50-54, 2009.

Evaluation

The PACU nurse evaluates the patient on outcomes identified as significant after the initial assessment. For the desired outcomes presented previously in this chapter, these might be stated as follows:

- The patient demonstrated adequate ventilation, perfusion, and expansion of lungs on discharge from the PACU. Oxygen saturation was adequate while receiving room air.
- The patient maintained adequate cardiac output; blood pressure and heart rate were within normal range.
- The patient was normothermic in discharge from the PACU.
- The patient had appropriate cognitive function and was oriented to time and person.
- The patient's pain was 4 or less (on a scale of 0 to 10) or at a pain/comfort level established as acceptable by patient. The patient was relaxed and slept at intervals. The patient verbalized satisfactory pain relief.

DISCHARGE FROM THE PACU

The PACU nurse completes a final assessment immediately before the patient's discharge and transfer to the surgical unit. The nurse assesses vital signs, level of consciousness, condition of the operative site, pain and comfort level, intake and output, respiratory function and oxygen saturation, and mobility. If the patient requires ongoing oxygen therapy, a transport oxygen canister is provided, and oxygen supply is prepared in the hospital room.

The patient usually is discharged from the PACU by an anesthesia care provider, who may be present and write a discharge order. Alternatively, a numeric scoring system approved by the department of anesthesia may be used to determine if the patient is ready for discharge. The most common scoring system in use is the Aldrete score. Activity, respiration, circulation, consciousness, and oxygen saturation level are scored from 0 to 2 (see Figure 9-3). A total score of 8 to 10 is generally acceptable for PACU discharge, with exceptions made by physician order.

A hand-off report on the patient's condition is given to the nurse who will assume care for the patient on the surgical or short procedure unit. This report may be given by telephone before the patient leaves the PACU or in person after the patient reaches the unit. The report should include a preoperative history, pertinent information regarding the patient's surgery and recovery, medications the patient was given, physician's orders, and all other appropriate information.

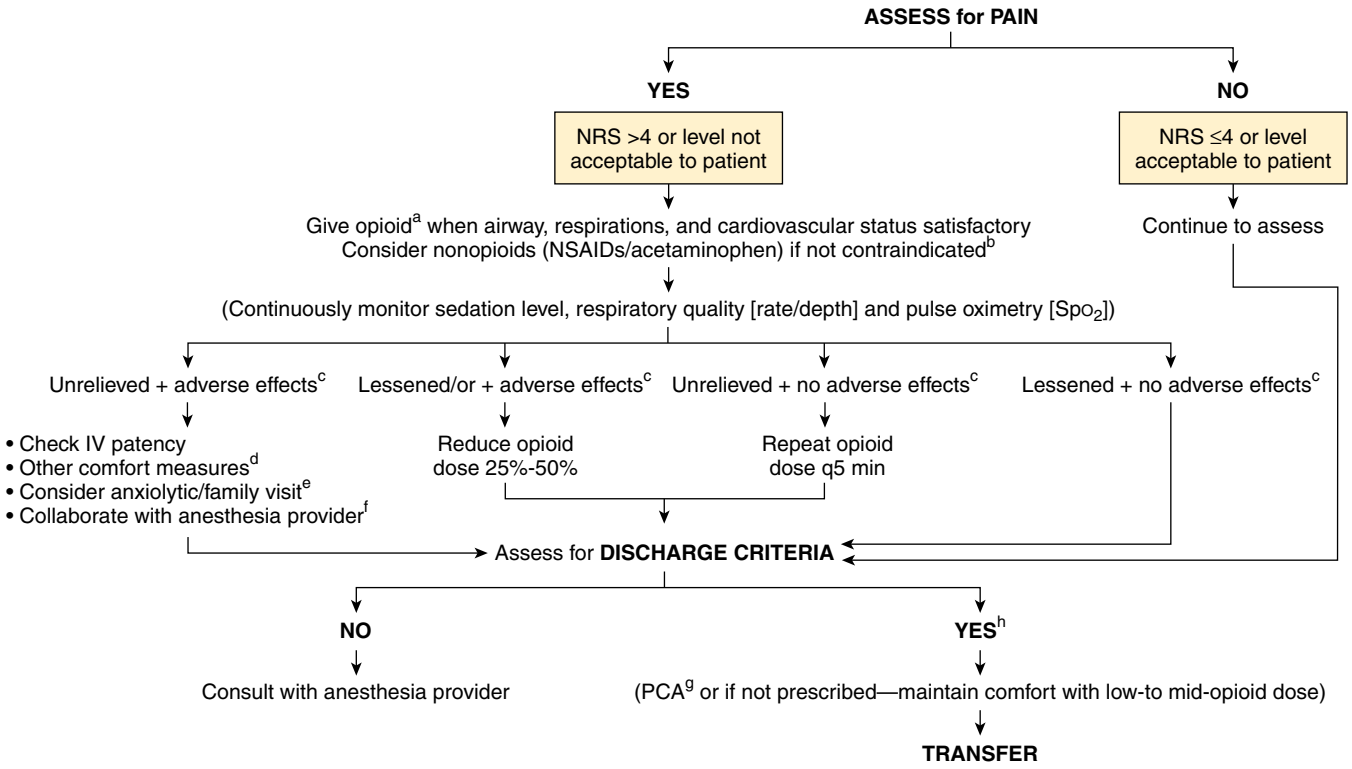
ADMISSION TO THE SURGICAL OR SHORT PROCEDURE UNIT

The patient's room is prepared for admission, and any necessary equipment is obtained. The patient is assisted into the bed. To prevent falls the bed rails should remain raised until the patient is fully awake. The patient is informed to notify the nurse for assistance to ambulate. Family members also are instructed and enlisted to maintain safety for the patient. Equipment and the patient's condition should be explained to family members present. A special concern is the use of PCA. Family members should be instructed that the PCA is for the patient's use only and that pushing the PCA button for the patient can have a detrimental effect on the patient's well-being.

POSTOPERATIVE NURSING CONSIDERATIONS

Assessment

The nurse in the receiving unit makes an immediate assessment as soon as the patient transfers to the bed. The nurse may choose a head-to-toe or systems' assessment. Parameters



Perianesthesia Pain Management Considerations (for Use in Conjunction with PACU Pain Algorithm)

- Using the Sedation Scale, level of sedation (LOS) 3 requires proceeding with opioid cautiously (reduce opioid dose 25%-50%/increase interval between doses). LOS 4 requires holding opioids, and other sedatives, regardless of numeric rating scale (NRS); administer naloxone if physical stimulation fails to reverse respiratory depression and sedation.
- Respiratory function in an emergent tachypneic patient can improve through use of opioids by reducing respiratory rate, the depth increases, and the Spo_2 rises.
- During preadmission testing/preparation, staff should identify candidates for PCA and teach its use. Include in teaching the benefits of effective pain control, use of the pain scale, and the importance of reporting pain early. This information should be reinforced before surgery/procedure and again in the PACU.
- Encourage patients preoperatively to consider and discuss with anesthesia provider the use of local, regional, or epidural anesthesia/analgesia for preemptive analgesia, because the most effective pain control is achieved through multimodal approach (combined use of local anesthesia, opioids, and nonopioids).
- Give nonopioids (acetaminophen, salicylates, NSAIDs) on admission to the PACU when not contraindicated or previously administered. Encourage anesthesia providers to administer intraprocedure for preemptive analgesia.
- Preferred opioids are morphine, fentanyl, and hydromorphone. Avoid meperidine except for treatment of shivering or allergy to other opioids; meperidine metabolite, normeperidine, is toxic to the central nervous system and can cause seizures and death.
- Determine patient's preoperative use of opioids, nonopioids, and substance/alcohol use for possible higher opioid requirements.
- Give feedback to anesthesia provider when a patient has prolonged pain with an NRS higher than 4 for collaborative solutions.
- Avoid sedatives and use of antiemetics that produce sedation. Avoid IM injections.
- Pain goal: Level of comfort should allow patient to deep breathe, cough, turn, and move into/out of bed. Opioid side effects should be minimal.
- Appearing to sleep may not equal comfort. Always ask patients to rate their pain.
- Initiate PCA early when possible for evaluating effectiveness of programmed dose. Opioid loading is indicated first for severe escalating pain with minimal opioids on board.
- This algorithm is a suggested guide. Interventions should be individualized to each patient.

[a]For a numeric rating scale (NRS) of 5 or higher, use the higher opioid dose range; for an NRS lower than 5, use the mid-to-low dose range.
[b]Acetaminophen, salicylates, or NSAIDs (which include ketorolac, ibuprofen, salsalate, nabumetone, choline magnesium trisalicylate, and so on). Rofecoxib (Vioxx) has been withdrawn from the market. Contraindications to NSAIDs are aspirin-sensitive asthma, bleeding, coagulopathy disorders, history of gastrointestinal bleeding, renal compromise, and hypovolemia.
[c]Adverse effects include but are not limited to increasing sedation (LOS 3), respiratory depression, local histamine reaction, and uncontrolled nausea and vomiting.
[d]Comfort measures include the following: reassurance, reposition, warm/cold applications, relaxation measures, and music therapy.
[e]Use anxiolytics for anxiety and muscle spasms only.
[f]Collaborate for other adjuvants or regional block. Consult also with surgeon.
[g]Start PCA early or after opioid loading (PCA pump or syringe) per anesthesia provider orders for rapidly escalating pain higher than an NRS of 4.
[h]Discharge criteria include the following: NRS of pain of 4 or less, LOS of 3 or less, respiratory rate of 10 or higher, Spo_2 of 93% or higher, and minimal other opioid side effects.

FIGURE 9-13 PACU pain algorithm.

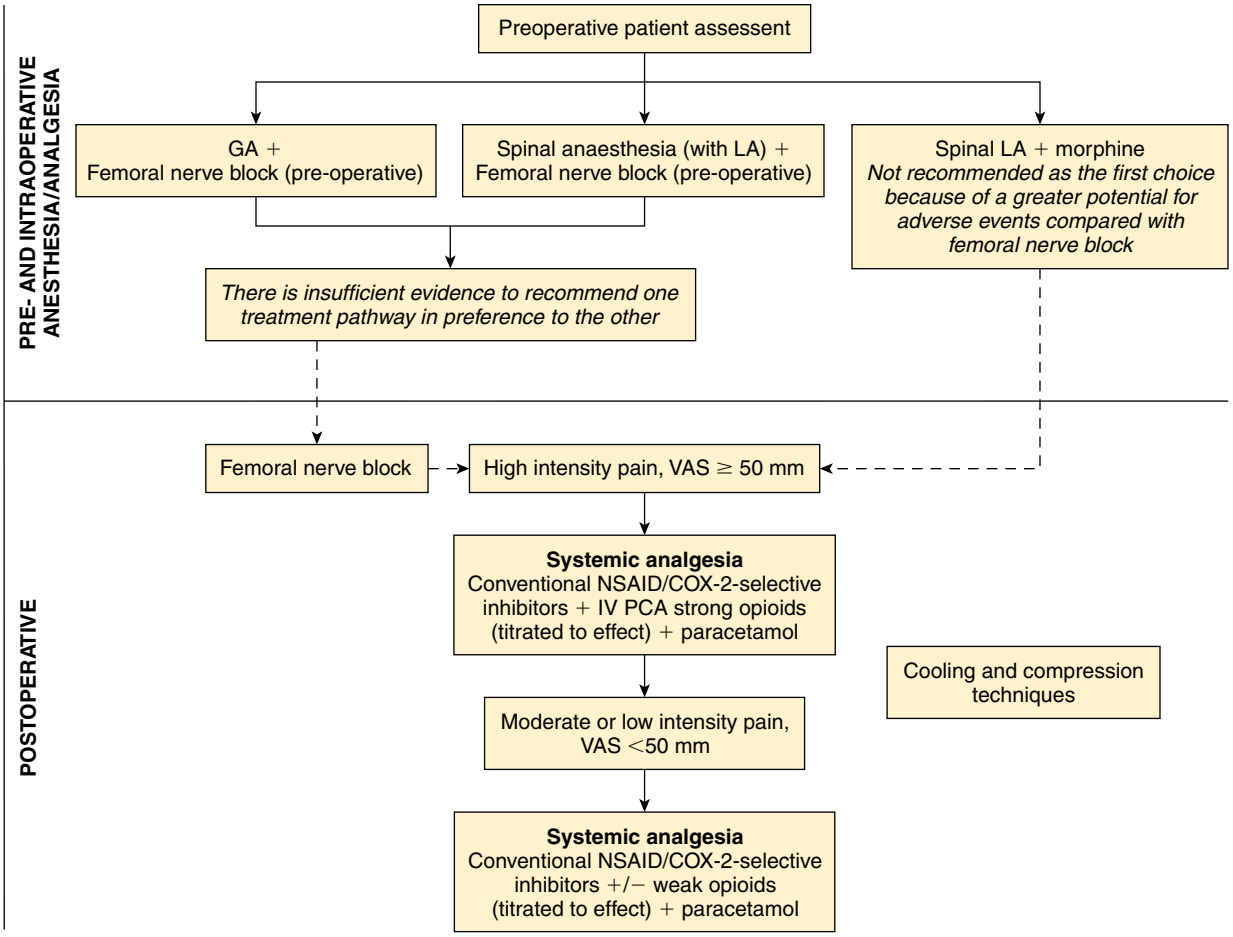


FIGURE 9-14 Algorithm for the management of postoperative pain—total knee arthroplasty (TKA).

include respiratory, cardiovascular, and neurologic status. The condition of the dressing and surgical site and patient comfort and safety also are assessed (Box 9-4).

Nursing Diagnosis

Nursing diagnoses related to the care of the postoperative patient include the following:

- Risk for Infection
- Ineffective Breathing Pattern
- Acute Pain
- Imbalanced Nutrition: Less Than Body Requirements
- Impaired Physical Mobility

Outcome Identification

Outcomes identified for the selected nursing diagnoses could be stated as follows:

- The patient will be free from infection as indicated by normal vital signs; temperature within normal range; normal white blood cell count; clear breath sounds; clear, yellow urine; warm, dry skin; and adequate nutritional intake.
- The patient's respirations will be easy, unlabored, and adequate.
- The patient will state subjective assertions of comfort: "I am in no pain." "My pain is a 2 on the scale of 0-10." The patient will have no objective signs of discomfort (e.g., grimaces, tachycardia).
- The patient will eat well from prescribed diet; weight loss will be minimal.
- The patient will ambulate at an appropriate level and carry out activities of daily living appropriate for condition.

Planning

Planning for the postoperative patient requires knowledge of surgical procedures and underlying medical conditions. Throughout the patient's stay, planning must always involve the family or significant others, with measurable goals determined by discharge. A Sample Plan of Care for the postoperative patient is on p. 290.

Implementation

Wound Healing. Nursing care of the postoperative patient includes a focus on wound healing. Nursing interventions focus on preventing and monitoring wound complications. The nurse should use strict aseptic technique when placing a new dressing and monitor for signs and symptoms of infection (e.g., elevated body temperature; red, swollen, warm area surrounding the incision; elevated white blood cell count; tachycardia; and purulent drainage from wound) (Smith, 2007). For

BOX 9-4

Patient Assessment on Admission to Postoperative Unit from the PACU

- Respiratory status
  - Patency of airway
  - Respirations—depth, rate, character
  - Breath sounds—presence, character
- Circulatory status
  - Pulse, blood pressure
  - Skin color, temperature
  - Capillary filling
- Neurologic status
  - Level of consciousness
  - Ability to move extremities, peripheral pulses (as applicable)
- Dressing
  - Presence of drainage
  - Presence of tubes to be connected to drainage systems
- Comfort
  - Presence of pain, nausea, vomiting
  - Pain score
  - Patient positioned for comfort and to facilitate ventilation
  - Other comfort measures as determined by patient preference (e.g., warm blanket, music, massage)
- Safety
  - Use of two patient identifiers
  - Necessity for side rails
  - Call cord within reach and instructions on operation reviewed
- Equipment
  - Monitors connected and functioning
  - Intravenous fluids—location of insertion site, type and size of intravenous device, type of infusion, rate, amount in bag, patency of tubing, assessment of site
  - Drainage systems (e.g., nasogastric, chest, urinary)—type, patency of tubing, connection of appropriate container, character and amount of drainage

a detailed discussion of the pathophysiology of wound healing, see Chapter 8.

Adequate Respirations. Postoperative patients are at risk for pulmonary complications because of increased respiratory secretions, decreased lung expansion, depression of the respiratory center, and the possibility of aspiration of gastric contents. These complications can be minimized by appropriate nursing management, including elevating the head of the bed whenever possible; encouraging coughing, turning, and deep breathing every 2 hours; ambulating the patient as soon as possible; and encouraging hydration (Smith, 2007).

Circulation. Venous stasis in the postoperative patient can lead to thrombophlebitis, which is usually a preventable complication. Platelets adhere to the venous wall and form a thrombus, with a resultant potential for deep venous thromboembolism (DVT) or pulmonary embolus.

Prevention often includes administration of prophylactic heparin, aspirin, dextran, or warfarin. Application of an intermittent external pneumatic sequential compression device (SCD) may be ordered, or application of antiembolic (AE) hosiery may be required. Nursing measures that can prevent formation of a thrombus include using the AE hosiery whether the patient is in or out of bed, teaching the patient not to cross the legs, having the patient perform isometric leg exercises, and encouraging early ambulation.

If thrombophlebitis is suspected (pain or tenderness, erythema, localized area of warmth, swelling), the patient should return to bed and the physician notified. Treatment consists of rest, heat, AE hosiery, and anticoagulant therapy.

Urinary Function. One of the priorities during surgery and immediately afterward is to keep the patient well hydrated so that voiding takes place 6 to 8 hours after surgery. Usually intake is greater than output for 48 hours, as the fluid and electrolyte balance returns to normal. Every effort is made to refrain from use of a catheter to avoid the risk of urinary tract infection. Measures to help the patient void include warming the bedpan, letting water run, applying warm water to the perineum, and allowing the patient to go to the bathroom when possible. If discomfort is present and the bladder is palpable, catheterization becomes necessary. In the event several catheterizations are required, an indwelling catheter is inserted. Hydration of the patient becomes a priority. Intake and output are recorded accurately. A urine output of less than 30 ml/hr is reported to the physician.

Bowel Elimination. The postoperative patient who underwent abdominal or pelvic surgery may have decreased peristalsis for at least 24 hours; this may persist for several days for the patient who had gastrointestinal surgery (Smith, 2007). Increased fluid intake and early ambulation promote the return of peristalsis. Bowel sounds should be auscultated with a stethoscope to ensure that peristalsis has returned, and the abdomen should be assessed for distention.

Constipation occurs frequently after surgery because of the effects of the anesthetic agents and narcotics, immobility, and decreased gastrointestinal motility. Fluids, roughage, and bulk laxatives can relieve constipation. Occasionally a suppository or an enema is needed to empty the lower bowel.

Early Ambulation. Early ambulation can expedite recovery and prevent complications. Early ambulation increases muscle tone, improves gastrointestinal and urinary tract function, stimulates circulation, and increases vital capacity (Smith, 2007). Benefits are shown in Figure 9-15. Ambulation usually is postponed if severe infection or thrombophlebitis is present.

Evaluation

Evaluation of the postoperative patient outcomes on the surgical unit might be stated as follows:

- The patient's vital signs and laboratory values were within normal limits; the surgical site showed no signs or symptoms of infection.
- The patient's breathing was easy and unlabored; breath sounds were clear bilaterally.
- The patient verbalized freedom from pain and was free from facial grimaces, moaning, and other evidence of pain or discomfort.
- The patient was eating well; there was no weight loss or complaints of nausea or vomiting.
- The patient ambulated regularly and was assessed as capable of performing appropriate activities of daily living.

SAMPLE PLAN OF CARE

Admission to the Postoperative Patient Care Unit

NURSING DIAGNOSIS

Risk for Infection related to altered skin integrity, compromised aseptic technique, or malnutrition

OUTCOME

The patient will be free from infection, as indicated by normal vital signs; temperature within normal range; normal white blood cell count; clear breath sounds; clear, yellow urine; warm, dry skin; and adequate nutritional intake.

INTERVENTIONS

- Monitor vital signs every 4 hours or as prescribed.
- Monitor temperature every 4 hours as needed; document and report increased temperature.
- Monitor laboratory values for evidence of infection; report variance from normal.
- Encourage patient to take deep breaths or sustained maximal inspiration or use respiratory aids.
- Preserve closed urinary system and provide catheter care. Remove catheter as soon as possible.
- Encourage patient to eat foods high in protein and vitamin C.
- Avoid antiinflammatory drugs such as steroids to facilitate healing.
- Use aseptic technique when changing dressings and change soiled dressings immediately.
- Monitor contents of wound drainage catheters.
- Teach patient and family members how to care for surgical site, what to expect, and when and who to call if drainage at incision or drain sites increases or if other symptoms develop, such as fever, increased pain at site, redness and swelling of incision.

NURSING DIAGNOSIS

Ineffective Breathing Pattern related to postoperative pain, decreased energy, fatigue, decreased lung expansion, surgery

OUTCOME

The patient's respirations will be easy, unlabored, and adequate.

INTERVENTIONS

- Monitor respirations and chest expansion frequently for 24 to 48 hours after the surgical intervention.
- Place the bed in high-Fowler position if possible.
- Auscultate lungs and evaluate productiveness of cough; document any adventitious breath sounds and nature and amount of sputum associated with cough (as appropriate).
- Have patient cough and deep breathe at regular intervals; collaborate with patient to identify cues to remember to undertake these activities or recommend 10 deep breaths each hour.
- Encourage use of respiratory aids (e.g., incentive spirometry, if appropriate).
- Treat underlying conditions, such as pain.
- Demonstrate splinting incisional area with pillow before cough.
- Encourage patient to turn and change positions at least every 2 to 3 hours.
- Encourage early and regular ambulation and explain importance to patient.

NURSING DIAGNOSIS

Acute Pain

OUTCOME

The patient will state subjective assertions of comfort: "I am in no pain." "My pain is a 2 on a scale of 0-10." The patient will have no objective signs of discomfort (e.g., grimaces, tachycardia).

INTERVENTIONS

- Discuss the concept of pain and what it means for patient (e.g., throbbing, aching, stabbing, burning, tight).
- Educate patient and family members on the use of pain rating scale:
  - Show pain rating scale and explain its purpose.
  - Explain the components of the scale (if numeric scale used, explain what the numbers mean).
  - Set realistic comfort goals (pain rating score should be ≤4).
- Encourage patient to report pain, emphasizing that this is an important part of his or her care (Rapid Response Team box).
- Consider personal, cultural, spiritual, and ethnic beliefs in developing a pain management plan with patient.
- Document assessment of pain (intensity, duration, location, frequency) and response to pain management therapies.
- If patient has continuous local anesthetic infusion therapy (also known as *site-specific infusion therapy*) (common with select orthopedic procedures, abdominal hysterectomy, mastectomy, or hernia repair):
  - Assess site to ensure dressing is intact and catheter site is clean and dry.
  - Query patient to determine if symptoms of local anesthetic toxicity are present (dizziness, ringing in the ears, metallic taste, tingling or numbness of lips, slowed speech); contact physician to initiate immediate treatment if assessment is positive.
- If patient is to be discharged with infusion therapy, provide verbal and written instructions.
- Support patient in the use of personally effective nonpharmacologic pain management strategies (e.g., relaxation techniques, distraction, massage, biofeedback, music, guided imagery, meditation).

NURSING DIAGNOSIS

Imbalanced Nutrition: Less Than Body Requirements related to surgery

OUTCOME

The patient will eat well from prescribed diet; weight loss will be minimal.

INTERVENTIONS

- Encourage patient to eat foods high in protein and vitamin C.
- Offer frequent, small amounts of food or high-protein liquids to patient with little or no appetite.
- Encourage ambulation (improves appetite).
- Schedule procedures not to conflict with mealtime.
- Administer medication for pain as needed.
- Determine patient's previous history of nausea and vomiting after surgery; consult with physician regarding preventive measures for discharge if history is positive.
- Refer to nutritional support team if appropriate; dietary consultation may be important for patient with cultural or ethnic food preferences.

NURSING DIAGNOSIS

Impaired Physical Mobility related to surgical procedure or pain

OUTCOME

The patient will ambulate at an appropriate level and carry out activities of daily living appropriate for condition.

INTERVENTIONS

- Encourage muscle-strengthening exercises before ambulation. Encourage ambulation or position changes and extremity exercises at least every 8 hours.
- Encourage leg exercises in bed.
- Before attempting to ambulate, have patient dangle legs over side of bed until pulse rate has stabilized and patient is not dizzy.
- Have two people to help ambulate if patient is weak or obese.
- Encourage patient to walk further with each ambulation.
- Teach proper use of appropriate devices (e.g., crutches, slings, ACE bandages) and observe return demonstration.

RAPID RESPONSE TEAM

Rapid response teams (RRTs) include various responders. When the RRT is activated, as in the following scenario, the nurse also contacts the patient's physician. The nurse stays with the patient and continues to monitor the patient's status. When the RRT arrives, a brief history is provided and RRT members conduct assessments and prescribe interventions.

A postoperative patient who had undergone a vaginal hysterectomy was in the PACU for 1 hour, after which she was discharged to a surgical floor for care. At the time of discharge, vital signs were normal, and self-reported pain level was 3 on a 0 to 10 scale. After 1 hour on the surgical unit, the patient, who had been dozing, rolled over and asked for more pain medicine, saying that her pain was now a 7. The nurse checked vital signs for the hour and noted that the current blood pressure was 90/60 mm Hg while it had been 120/70 to 130/78 mm Hg since before surgery. She checked the vaginal pad, which was dry. Because the nurse had administered a dose of pain medication and because the blood pressure had changed to low-normal from previous measurements, the nurse rechecked the blood pressure in 15 minutes. The pressure was now 85/58 mm Hg. At that point in time, the nurse checked the heart rate, which was 120 beats/min, increased from the 80-89 beats/min range. She noted the vaginal pad was still dry, but checked the abdomen and discovered a hard knot on the left side of the abdomen that had not been present on admission from the PACU. The nurse immediately lowered the head of the bed, increased the intravenous rate of fluid, and called the rapid response ream.

The rapid response team arrived immediately. A stat hematocrit and type and crossmatch were drawn, and a urinary catheter was inserted to ascertain that the knot in the abdomen was not caused by a full bladder. A plasma volume expander, Hespan, was begun immediately and the patient placed in Trendelenburg's position after the BP measurement was determined to be 70/40 mm Hg. The surgeon and anesthesia provider were notified and the patient was immediately taken back to surgery; in the OR the patient was determined to have an arterial bleed, which was resutured, and then the abdomen was reexplored to verify hemostasis. The patient recovered without further incident and was discharged home 2 days later.

Modified from Mattiace R: Preventing hypovolemic shock, *Am Nurse Today* 3(3):28, 2008.

PATIENT SAFETY

Educating Patients about Medications for Pain Management

- Explain the purpose, dosage, schedule, and route of administration of any prescribed drugs and side effects to report to a physician or nurse.
- Give the patient general guidelines for the use of pain medications.
  - Provide information from the Agency for Healthcare Research and Quality Guidelines for patients.
  - Explain that a variety of pain-relief measures may be necessary for some types of pain.
  - Instruct the patient to use pain-relief measures before pain becomes severe. Determine the patient's ability or willingness to participate actively in the use of pain-relief measures, and suggest pain-relief measures the patient believes would be helpful.
  - Rely on patient behavior that indicates pain severity rather than on known physical stimuli.
  - Encourage the patient to try a pain-relief measure at least twice before abandoning it as ineffective. Instruct the patient to keep an open mind as to what may relieve pain.
  - Urge the patient to keep trying to relieve the pain and not to become discouraged.
- Discuss the use of nonopioid analgesics.
  - Inform the patient that nonopioid analgesics include acetaminophen, aspirin, and nonsteroidal antiinflammatory drugs, such as ibuprofen, indomethacin, and naproxen.
  - Explain that these medications are generally well tolerated, but have the potential to cause gastrointestinal ulceration, renal and hepatic toxic effects, and inhibition of platelet aggregation.
  - Tell the patient that if the nonopioid drug does not have a therapeutic effect initially, the dosage should be increased before another type of drug is tried.
- Discuss the use of opioids, which are indicated for severe postoperative pain or intractable pain such as that associated with cancer.
  - Inform the patient that opioids include morphine, hydromorphone, and methadone, and that these may be administered by oral route, intravenous drip, intrathecally, or epidurally to enhance the analgesic effect.
  - Explain that fixed dosage schedules with adequate doses for pain relief provide more constant blood levels and predictable pain relief. Suggest that additional doses may be needed for breakthrough pain.
  - Discuss the side effects of opioid analgesics, including constipation, vomiting, and respiratory and central nervous system depression.
  - Review the use of opioid agonists and antagonists, including nalbuphine (Nubain), butorphanol (Stadol), pentazocine (Talwin), and buprenorphine (Buprenex).
- Explain the use of analgesic potentiators.
  - Inform the patient that these drugs include hydroxyzine (Vistaril), diazepam (Valium), lorazepam (Ativan), diphenhydramine (Benadryl), and phenothiazine derivatives, such as promethazine (Phenergan), prochlorperazine (Compazine), and chlorpromazine (Thorazine).
  - Discuss the use of stimulants.
  - Inform the patient that these drugs include cocaine, methylphenidate (Ritalin), dextroamphetamine, and caffeine.
- Discuss other types of drugs used in pain control, including tricyclic antidepressants, such as amitriptyline (Elavil), imipramine (Tofranil), and doxepin (Sinequan); and butyrophenones, such as droperidol (Inapsine) and haloperidol (Haldol).
- Discuss and demonstrate the use of equipment for administering pain-relief medications.
  - External and implantable pumps for intravenous, epidural, and intrathecal administration of opioid analgesics
  - Patient-controlled analgesia, particularly for the management of acute pain, such as postoperative pain
  - Continuous subcutaneous infusion with an ambulatory infusion pump
  - Transcutaneous electrical nerve stimulation (TENS)
- Discuss the side effects of opioids. For example, constipation requires the use of laxatives and stool softeners (e.g., senna [Senokot]).

From Canobbio MM: *Mosby's handbook of patient teaching,* ed 3, St Louis, 2006, Mosby.

RESEARCH HIGHLIGHT

Patient Retention of Discharge Instructions

Lee and Bokovoy conducted a study to describe patient responses to predischarge instructions and teaching. The study sample included patients who had undergone either femoropopliteal bypass or abdominal aortic aneurysm repair. All patients in the study received standardized prewritten discharge instructions and verbal education from a staff nurse on the day of discharge. Items discussed in the discharge instructions included pain control, diet, bowel elimination, medications, activity limitations and progression, driving, sexual activity, bathing, incision care, clothing, foot care, and reasons to contact the surgeon. Three days after discharge, patients were contacted and surveyed to determine their understanding of the education provided.

The overall mean of comprehension was 67% with no significant difference between surgery groups. Further research on patient knowledge retention of preprinted patient education materials needs to be conducted. The authors also request more research to test the association of patient knowledge with objective outcomes, such as wound infection rates. Nurses need to be aware of patients' knowledge of discharge instructions because understanding is vital to the patient's outcome. Strategies such as "teach-back" are part of patient safety. In this type of strategy, the patient and family members, as applicable, or the individuals responsible for providing continuing care should be asked to recount in their own words what they have been told or reviewed as part of discharge education and planning.

Modified from Lee TL, Bokovoy J: Understanding discharge instructions after vascular surgery: an observational study, *J Vasc Nurs* 23(1):25-29, 2005.

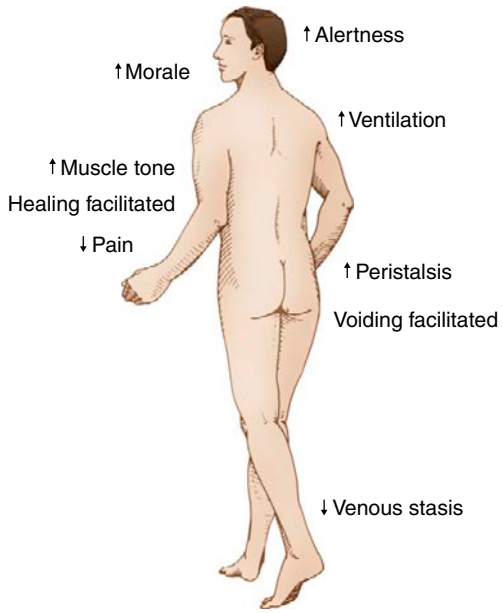


FIGURE 9-15 Benefits from early postoperative ambulation.

PATIENT AND FAMILY EDUCATION AND DISCHARGE PLANNING

Ideally, patient and family education and discharge planning begin before the patient's admission for surgery. The patient and family should be prepared to assume any care that may be needed after discharge. If needed, community resources are used. Home healthcare is a valuable resource for patients with treatment needs after discharge. The nurse responsible for the patient's care in the acute care setting collaborates and communicates with the home health team as soon as the need is identified so that the patient's care will be consistent.

The patient and family members should be instructed in the proper care of the wound or incision and signs and symptoms of a wound infection. They should know how to take a temperature and when the physician should be notified for elevated temperature. They should be knowledgeable about medication that the patient will be using at home, including analgesics (Patient Safety). Appropriate nonpharmacologic methods of pain control, such as imagery, distraction, massage, music therapy, and relaxation, also can be taught. An appointment for a return visit with the surgeon should be scheduled as ordered, and the nurse should emphasize the importance of the return visit. The patient resumes normal activities gradually according to the physician recommendations. The chapters on surgical interventions in Unit II have incorporated important elements for patient and family education and discharge planning. These elements assist the perioperative nurse in identifying and teaching what patients need to know and they facilitate safe self-care during recovery from operative and other invasive procedures (Research Highlight).

REFERENCES

AHCPR Acute Pain Management Guideline Panel: *Acute pain management: operative or medical procedures and trauma. Clinical practice guideline,* AHCPR Pub. No. 92-0032, Rockville, Md, 1992, Agency for Health Care Policy and Research, Public Health Service, U.S. Department of Health and Human Services. Available at: www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=hstat6.chapter. 8991. Accessed July 9, 2009.

Ahmed I: Prevention and management of laryngospasm, *Anaesthesia* 59:920, 2004.

American Society of Anesthesiologists: *Standards for postanesthesia care* (amended by House of Delegates, October 27, 2004), Park Ridge, Ill, The Society. Available at: www.asahq.org/publicationsAndServices/standards/36.pdf. Accessed July 9, 2009.

American Society of PeriAnesthesia Nurses: ASPAN pain and comfort clinical guideline, *J Perianesth Nurs* 18:232–236, 2003.

American Society of PeriAnesthesia Nurses: ASPAN's evidence-based clinical practice guideline for the prevention and/or management of PONV/PDNV, *J Perianesth Nurs* 21:230–242, 2006.

American Society of PeriAnesthesia Nurses: *2008-2010 Standards of perianesthesia nursing practice,* Cherry Hill, NJ, 2009a, The Society.

American Society of PeriAnesthesia Nurses: ASPAN'S evidence-based clinical practice guideline for the promotion of perioperative normothermia, *J Perianesth Nurs.* 24:271–287, 2009b.

Apfel CC et al: A simplified risk score for predicting postoperative nausea and vomiting, *Anesthesiology* 91:693–700, 1999.

Apfel CC et al: Comparison of predictive models for postoperative nausea and vomiting, *Br J Anaesth* 88:234–240, 2002.

Apfelbaum JL et al: Postoperative pain experience: results from a national survey suggest postoperative pain continues to be undermanaged, *Anesthe Analge* 97:534–540, 2003.

Banks A: Innovations in postoperative pain management; continuous infusion of local anesthetics, *AORN J* 85(5):904–914, 2007.

Benca J: Bronchospasm. In Atlee JL: *Complications in anesthesia*, ed 2, Philadelphia, 2007, Saunders, pp 189–192.

Brophy JM: Celecoxib and cardiovascular risks, *Expert Opin Drug Saf* 4(6):1005–1015, 2005.

Buss HE, Melderis K: PACU pain management algorithm, *J Perianesth Nurs* 17(1):11–20, 2002.

Doufas AG: Consequences of inadvertent perioperative hypothermia, *Best Pract Res Clin Anaesthiol* 17(4):535–549, 2003.

Dunwoody CJ et al: Assessment, physiological monitoring, and consequences of inadequately treated acute pain, *J Perianesth Nurs* 23:S15–S17, 2008.

Flaherty E: Using pain-rating scales with older adults, *AJN* 108(6):40–47, 2008.

Gan TJ et al: Society for Ambulatory Anesthesia guidelines for the management of postoperative nausea and vomiting, *Anesth Analg* 105: 1615–1628, 2007.

Golembiewski J, Tokumaru S: Pharmacological prophylaxis and management of adult postoperative/postdischarge nausea and vomiting, *J Perianesth Nurs* 21:385–397, 2006.

Good KK et al: Postoperative hypothermia: the chilling consequences, *AORN J* 83:1055–1070, 2006.

Hooper VD, Andrews JO: Accuracy of noninvasive core temperature measurement in acutely ill adults: the state of the science, *Biol Res Nurs* 8: 24–34, 2006.

Joshi GP: Multimodal analgesia techniques and postoperative rehabilitation, *Anesthesiol Clin* 23:185–202, 2005.

Kalinowski CPH, Kirsch JR: Strategies for prophylaxis and treatment for aspiration, *Best Pract Res Clin Anaesthesiol* 18(4):719–737, 2004.

Kehlet H et al: PROSPECT: Evidence-based, procedure-specific postoperative pain management, *Best Pract Res Clin Anaesthiol* 21:149–159, 2007.

Krenszichek DA: Pain and comfort management. In Schick L, Windle P, editors: *Perianesthesia nursing core curriculum*, St Louis, 2009, Mosby.

Langham GE et al: Noninvasive temperature monitoring in postanesthesia care units, *Anesthesiology* 111:90–96, 2009.

Leslie K, Sessler D: Perioperative hypothermia in the high-risk surgical patient, *Best Pract Res Clin Anaesthesiol* 17(4):485–498, 2003.

Macario A, Dexter F: What are the most important risk factors for a patient's developing intraoperative hypothermia? *Anesth Analg* 94: 215–220, 2002.

Moos DD: Sevoflurane and emergence behavioral changes in pediatrics, *J Perianesth Nurs* 17:384–392, 2005.

Murphy MJ et al: Identification of risk factors for postoperative nausea and vomiting in the perianesthesia patient, *J Perianesth Nurs* 21:377–384, 2006.

National Pharmaceutical Council, Inc, Joint Commission on Accreditation of Healthcare Organizations: *Pain: current understanding of assessment, management, and treatments,* December 2001, available at http://d.scribd.com/docs/1qeor4k1bd6nmb8g71hj.pdf. Accessed July 30,2006.

Nicholau D: The postanesthesia care unit. In Miller R, editor: *Anesthesia*, ed 7, New York, 2009, Churchill Livingstone.

Nightingale F: *Notes on hospitals*, ed. 3, London, 1863, Longman, Green, Roberts, Longman & Green..

Nillson U: The anxiety- and pain-reducing effects of music interventions: a systematic review, *AORN J* 87(4):780–807, 2008.

O'Brien D: Postanesthesia care complications. In Drain CB, Odom-Forren J: *Perianesthesia nursing: a critical care approach*, St Louis, 2009, Saunders.

Odom-Forren J et al: Postanesthesia recovery. In Nagelhout JJ, Plaus KL, editors: *Nurse anesthesia*, ed 4, St Louis, 2010, Saunders.

Odom-Forren J et al: Evidence-based interventions for post discharge nausea and vomiting: a review of the literature, *J Perianes Nurs* 21:411–430, 2006.

Odom-Forren J, Moser DK: Postdischarge nausea and vomiting: a review of current literature, *Ambulatory Surg* 12:99–105, 2005.

Paulikas CA: Prevention of unplanned hypothermia, *AORN J* 88(3):358–364, 2008.

Pasero C: The challenge of pain assessment in the PACU, *J Perianesth Nurs* 17:348–350, 2002a.

Pasero C: Perineural local anesthetic infusion: when close is almost perfect, *AJN* 104(7):89–92, 2002b.

Pasero C: Procedure-specific pain management: PROSPECT, *J Perianes Nurs* 22:335–340, 2007.

Pasero C: Challenges in pain assessment, *J Perianesth Nurs* 24:50–54, 2009.

Pasero C, McCaffery J: Extended-release epidural morphine, *J Perianesth Nurs* 20:245–250, 2005.

PROSPECT: *Procedure-Specific Postoperative Pain Management,* available at www.postoppain.org. Accessed July 9, 2009.

Regenbogen SE et al: Utility of the surgical Apgar score, *Arch Surg* 144(1):30–36, 2009.

Reynolds L et al: Perioperative complications of hypothermia, *Best Pract Res Clin Anaesthesiol* 22:645–657, 2008.

Rosero EB et al: Trends and outcomes of malignant hyperthermia in the United States, 2000 to 2005, *Anesthesiology* 110:89–94, 2009.

Ruth HS et al: Anesthesia study commission, *JAMA* 35:881–884, 1947.

Sessler DI: Complications and treatment of mild hypothermia, *Anesthesiology* 95:531–543, 2001.

Siew-Fong N et al: A comparative study of three warming interventions to determine the most effective in maintaining perioperative normothermia, *Anesth Analg* 96:171–176, 2003.

Smith DJ: Nursing management postoperative care. In Lewis SM et al, editors: *Medical-surgical nursing: assessment and management of clinical problems*, ed 7, St Louis, 2007, Mosby.

Tarrac SE: A description of intraoperative and postanesthesia complication rates, *J Perianesth Nurs* 21:88–96, 2006.

The Joint Commission: *Hospital/critical access hospital national patient safety goals,* available at www.jointcommission.org/PatientSafety/NationalPatientSafetyGoals/08_cah_npsgs.htm. Accessed July 9, 2009.

Viscusi ER: Emerging techniques in the treatment of postoperative pain, *Am J Health Syst Pharm* 61(Suppl 1):S11–S14, 2004.

Vlajkovic GP, Sindjelic RP: Emergence delirium in children: many questions, few answers, *Int J Anesth* 104:84–91, 2007.

Wagner DV: Unplanned perioperative hypothermia, *AORN J* 83:470, 2006.

Wong PF et al: Randomized clinical trial of perioperative warming in major elective abdominal surgery, *Br J Surg* 94:421–426, 2007.

This page intentionally left blank

CHAPTER 10

Gastrointestinal Surgery

CHRISTINE E. SMITH

Surgery of the gastrointestinal (GI) system may be indicated to establish a diagnosis, to prevent or cure disease, to relieve symptoms or restore function, or to afford palliative measures that provide comfort or nutrition and promote quality of life. Advances in scientific knowledge, research, pharmacology, and technologic developments in the interventional disciplines as well as successful outcomes based on clinical evidence continue to broaden the spectrum of modalities and approaches to managing patients with GI disorders.

GI surgery, a subspecialty within the domain of general surgery, traditionally concerns itself with surgical management of the esophagus, stomach, small intestine, large intestine, and rectum. Gastroenterology is a medical specialty that diagnoses and manages GI disorders and conditions through endoscopic and pharmacologic approaches. Many surgical procedures that once entailed laparotomy and extensive postoperative recovery have been replaced or duplicated by endoscopic access and intervention. Endoscopic examination, enhanced with fluoroscopy, ultrasound, and video magnification in conjunction with interventional radiology, is a critical component of surgical diagnosis and postoperative evaluation. Laparoscopy, a minimally invasive approach to the intraabdominal compartment, has revolutionized GI surgery. Medical and surgical specialties have evolved to embrace and facilitate these advancements. Although clinicians may specialize in the disciplines of laparoscopy, gastroenterology, general surgery, bariatrics, GI surgical oncology, or colorectal surgery, the perioperative nurse and surgical technologist must know the fundamentals of GI surgery, interventional options available to patients, and care requirements common to all GI patients.

Surgical Anatomy

The GI tract, or alimentary canal, is a continuous tubelike structure that extends the entire length of the trunk (Figure 10-1). The tract includes the mouth; pharynx; esophagus; stomach; small intestine, consisting of the duodenum, jejunum, and ileum; and large intestine, which comprises the cecum, ascending colon, transverse colon, descending colon, sigmoid colon, rectum, and anus. The length of the GI tract in a cadaver is about 9 meters, or 30 feet. In a living person it is shorter because of sustained muscle contraction and tone. The six basic functions of the GI tract are ingestion, secretion, mixing and propulsion, digestion, absorption, and defecation.

The esophagus extends from the pharynx, at the level of the sixth cervical vertebra, and passes through the neck, posterior to the trachea and heart, and anterior to the vertebral column. The lower portion of the esophagus passes in front of the aorta and through the diaphragm, slightly to the left of the midline, to join the cardia of the stomach. Blood is supplied to the esophagus from branches of the inferior thyroid arteries, bronchial arteries, thoracic aorta, and branches of the left gastric and inferior phrenic arteries. The nerve supply comes from branches of the vagus and sympathetic nervous system. The length of the esophagus in an adult is about 25 cm, or 10 inches. The esophagus is a collapsible musculomembranous tube that functions primarily to transport ingested material, by peristalsis, from the pharynx to the stomach.

The stomach is an expanded J-shaped organ situated between the esophagus and the duodenum. It lies in the upper left abdominal cavity, slightly to the left of the midline and beneath the diaphragm. The stomach is divided into three parts: the fundus, the body, and the antrum (Figure 10-2). The fundus lies below the left dome of the diaphragm, behind the apex of the heart. The body and antrum lie in an oblique direction within the abdominal cavity. The stomach is stabilized indirectly by the lower portion of the esophagus and directly by its attachment to the duodenum, which is anchored to the posterior parietal peritoneum. The omentum, the peritoneal ligaments, and branches of the celiac vessel provide additional support to the stomach.

The convex, or lower, margin of the stomach is known as the *greater curvature;* the concave, or upper, margin is the *lesser curvature*. Attached to the greater curvature is the greater omentum, which is a double fold of peritoneum containing fat. It covers the intestines loosely and is not to be confused with the mesentery, which connects the intestines with the posterior abdominal wall. The left gastroepiploic branch of the splenic artery and the right gastroepiploic branch of the hepatic artery run through the greater omentum. The lesser omentum, attached to the lesser curvature of the stomach, contains the left gastric artery, a branch of the celiac axis, and the right gastric branch of the hepatic artery.

Stomach functions include acceptance and storage of ingested material; chemical and mechanical digestion through the production of gastric lipase, pepsinogen, hydrochloric acid, gastrin, and intrinsic factor, responsibility for the absorption of vitamin B_{12}; and peristaltic waves, which both mix and propel stomach contents, or chyme, into the duodenum.

The small intestine, the longest part of the digestive tract, begins at the pylorus and ends at the ileocecal valve (Figure 10-3). The small intestine varies in size with the degree of contraction but is usually about 3 meters in length and 2.5 cm in diameter in the adult. It is divided into three parts: the duodenum, about 25 cm long; the jejunum, which is about two

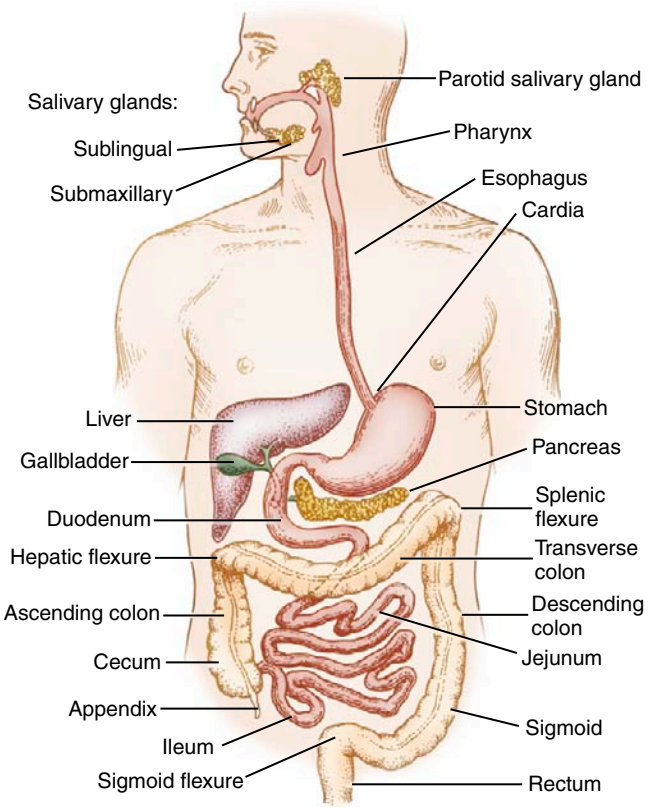


FIGURE 10-1 Alimentary canal and its appendages.

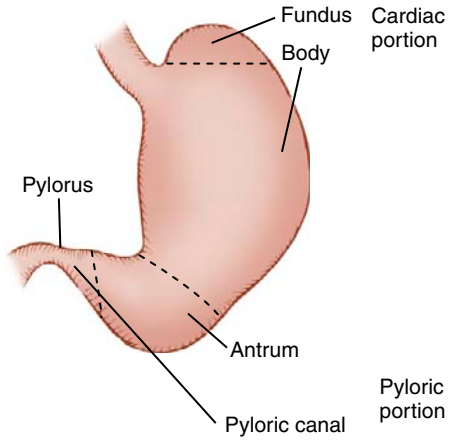


FIGURE 10-2 Regional anatomy of stomach.

fifths of the length of the entire small intestine; and the ileum, which makes up the remaining length in an adult. The duodenum, which is the proximal portion of the small intestine, begins at the pylorus, is contiguous with the jejunum, and is stabilized by a fusion between the pancreas and the posterior parietal peritoneum. The duodenum is divided into four portions: superior (I), descending (II), transverse (III), and ascending (IV) (Figure 10-4). Nearly all of the superior portion mucosa is characterized by the lack of folds; it appears slightly dilated and is referred to as the *duodenal bulb*. The characteristic circular folds of the small intestinal mucosa begin proximal to the end of the superior portion of the duodenum and

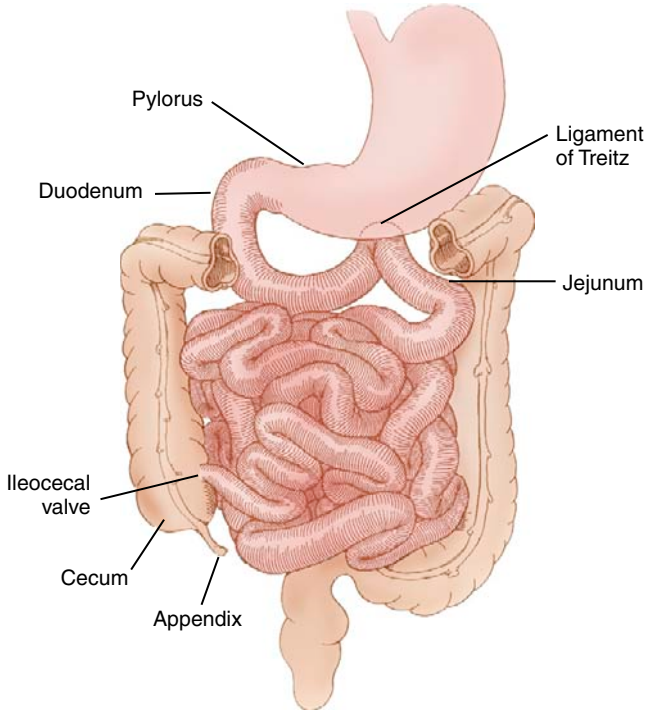


FIGURE 10-3 Illustration of the small bowel; the duodenum originates at the pylorus and flexes at the ligament of Treitz where the jejunum begins. The jejunum extends into the ileum, which terminates at the ileocecal valve at the cecum.

extend through the jejunum. They become less prominent in the ileum. The purpose of the circular mucosal folds, called *plicae circulares of Kerckring* or *valvulae conniventes,* is to provide greater mucosal surface area.

The common bile duct and the main pancreatic duct enter the medial wall of the middle of the second portion of the duodenum at the ampulla of Vater. The first, second, and third portions of the duodenum curve in a C-loop concavity in which the head of the pancreas is located. The fourth portion of the duodenum ascends to the duodenojejunal flexure. The duodenojejunal flexure is stabilized by the ligament of Treitz, which suspends the duodenum from the posterior body wall. The ligament of Treitz serves as a landmark during any abdominal exploration because it provides the surgeon with a reliable orientation of the patient's anatomy.

The blood supply of the duodenum comes from the arterial branches of the celiac axis (Figure 10-5). The gastroduodenal artery branches off the hepatic artery and is located behind the duodenal bulb. At the inferior margin of the bulb, the gastroduodenal artery divides into the right gastroepiploic artery and a superior pancreaticoduodenal branch. The superior pancreaticoduodenal artery supplies blood to the proximal duodenum and head of the pancreas. The inferior pancreaticoduodenal artery branch of the superior mesenteric artery supplies blood to the third and fourth portions of the duodenum as well as to the head and body of the pancreas.

The jejunum, situated in the upper portion of the abdomen, joins with the ileum, situated in the lower portion of the abdominal cavity. The ileum empties into the large intestine through the ileocecal valve. The jejunum and ileum are suspended by the mesentery, which is attached to the posterior

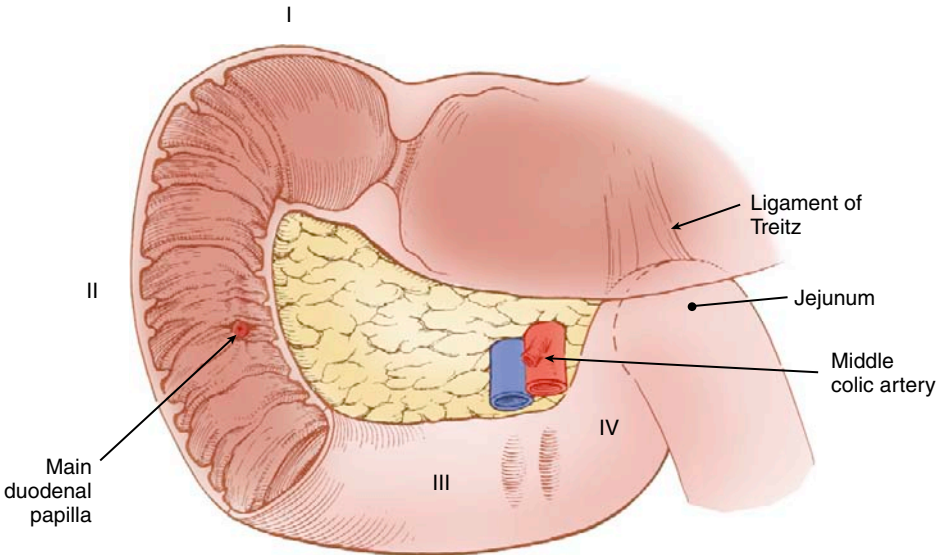


FIGURE 10-4 The duodenum consists of four portions, as illustrated.

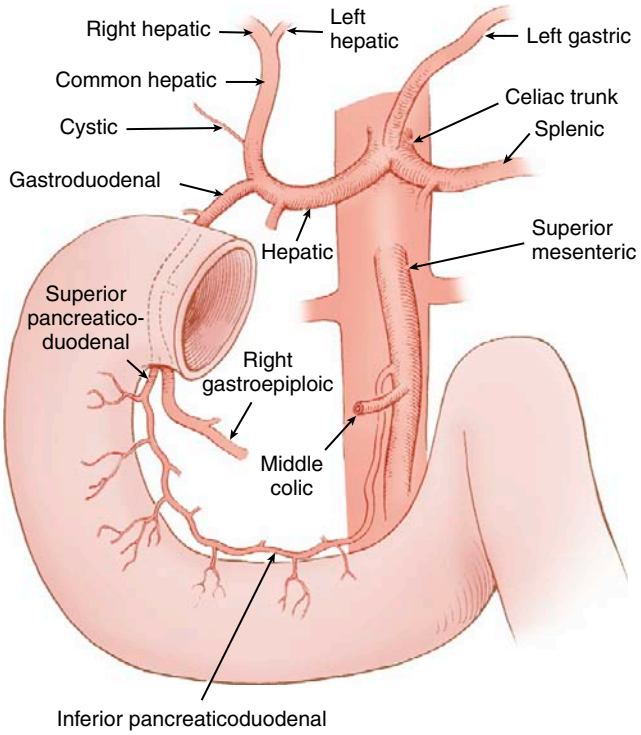


FIGURE 10-5 Blood supply of the duodenum.

abdominal wall. The free border of the mesentery, which is about 5.5 meters (18 feet) long, contains branches of the superior mesenteric artery, many veins, lymph nodes, and nerve fibers. The blood supply to the jejunum and ileum comes entirely from the superior mesenteric artery. The small bowel contains major deposits of lymphatic tissue, known as *Peyer's patches,* in the ileum. The rich lymphatic drainage of the small bowel plays a major role in fat absorption. Lymphatic drainage from the mucosa proceeds through the wall of the small intestine to lymph nodes adjacent to the mesentery. Lymphatic drainage then proceeds to larger lymphatics that communicate with the retroperitoneal cisterna chyli and from there to the thoracic duct. The lymphatics of the intestine play a major role in the body's immune defense as well as in the distribution of cells arising from intestinal neoplasms.

Compared to the ileum, the jejunum has a larger circumference and thickness. The mesenteric vessels usually form only one or two arcades, a series of anastomosing arterial arches, compared with the multiple vascular arcades of the ileum. The jejunal mucosa is thick and has prominent *plicae circulares*. The ileum mucosa is thinner with few plicae.

The small intestine serves two important, but opposite, functions simultaneously. It absorbs essential nutrients at 95% efficiency while it provides an effective barrier from harmful ingested environmental elements. The remarkably large surface area of the combined small and large intestinal mucosa is estimated to be 200 square meters, about the size of a doubles' tennis court.

The large intestine begins at the ileocecal valve and ends at the anus. It is divided into the cecum, colon, and rectum. The cecum attaches to the ileum and extends about 7 cm below it. The cecum in an adult usually adheres to the posterior wall of the peritoneal cavity and has a serosal covering on its anterior wall only. The cecum forms a blind pouch from which the appendix projects.

The colon, about 1.5 meters long, is divided into four parts: the ascending colon, the transverse colon, the descending colon, and the sigmoid colon (Figure 10-6). The *ascending colon* extends upward from the ileocecal valve to the hepatic flexure. The upper portion of the ascending colon lies behind the right lobe of the liver and in front of the anterior surface of the right kidney. The *transverse colon* begins at the hepatic flexure and ends at the splenic flexure. It lies below the stomach and is attached to the transverse mesocolon. The *descending colon* extends downward from the splenic flexure to just below the iliac crest. The iliac portion of the sigmoid colon lies on the inner surface of the left iliac muscle. The remaining portion of the colon passes over the pelvic rim into the pelvic cavity and lies partly in the abdomen and partly in the pelvis. It then forms an S-shaped curve in the pelvis and

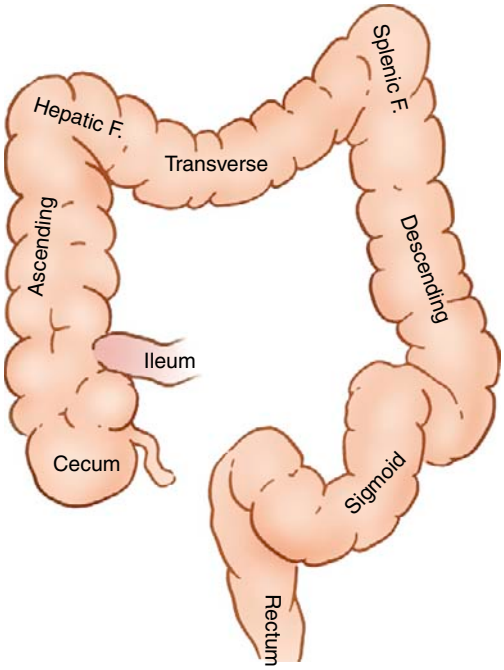


FIGURE 10-6 Anatomic division of large intestine, showing locations of hepatic flexure and splenic flexure. *F,* Flexure.

terminates in the rectum at the level of the third segment of the sacral vertebrae. The blood supply to the ascending colon, hepatic flexure, and transverse colon comes from the superior mesenteric artery, whereas the blood supply to the descending colon and rectum comes from the inferior mesenteric artery (Figure 10-7).

The wall of the colon consists of taeniae coli, epiploic appendices, and haustra. The taeniae coli are three longitudinal, or axial, strips of muscles distributed around the circumference of the colon. They represent the longitudinal muscle layer, which is not complete in the colon (the small intestine and rectum have both circular and complete longitudinal muscle layers). The epiploic appendices are fatty appendages along the bowel that have no particular function. The haustra are sacculations that outpouch from the bowel wall among the taeniae coli. The diameter of the colon varies in size from about 9 cm (3½ inches) in the cecum to an average of about 1.25 cm (½ inch) in the sigmoid colon.

The rectum begins at the sigmoid colon and ends in the anus. This slightly curved passage is surrounded by the pelvic fascia as it lies on the anterior surface of the sacrum and coccyx. In the male, the rectum lies behind the prostate gland, seminal vesicles, and bladder. In the female, the rectum lies behind the uterus and the vagina. A septum rectovesical, also

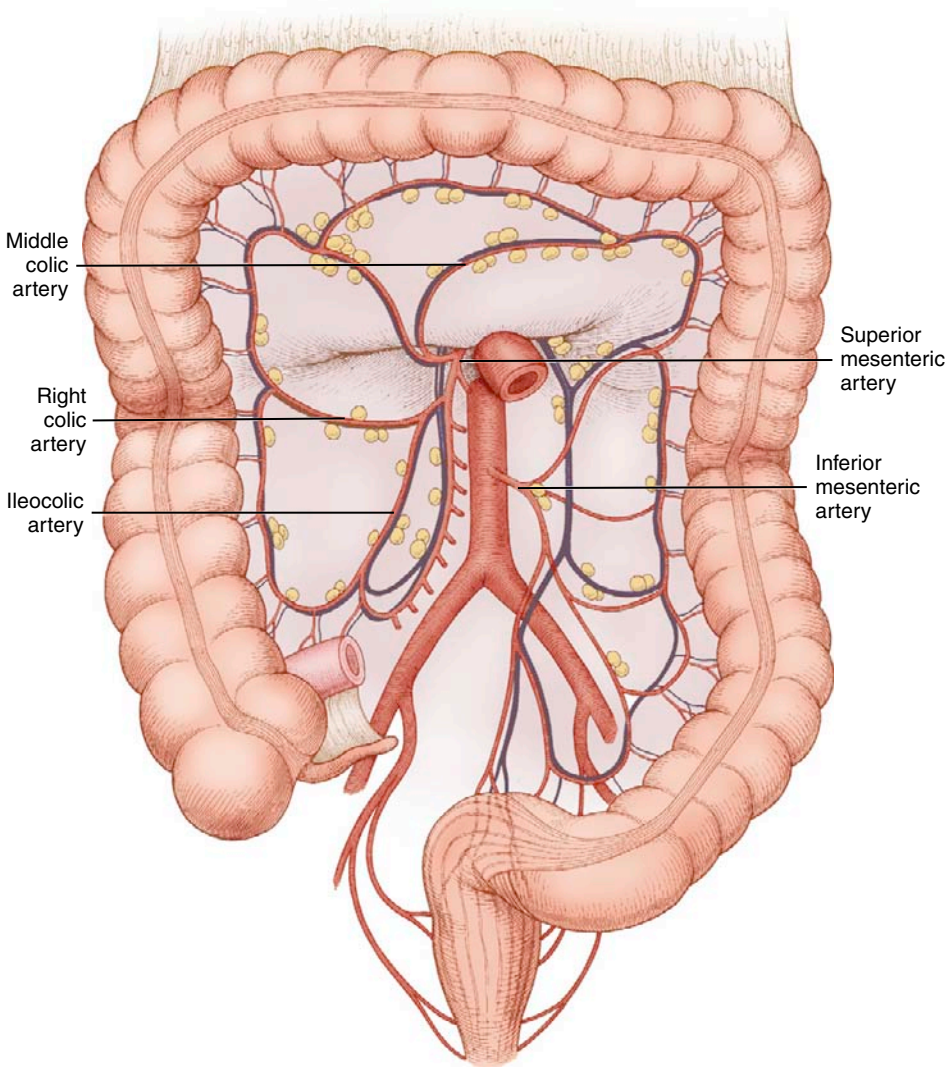


FIGURE 10-7 Blood supply of the colon.

called *Denonvilliers' fascia,* separates the rectum from the urogenital structures. The rectum is suspended in the pelvis by fascia extending from the right and left pelvic sidewalls. Rectosacral fascia extends from the sacrum to the anorectal junction and suspends the rectum posteriorly. The rectum dilates just before it becomes the anal canal. This dilation, or ampulla, presents folds called *Houston's valves*. The wall of the rectum consists of four layers, similar to those of the small intestine.

The anal canal is a narrow passage that passes downward and slightly posteriorly. It is surrounded and controlled by two circular muscle groups, which form the external and internal anal sphincters. The internal sphincter is a continuation of the longitudinal muscle layer.

The primary function of the large intestine is to reabsorb water and electrolytes, to form solid waste into feces, to synthesize vitamin K and B-complex vitamins, and to propel and eliminate solid food residue and waste through defecation.

The GI tract constitutes a complex microbiologic ecosystem that supports and maintains essential digestive and protective functions vital to life, yet it presents significant risks and challenges during diagnostic and surgical interventions. Substantial populations of microorganisms, both obligate anaerobes and facultative bacterial spores, exist in the intestinal lumen. The organisms of the upper tract differ from those of the lower tract, with the highest concentration in the distal bowel. These organisms can contribute to contamination and disease processes within the intestinal tract and throughout the body. Gastric and intestinal pH, while necessary for digestive benefit and protection from selected organisms, can compromise peritoneal tissues and structures when unplanned spillage or leakage occurs. The pH of the stomach ranges from 1.5 to 3, whereas the pH of the intestines can range from 7 to 8.5.

Perioperative Nursing Considerations

GI surgery and endoscopic procedures present special considerations related to the planned procedure, instrumentation, approach, anatomic structures involved, primary and secondary diagnoses, health status of the patient, surgeon and patient preferences, and availability of special institutional resources. Special institutional resources may include a bariatric program, an oncology program with research protocols, a transplant program, a trauma center, or a technologically advanced OR with computer-integrated imaging display and robotics. Optimum care of the patient undergoing GI surgery and other invasive GI procedures relies on sound knowledge and experience, thorough assessment of the patient with identification of care needs, preplanning and preparation, and follow-through with competent care and evaluation of the completed process and its results. The risks for injury or failure to achieve the intended outcome are equally present in GI surgery as in any surgical or invasive procedure. No procedure is routine and unexpected outcomes can occur even when planning and preventive measures have been employed under the most optimal circumstances. Although it is prudent to address and review the vulnerabilities faced by all surgical patients, specific concerns arise for patients undergoing GI surgery and other invasive GI procedures.

Assessment

Patient care begins with assessment. Individualized care that integrates physiologic with psychologic preparation is given to each patient. Patients undergoing GI surgery need to understand why they need preoperative preparation, what the intended surgical intervention will be, and how it will affect them and their family postoperatively. A preoperative nursing assessment of the patient is essential to plan and implement intraoperative nursing care and evaluate patient outcomes. The nurse ensures that the patient understands the nature of the surgery, the expected site of the incision(s), the anticipated outcome(s), and follow-up recovery and care. Turning, coughing, and deep breathing are taught preoperatively and reinforced after surgery. If an ostomy is anticipated, a wound ostomy continence nurse (WOCN, formerly called an *enterostomal therapist*) is consulted to site-mark the abdomen for optimal stoma placement (Box 10-1) and prepare the patient for the postoperative management and care. The WOCN also helps to allay fears and anxieties for the patient and the family (Carmel and Goldberg, 2004).

BOX 10-1

Ostomy Site-Marking

- Determine planned surgical procedure and ostomy (refer to surgeon's notes and preferences).
- Explain procedure to patient, and establish privacy.
- Provide ostomy appliance and literature for patient and family to read and examine.
- Verify patient's knowledge and understanding of surgery and planned ostomy.
- Examine abdominal skin integrity and surface for scars, lesions, bulges, implants, and stomas.
- Locate waistline and patient's preferred beltline. Patient may have to put on pants to illustrate.
- Locate abdominal skinfolds, creases, and bulges as patient lies flat, stands, bends forward, and sits upright.
- Identify the lateral margins of the rectus abdominis muscle. Palpate while patient coughs.
- Select a site within the rectus margin on the crest of the infraumbilical or infraabdominal bulge.
- Place fingertip on proposed site and verify patient can see site when standing or sitting.
- Avoid belt or waistline, bony prominences, scars, excoriated lesions, creases, folds, below pendulous breasts, umbilicus, hernia, or horizontal plane with existing stoma or fistula.
- Position ostomy pouch faceplate on proposed site as template to ensure avoidance of umbilicus, beltline, and waistline. At least 2 inches of smooth skin should surround stoma for good seal. (Patients who wear their pants low below the waistline and have selected a lower quadrant site for the ostomy can wear suspenders or sweat pants postoperatively; this enables the pants to be held loosely above the stoma without irritating the site and surrounding skin.)
- Mark site boldly with indelible or permanent skin marking pen. Cover with clear adhesive dressing to protect from shower or wear.
- Verify site by having patient stand, sit, and twist, noting avoidance of creases and interference. Patient must be able to see site for later self-care.
- Document skin assessment, teaching, patient's understanding and level of acceptance, site selected, and rationale for choice.

Nursing assessment of the patient before GI procedures includes the following information (Box 10-2):

- Demographic data
- Present problems, chief complaint, or symptoms that led the patient to seek medical attention
- Medical history, including nutrition and allergies to foods, drugs, latex, or other substances
- History of chronic disease or other medical conditions
- Surgical history, including prior procedures and anesthesia experiences
- Medications, including use of nonsteroidal antiinflammatory drugs (NSAIDs), antacids, histamine blockers, proton pump inhibitors, steroids, or anticoagulants
- Family history
- Personal and social history, including use of alcohol, nicotine, herbal nutraceuticals, and illicit substances
- Focused GI assessment, including bowel sounds, pain, abdomen appearance, and GI risk factors

BOX 10-2

Assessment Data

GENERAL DATA

Usual height, weight, and body mass index (BMI, measured as weight in kilograms divided by height in meters squared)

Nutrition
- Types of food usually eaten at each meal or snack
- Food likes and dislikes
- Alcohol consumption
- Tobacco use
- Religious, cultural, ethnic, or medically prescribed food restrictions
- Food intolerances or allergies
- Patient's perception and concerns pertaining to diet and weight
- Effects of lifestyle on diet and weight gain or loss
- Vitamins and other nutritional or herbal supplements used

Oral hygiene

Bowel elimination patterns

Use of medications or laxatives
- Stool softeners
- Antiemetics
- Antidiarrheals
- Antacids
- Histamine blockers or proton pump inhibitors
- Frequent or high doses of aspirin, acetaminophen, or ibuprofen

SPECIFIC DATA

Oral lesions

Appetite

Digestion or indigestion

Dysphagia

Nausea

Vomiting

Hematemesis

Change in stool
- Color (clay color, black)
- Contents (undigested food, blood, mucus)

Constipation

Diarrhea

Flatulence

Hemorrhoids

Abdominal pain

Hepatitis

Jaundice

Ulcers

Gallstones

Polyps

Tumors

Anal discomfort

Fecal incontinence

Exposure to infectious disease

Examination of the patient's abdomen includes inspection, palpation, and auscultation of bowel sounds. Systematic investigation, with open-ended questions, addresses descriptions of pain with or without palpation; digestion; presence of nausea, vomiting, diarrhea, or constipation; bleeding; recent trauma; anorexia or bulimia; weight loss or gain programs; and nutrition.

Laboratory studies might include a complete blood count (CBC) with differential, serum electrolytes, platelet count, cholesterol level, vitamin and mineral levels, liver function, serum proteins, coagulation profile, pancreatic function, and indices of nutritional status (Table 10-1).

Diagnostic endoscopic examinations, radiologic studies with or without contrast markers, abdominal ultrasound, endoscopic ultrasound (EUS), magnetic resonance imaging (MRI), positron emission tomography (PET), and computed tomography (CT) imaging scans plus GI secretion studies add further information about the patient's health or disease process to help formulate the surgical plan. Advances in endoscopic technology provide enhanced details of GI anatomy and pathology. EUS combines endoscopy and ultrasound, using sound waves to generate an image of the histologic layers of the esophageal, gastric, and intestinal walls. The frequencies used, higher than those used in traditional ultrasound, provide high-level accuracy of depth of mucosal invasion (Birn, 2005). EUS is of critical importance in staging GI malignancies and determining surgical options and potential for therapeutic resection. Endoscopic image-enhancement techniques include high-resolution endoscopes with narrow-band imaging and magnification to identify mucosal surface details; narrow-band filters to see capillary patterns, pits, and villi; and chromoendoscopy (staining techniques) and fluorescence to differentiate between normal and dysplastic tissue (Kwon et al, 2005).

Capsule endoscopy is an emerging technology and noninvasive diagnostic test that uses a small wireless camera in the shape of a capsule about the size of a large vitamin. It is swallowed with a few sips of water and propelled along the GI tract by normal peristalsis. The capsule glides down the esophagus taking two color digital pictures per second, which are transmitted to a data recording device worn by the patient. This device is suitable for imaging the mucosal surface of the esophagus, stomach, and small intestine. The battery power of the capsule lasts about 8 hours. The capsule is eventually passed naturally within 24 to 72 hours. The wireless capsule has dramatically enhanced the ability to visualize the mucosal surface of the small intestine. The small bowel makes up 90% of the mucosal surface of the entire GI tract and had formerly been constrained by the limits of traditional diagnostic modalities. The only preprocedure preparation is an 8-hour fast. Contraindications to capsule endoscopy include inability to swallow a large capsule; small bowel strictures, narrowing,

TABLE 10-1

Common Serum Studies with Relevance to GI Surgery

Test	Normal Adult Values	Significance of Abnormal Values
COMPLETE BLOOD COUNT WITH DIFFERENTIAL (CBC WITH DIFF)		
Red blood cell count (RBC)	*Men:* 4.7-6.1 million/mm^3 *Women:* 4.2-5.4 million/mm^3	Low value indicates anemia from blood loss, hemolysis, dietary deficiency, drug ingestion, bone marrow failure, or chronic illness. High value indicates compensation for high altitudes, chronic anoxia, or polycythemia vera.
Hemoglobin (Hb) concentration	*Men:* 14-18 g/dl *Women:* 12-16 g/dl	Low and high values tend to be caused by same processes that cause low or high values for RBCs. Artificially high values seen in dehydration.
Hematocrit (Hct)	*Men:* 42%-52% *Women:* 37%-47%	Low and high values are same as above.
Mean corpuscular volume (MCV)	*Adults:* 80-95/mm^3	High values found in megaloblastic anemias (vitamin B_{12} deficiency). Low values seen in iron-deficiency anemia or thalassemia.
Mean corpuscular hemoglobin (MCH)	*Adults:* 27-31 pg	Low and high values tend to be caused by same processes that cause low or high values for MCV.
Mean corpuscular hemoglobin concentration (MCHC)	*Adults:* 32-36 g/dl	Low value indicates hemoglobin deficiency seen in iron-deficiency anemia or thalassemia.
White blood cell count (WBC) differential	*Adults:* 5000-10,000/mm^3	Elevated WBC level indicates infection or leukemia, trauma, or stress. Decreased WBC level may indicate bone marrow failure, overwhelming infection, dietary deficiency, drug toxicity, or autoimmune disease.
Neutrophils	55%-70%	Elevated neutrophil count may indicate acute suppurative infection.
Lymphocytes, monocytes	20%-40%, 2%-8%	Decreased neutrophil count may indicate overwhelming bacterial infection (especially in elderly) or dietary deficiency.
Eosinophils	1%-4%	Elevated lymphocyte count may indicate chronic bacterial or viral infection.
Basophils	0.5%-1%	Decreased lymphocytes may indicate sepsis. Elevated eosinophils may indicate parasitic infestation, allergic reactions, or autoimmune diseases. A "shift to the left" means percentage of neutrophils and immature leukocytes is increased, which occurs with infection.
Platelet count	150,000-400,000/mm^3	Reduced levels of platelets may result from decreased platelet production, increased sequestration (as seen in hypersplenism), increased platelet destruction or consumption (e.g., disseminated intravascular coagulation [DIC]), or loss of platelets through hemorrhage. Elevated levels may indicate severe hemorrhage, polycythemia vera, postsplenectomy syndromes, and some malignant disorders.
SERUM ELECTROLYTES		
Sodium (Na^+)	136-145 mEq/L	Elevated levels may be seen with excessive sweating, extensive burns, osmotic diuresis, and excessive sodium intake or reduced sodium excretion. Reduced levels may be seen with inadequate sodium intake, increased sodium losses (e.g., vomiting, nasogastric suction, diarrhea, renal disease, third-space losses of sodium).
Phosphate (PO_4^{2-})	3-4 mg/dl	Decreased levels seen in long-term antacid ingestion.
Potassium (K^+)	3.5-5 mEq/L	Elevated levels may indicate excessive intake or reduced excretion of potassium (e.g., renal failure). Crush injuries cause release of intracellular potassium, or metabolic acidosis. Reduced levels may indicate inadequate intake or excessive losses (e.g., diarrhea, vomiting, use of diuretics, hyperaldosteronism) or result of metabolic alkalosis or administration of glucose, insulin, or calcium (which causes a shift of potassium from bloodstream into cells).
Chloride (Cl^-)	98-106 mEq/L	Changes in chloride concentration usually parallel changes in sodium concentration. Decreased levels seen in patients who undergo long-term gastric suctioning.
Carbon dioxide (CO_2)	23-30 mEq/L	Elevated levels are seen with acidosis. Reduced levels are seen with alkalosis.

Continued

TABLE 10-1

Common Serum Studies with Relevance to GI Surgery—cont'd

Test	Normal Adult Values	Significance of Abnormal Values
ARTERIAL BLOOD GASES		
pH	7.35-7.45	High levels indicate alkalosis. Low levels reflect acidosis.
Partial pressure of carbon dioxide (P_{CO_2})	35-45 mm Hg	High levels indicate carbon dioxide retention caused by respiratory depression or pulmonary disease (respiratory acidosis). Low levels reflect excessive loss of carbon dioxide through hyperventilation (respiratory alkalosis from overventilation or emotional trauma; may also be seen as compensatory response in metabolic acidosis).
Bicarbonate (HCO_3^-)	21-28 mEq/L	Low levels indicate metabolic acidosis caused by excessive acid production, resulting in depletion of HCO_3^- (e.g., diabetic acidosis); failure to eliminate H^+ ions, resulting in depletion of HCO_3^- (e.g., renal failure); or excessive loss of HCO_3^- (e.g., intestinal losses through diarrhea, fistula drainage). Low levels may also be seen with insulin overdose, insulinoma, hypothyroidism, hypopituitarism, Addison's disease, and extensive liver disease. High levels indicate metabolic alkalosis resulting from bicarbonate overdose or excessive gastric losses. May also be seen as compensatory response in patients with prolonged respiratory acidosis, pancreatic disorders (e.g., adenoma, pancreatitis), corticosteroid therapy, diuretics, Cushing's disease, and hyperthyroidism.
COAGULATION STUDIES		
Prothrombin time (PT)	85%-100% or 11-12.5 sec	Elevated times with anticoagulant, acetylsalicylic acid (ASA), and nonsteroidal antiinflammatory drug (NSAID) use. Decreased times may be seen in malignant disease caused by unidentified hypercoagulability factors.
Partial prothrombin time (PTT)	60-70 sec	Increased in acquired or congenital clotting factor deficiencies, cirrhosis, vitamin K deficiency, leukemia, DIC, heparin administration, hypofibrinogenemia, von Willebrand's disease, hemophilia. Decreased in early stages of DIC, extensive cancer.
Activated partial prothrombin time (APTT)	30-40 sec	Same as for PTT.
OTHER SERUM STUDIES		
Albumin	3.5-5.5 mg/day	Decreased levels seen in protein malnutrition and hepatocellular injury.
Alkaline phosphatase (ALP)	30-120 units/L	Slightly elevated in elderly. Elevated in intestinal ischemia. Decreased with excess vitamin B ingestion.
Amylase	60-120 Somogyi units/dl	Increased in penetrating or perforated peptic ulcer, perforated or necrotic bowel, or duodenal obstruction.
Ammonia	10-80 mcg/dl	Increased in gastrointestinal (GI) bleeding, GI obstruction, or liver disease.
Carcinoembryonic antigen (CEA)	<5 ng/ml	Elevated in GI cancer, colitis, diverticulitis, cirrhosis, peptic ulcer, hepatobiliary and pancreatic cancers.
Complement assay (C3 and C4)	C3: 55-120 mg/dl C4: 20-50 mg/dl Total complement: 75-160 mg/dl	Elevated in ulcerative colitis and cancer.
Cortisol (hydrocortisone)	8 AM: 5-23 mcg/dl 4 PM: 3-13 mcg/dl	Elevated in obesity.
C-reactive protein	<1 mg/dl	Elevated in Crohn's disease, postoperative wound infection, malignant disease.
Transferrin (serum)	250-300 mg/dl	Decreased levels may indicate protein malnutrition; transferrin levels may be used to monitor a patient's response to nutritional support therapy since half-life of transferrin is 8-10 days, whereas half-life of albumin is 19-20 days (this means that, compared to albumin levels, transferrin levels reflect changes in patient's visceral protein status much faster).

TABLE 10-1

Common Serum Studies with Relevance to GI Surgery—cont'd

Test	Normal Adult Values	Significance of Abnormal Values
Prealbumin (serum)	15-32 mg/dl	Decreased levels seen in protein malnutrition. Because half-life of prealbumin is 2-3 days, these values, compared to transferrin levels, reflect changes in patient's visceral protein status even faster.
Total lymphocyte count (serum)	>150,000/mm^3	Decreased levels may be seen in protein malnutrition; however, many other conditions affect total lymphocyte count (e.g., infections, conditions affecting WBC production).

Data from Pagana KD, Pagana TJ: *Mosby's diagnostic and laboratory test reference,* ed 9, St Louis, 2009, Mosby.

or fistulas; swallowing disorders; suspected intestinal obstruction; and pacemakers. The patient is instructed not to undergo MRI imaging for at least 30 days to ensure that the capsule has been passed and will not cause internal thermal injury. Reports and images of capsule endoscopy results should be available at the time of surgery.

Nursing Diagnosis

Perioperative nurses often assess, diagnose, and plan care in a short preoperative time frame, often sharing the patient's attention with other members of the surgical team and the patient's family. They must be aware of the care considerations general to all surgical patients plus those implications specific to patients anticipating GI surgery. A focused preoperative assessment provides data to formulate nursing diagnoses, identify desired outcomes, and organize and prioritize the plan for intraoperative care.

Nursing diagnoses related to the care of patients undergoing GI surgery might include the following:

- Anxiety related to perioperative events
- Deficient Knowledge related to impending surgery
- Disturbed Body Image related to intestinal diversion (when diversion possible or planned)
- Risk for Imbalanced Body Temperature
- Risk for Infection at the surgical site
- Risk for Perioperative Positioning Injury
- Impaired Tissue Integrity related to lasers, thermal devices, electrosurgery, radiation, or chemical solutions
- Risk for Injury from retained surgical items, wrong procedure, wrong site, or administration of wrong or incorrect medications
- Risk for Imbalanced Fluid Volume

Outcome Identification

Outcomes identified for selected nursing diagnoses could be stated as follows:

- The patient will demonstrate or verbalize decreased anxiety and ability to cope throughout the perioperative period.
- The patient will verbalize understanding of the surgical procedure and expected responses.
- The patient will demonstrate ability to cope and acceptance of appearance and self-care.
- The patient will be at or returning to normothermia at the conclusion of the immediate postoperative period.
- The patient will be free from signs and symptoms of surgical site infection.
- The patient will be free from perioperative positioning injury.
- The patient will be free of evidence of impaired tissue integrity.
- The patient will be free from injury related to retained surgical items, wrong procedure, wrong site, and medication errors.
- The patient's fluid volume, electrolyte levels, and acid-base balance will be consistent with or improved from preoperative baseline levels (Carpenito-Moyet, 2007).

Rationales guide the interventions aimed at achieving nursing outcomes for the surgical patient. Rationales identified for the selected nursing outcomes are presented in Box 10-3, p. 306.

Planning

The plan of care is designed to guide both the nurse and the surgical technologist in selecting materials and supplies and providing interventions based on evidence, research, and past successful outcomes. Planning and preparation extend beyond the list of items and informational notes on the surgeon's preference card/pick list.

Preoperative assessment enables the perioperative nurse to plan for specific physiologic, psychologic, and technical needs of the patient. For example, patient size influences surgical positioning and may require additional instruments, such as deeper retractors and longer forceps and scissors. A safe, clean, and well-equipped surgical environment requires meticulous planning that integrates standard recommended practices with information specific to the patient with materials typically used during this procedure by this surgical team. The perioperative nurse and surgical technologist proactively organize, prioritize, ensure safety, and expedite all aspects of the surgical experience for the patient.

A Sample Plan of Care for a patient undergoing GI surgery follows on pp. 304-305.

Implementation

Implementation includes activities involved with the preparation of the surgical environment; procurement of the supplies, equipment, materials, and devices; and team communication based on materials and processes typical for this particular procedure and team, along with data gathered from the patient, family, and medical record.

Both open laparotomy and laparoscopic approaches are usually performed with general endotracheal or spinal anesthesia. The choice of anesthetic depends on the patient's health status, planned surgical or laparoscopic approach, length of

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Anxiety related to perioperative events

OUTCOME
The patient will demonstrate or verbalize decreased anxiety and ability to cope throughout the perioperative period.

INTERVENTIONS
- Explain preoperative activities and expectations (e.g., IV lines, skin preparation, positioning), sequence of sensory experiences and activities in the OR, and postoperative expectations (e.g., postanesthesia care unit [PACU], drains, catheters, dressings).
- Provide time for patient and family members to ask questions.
- Determine effective coping strategies used by patient in the past; support these as appropriate.
- Minimize stimuli in the OR that can contribute to anxiety (e.g., high noise levels, excessive talking, music that is not of the patient's preference).
- Remain with the patient during induction; convey caring behaviors (e.g., appropriate touch; a soft, reassuring voice; warm blankets).
- Maintain the patient's dignity and privacy.
- Encourage expression of feelings and concerns.
- Communicate unresolved or excessive anxiety to team members.

NURSING DIAGNOSIS
Deficient Knowledge related to impending surgery

OUTCOME
The patient will verbalize understanding of the surgical procedure and expected responses.

INTERVENTIONS
- Verify information the patient and family need and want to know. Determine current knowledge level and perceptions of surgery. Take into consideration language, culture, hearing or visual impairment, health literacy, cognitive impairments, and any relevant disability.
- Initiate preoperative education and discharge planning early in the perioperative process.
- Assess readiness to learn and patient's preferred learning style.
- Include family or patient's accompanying responsible adult in teaching. Use simple language. Present information in the patient's dominant language (use an interpreter if necessary). Note any sensory impairments and accommodate. When possible, provide written information that replicates verbal education.
- Verify patient's understanding of material presented by having the patient repeat back, in his or her own words, information that has been presented. Correct misunderstandings.
- Communicate patient or family concerns to appropriate surgical team members, or make appropriate referral.

NURSING DIAGNOSIS
Disturbed Body Image related to intestinal diversion (when diversion possible or planned)

OUTCOME
Patient will demonstrate ability to cope and acceptance of appearance and self-care.

INTERVENTIONS
- Encourage verbalization of feelings about anticipated alterations in body function if diversion procedure planned.
- Elicit patient's and family's (if appropriate) perceptions of planned surgical intervention.
- Identify effective sources of support.
- Encourage patient to implement cultural, religious, ethnic, or social customs associated with perceived loss.
- Provide accurate information relevant to patient's postoperative expectations (general principles of ostomy care and solutions to concerns that may be worrying patient).
- Refer patient to wound, ostomy, and continence nurse (WOCN) if this has not already been done.

NURSING DIAGNOSIS
Risk for Imbalanced Body Temperature

OUTCOME
Patient will be at or returning to normothermia at the conclusion of the immediate postoperative period.

INTERVENTIONS
- Determine patient's risk for developing inadvertent hypothermia.
- Regulate ambient room temperature in range between 20° C and 25.6° C (68° F and 78° F) as appropriate.
- Monitor patient temperature during surgery.
- Minimize unnecessary patient exposure. Keep patient covered with warm blankets before induction. Ask patient if he or she is comfortable/warm.
- Use effective skin-surface warming methods (e.g., forced-air warming, circulating water garment, energy transfer pads) preoperatively, intraoperatively, and in PACU as needed.
- Use warmed irrigating solutions and fluid replacement therapy (e.g., IVs) as appropriate. Follow manufacturer's recommendations when using warming equipment.
- Cover patient with a warm blanket before transport to the PACU.

NURSING DIAGNOSIS
Risk for Infection at the surgical site related to operative or other invasive procedure

OUTCOME
Patient will be free from signs and symptoms of surgical site infection.

INTERVENTIONS
- Identify patient-specific risk factors for infection (e.g., altered nutritional status, chronic diseases, preoperative radiation therapy, total parenteral nutrition [TPN]).
- Follow institutional protocol for perioperative skin preparation (patient bath or shower preoperatively with prescribed antimicrobial agent; intraoperative skin preparation with antimicrobial agent).
- Initiate practices required for creating and maintaining a sterile field.
- Protect the patient from cross-contamination—employ bowel/GI technique as appropriate.
- Designate appropriate wound classification (clean, clean-contaminated, contaminated, dirty/infected) at end of procedure.
- Utilize Standard Precautions when handling contaminated instruments, specimens, and cultures.
- Initiate traffic control measures/protocols.
- Administer medication as prescribed (e.g., antibiotic prophylaxis), using safe medication practices and document same.

NURSING DIAGNOSIS
Risk for Perioperative Positioning Injury

OUTCOME
Patient will be free from signs of perioperative positioning injury.

SAMPLE PLAN OF CARE—cont'd

INTERVENTIONS
- Assess patient for physical alteration, prosthetics, or corrective devices requiring modifications to procedure-specific position.
- Position patient in body alignment with attention to possible modifications of surgical position, patient limitations, and safety.
- Use adequate body supports, restraints, and padding of pressure sites specific to planned position and patient body mass. Reassess position status throughout procedure.
- Lift and transport patient carefully with sufficient assistance and lifting aids as needed.
- Reassess patient for signs and symptoms of injury at conclusion of procedure.

NURSING DIAGNOSIS
Risk for Impaired Tissue Integrity related to lasers, thermal devices, electrosurgery, radiation, and chemical solutions

OUTCOME
The patient will be free from evidence of impaired tissue integrity.

INTERVENTIONS
- Inspect skin condition, and determine patient's risk factors related to skin injury.
- If hair must be removed from surgical site, select removal method most likely to preserve skin integrity.
- Protect patient from thermal, electrical, laser, and chemical injury by following institutional practice guidelines. Implement fire precautions with skin prep solution.
- Before applying dressings, clean and dry skin at incision site or sites.
- Prevent stretching of the skin when securing dressings with tape.
- Reassess patient for signs of skin injury at conclusion of procedure and document findings.
- Wash patient of blood and body fluids and cover with clean gown and blankets before transfer to PACU.

NURSING DIAGNOSIS
Risk for Injury from retained surgical items, wrong procedure, wrong site, or medication administration

OUTCOME
The patient will be free from injury related to retained surgical items, wrong procedure, wrong site, and medication errors.

INTERVENTIONS
- Confirm patient identity.
- Initiate preoperative verification process. Verify surgical procedure, and involve patient in marking surgical site.
- Identify any allergies to medications.
- Perform and document required counts. If necessary, take a "pause for the count" to avoid distractions.
- Administer medications and solutions as prescribed. Label all medications and solutions on and off the sterile field.
- Verify and record implants.
- Follow protocols for containing, identifying, labeling, preserving, transferring, and transporting surgical specimens.

NURSING DIAGNOSIS
Risk for Imbalanced Fluid Volume

OUTCOME
The patient's fluid volume, electrolyte, and acid-base balance will be consistent with or improved from preoperative baseline levels.

INTERVENTIONS
- Review baseline laboratory data; confer with surgeon or anesthesia provider regarding deviations from normal.
- Assess nutritional status, skin turgor, renal status, and other conditions or medications affecting fluid, acid-base, and electrolyte balance.
- Collaborate with surgeon and anesthesia provider in accurately estimating fluid and blood loss and maintaining or correcting losses (administration of fluid replacement therapies, electrolytes, or medications).
- Record all solutions administered from the surgical field.
- As appropriate, include estimated blood loss (EBL) in hand-off report to receiving unit. In some institutions, a surgical Apgar score is calculated at the end of the surgical procedure from the EBL, lowest mean arterial pressure (expressed in mm Hg), and the lowest heart rate rhythm recorded on the anesthesia record during the procedure. The score may be used to identify patients with a higher likelihood of developing complications after surgery.

surgery, the patient's preference, and the collaborative judgment of the anesthesia provider and surgeon. Procedures done endoscopically, such as esophagogastroduodenoscopy (EGD) (upper endoscopy) or colonoscopy, typically use intravenous (IV) moderate sedation. Monitoring devices and parameters typical to those anesthesia plans will be used (see Chapter 4). Patients at risk for fluid and electrolyte shifts, or significant blood loss, require arterial monitoring and frequent intraoperative sampling of hemoglobin and hematocrit, arterial blood gases, electrolytes, and coagulation studies. Preoperative fasting and bowel cleansing, combined with alterations in nutrition, may severely deplete fluids and electrolytes. These must be measured, replaced, and balanced throughout and after the procedure. A nasogastric tube may be inserted to decompress the stomach and to suction gastric secretions. A urinary catheter may be inserted to decompress the bladder and provide accurate measurement of urinary output and renal function.

Preoperatively, the physician may order blood for open laparotomy or laparoscopic GI surgery patients whose blood replacement is predictable. Elective surgery patients may choose to donate 1 or 2 units of autologous blood; friends and family may also donate donor-directed blood. Autotransfusion (or cell salvage) of the patient's blood during surgery may not be appropriate, given potential contamination from bowel contents such as organisms or malignant GI neoplasm cells. Blood replacement is augmented, managed, and balanced with IV colloids and crystalloids, albumin, platelets, fresh frozen plasma, and electrolytes.

IV antibiotics are given before the incision is made and throughout the procedure (Surgical Pharmacology). Antibiotic irrigation solutions may be used intraabdominally during the procedure and before closure. Additional intraoperative medications may be indicated per institutional standard or surgeon preference. Hemostatic agents, anticoagulants, steroid preparations, and local anesthetics may be utilized. The best guide is a comprehensive and frequently updated plan of care, pick list, or surgeon/procedure preference sheet.

For laparotomy and laparoscopic approaches, the patient typically is placed in the supine position. Arms are placed on padded armboards with the palms up and fingers extended. Armboards are maintained at less than a 90-degree angle to

BOX 10-3

Rationales for Perioperative Nursing Interventions

- Providing emotional support and sharing may clarify fears. Fears may be based on inaccurate information.
- Anxiety and sensory deficits may impair the patient's readiness to learn or retain new knowledge.
- Patients who are prepared for painful procedures by an explanation of the actual sensory experience have less stress than those with vague information.
- Use of noninvasive pain management measures can enhance comfort and the therapeutic effect of pain medications.
- Pain management should be aggressive and individualized at regular intervals of administration rather than as needed (PRN).
- Divert focus from changes to positive characteristics that reinforce self-concept and control.
- The surgical and anesthesia experience, with exposure of body surfaces, introduction of fluids and instruments, and an open wound, will decrease core body temperature.
- The physiologic stress of surgery may impair normal thermoregulating mechanisms.
- The surgical and anesthesia experience challenges the immune system and poses many risks of introducing endogenous and exogenous microorganisms.
- Hyperextension of limbs, mechanical pressure, and prolonged positioning can cause skin, nerve, vascular, and musculoskeletal compromise.
- Repositioning and transfer can cause shearing force and skin injuries.
- Directed energy modalities such as electrosurgery, lasers, radiation, and fiberoptic light cords can cause tissue burns and fire.
- Antimicrobial prep solutions, chemical sterilants, and alcohol can cause tissue irritation and burns.
- Surgical patients are at risk for wrong procedure and wrong site surgery when patient identification practices are flawed and not repeated at each stage of perioperative care.
- Multiple surgical items, such as instruments, sharps, and sponges, present the risk of retention if counting practices are flawed.
- Anesthetized patients are vulnerable and unable to advocate for themselves.
- The physiologic stressors of surgery and anesthesia can result in fluid shifts from excess to depletion throughout the entire procedure (Carpenito-Moyet, 2007).

Carpenito-Moyet LJ: *Nursing diagnosis: application to practice,* ed 12, Philadelphia, 2007, Lippincott Williams & Wilkins.

SURGICAL PHARMACOLOGY

GI-Specific Prophylactic Systemic Antibiotics

Although prophylactic systemic antibiotics are not indicated for patients undergoing low-risk, "clean" surgical procedures, there are clinical situations where their administration is beneficial. High-risk GI procedures are an example of a situation when prophylactic systemic antibiotics reduce infection and clinically benefit the patient. These procedures include surgery for gastric cancer, ulcer, obstruction, or bleeding. Antibiotics are also useful in patients whose gastric acid secretion has been suppressed and in patients undergoing gastric surgery for morbid obesity. Oral antibiotics before procedures on the colon suppress both aerobic and anaerobic flora (Anaya and Dellinger, 2008).

GASTROINTESTINAL-SPECIFIC ANTIBIOTICS

- Ampicillin—prophylaxis against gram-positive cocci such as *Enterococcus faecalis* and gram-negative bacilli such as *Salmonella* and *Shigella*
- Cephalosporin—prophylaxis against aerobes and anaerobes
- Clindamycin—prophylaxis against aerobes and anaerobes
- Ertapenem—broad-spectrum prophylaxis for colorectal surgery
- Fluoroquinolone—prophylaxis in combination with metronidazole or clindamycin
- Gentamicin—prophylaxis against gram-negative rods and enterococci
- Metronidazole HCl—prophylaxis in Crohn's disease, pseudomembranous colitis
- Tetracycline HCl—prophylaxis against shigellosis, cholera, *Helicobacter pylori*
- Tobramycin—prophylaxis against aerobic gram-negative bacilli, *Pseudomonas aeruginosa*
- Vancomycin—prophylaxis in penicillin allergy, pseudomembranous colitis, staphylococcal enterocolitis

Anaya DA, Dellinger EP et al: Surgical infection and choice of antibiotics. In Townsend CM et al, editors: *Sabiston textbook of surgery,* ed 18, Philadelphia, 2008, Saunders.

prevent brachial plexus stretch. If there are surgical reasons to tuck the arms at the side, the elbows are padded to protect the ulnar nerve, the palms face inward, and the wrist is maintained in a neutral position (Denholm, 2009). A drape secures the arms. It should be tucked snuggly under the patient, not under the mattress. This prevents the arm from shifting downward intraoperatively and resting against the OR bed rail. Modifications may include flexion of the knees to a modified lithotomy position with the legs in self-balancing stirrups (Allen or Yellofin) for procedures where access to the rectum is necessary. Check for the presence of bilateral posterior popliteal, posterior tibial, and dorsalis pedis pulses, and document. Monitor and document circulation throughout the procedure. Intraoperative access and exposure may require frequent alterations of patient position with side-to-side tilt, elevation of the kidney rest, and shifts to Trendelenburg's or reverse Trendelenburg's position to permit gravity displacement of abdominal organs for surgical exposure. Entry into the thoracic and abdominal space is often approached via thoracoabdominal access; the patient is placed and immobilized in a lateral or side-lying position. EGD is typically done with the patient in slight semi-Fowler position, whereas colonoscopy is accomplished with the patient in left lateral position with the knees flexed.

Morbidly obese patients pose a positioning challenge as to safety, exposure, and access, as well as for the safety of staff that must transfer and position the patient (see Chapter 30 for a discussion of staff safety). These patients require a surgical bed that accommodates their weight and size, protects them from falls, and supports their frame while preventing skin and musculoskeletal injury. More than four staff persons are often needed to transfer and position the patient safely. Transfer aids, such as rollers, sliders, lift sheets, air-filled transfer mattresses, and hydraulic lifts, are used when available. Encourage patients to assist in their transfer. Determine the patient's level of comfort, and make appropriate adjustments before anesthesia induction. Meticulous assessment and continued evaluation of skin and tissue are critical to recognize compromise early and to prevent injury.

GI surgery patients will have a sequential compression device (SCD) ordered for use during surgery. SCDs are applied as soon as possible before anesthesia induction to prevent deep vein thrombosis (DVT) (Hageman et al, 2008). Wrap the sleeves around the legs smoothly, to prevent folds when the legs are positioned in stirrups. The unit is hung on the OR bed or an IV pole or is placed on the floor under the OR bed in an area away from team members' feet and areas that may be wet. The vibration noise can be buffered with a blanket or mat placed under the unit.

Positioning requires attention to body alignment; access and exposure to the intended incision site; positioning of the surgical light and instrument accessories and equipment, which may be attached to the OR bed; and padding and protection of potential pressure sites (see Chapter 5).

The large amount of skin exposure required for either a laparotomy or a laparoscopic approach presents a risk for hypothermia. Prewarming the patient for at least 15 minutes before anesthesia induction is recommended (AORN, 2009a). A forced-air warming blanket may be positioned under the sterile drapes. Temperature settings range from "low" at 32° C (89.6° F) to "high" at 43° C (109.4° F). Keep the ambient room temperature warm (between 20° C [68° F] and 26° C [78° F]) until after the patient is prepped and draped. Keep the patient covered with warm bath blankets until the skin prep is begun. Expose only the areas to be prepped. Warm all irrigation fluids to a temperature not greater than 40.5° C (105° F). Consult with the anesthesia provider for an assessment of the patient's body temperature during the procedure. Raise the room temperature before the conclusion of the procedure. IV fluids and blood products are administered by way of a fluid warming system with blood warmed to 37° C (98.6° F) and IV fluids between 37° C (98.6° F) and 40° C (104° F). Surgical skin prep solutions are not warmed unless recommended. The manufacturer of the prep solution must provide clear directions for solution warming (AORN, 2009b).

If prescribed, hair removal at the operative site is done as close as possible to the time of incision. Hair should be removed according to institutional protocol; many institutions require a physician's order for this procedure. Direct special attention to existing or intended ostomy sites, avoiding further skin injury. Existing ostomy stomas may be covered and protected with an occlusive sterile plastic dressing or a collection appliance, or be isolated with a plastic drape with adhesive strip. Antimicrobial skin preparation follows general protocol for laparotomy, with generous borders in the event that the surgeon extends the incision. Precautions are taken to prevent accumulated fluid at or under the bed line, skin injury, and surgical fires. Sites within the prep area that provide concentrated microorganisms, such as an existing ostomy, draining fistula, or the rectum, are prepped last.

Intraoperative draping follows standard draping for patients undergoing laparotomy or laparoscopy. Extra drapes are needed when the patient is placed in a modified lithotomy position and where bowel isolation precautions are taken. The patient may be redraped or the existing drapes reinforced before incision closure.

All surgical team members pause for a "time out briefing" before the incision is made. Participation is required by all team members, who engage in a comprehensive review and consensus that includes the following: an introduction of all present team members, patient identification, intended surgical procedure or procedures, marked site (and laterality if appropriate, which must be visible when the patient is draped), patient position, pertinent medical conditions or concerns, availability of implants or any special equipment or devices, potential threats to good outcome, fire risk score, and verification that prep solutions have dried.

GI surgery instrumentation, for both the laparotomy and laparoscopic approach, requires a basic laparotomy instrument set. Sharp cutting instruments include #3 and #4 knife handles (#11 or #15 knife handles are required for laparoscopic port stab incisions), curved tissue dissection scissors, and curved and straight utility scissors. Clamps include curved and straight hemostats; Kelly clamps; Kocher, right angle, and Crile (tonsil) hemostats; Babcock and Allis clamps; towel clamps; ring or sponge forceps; and assorted needle holders. Tissue-grasping forceps include short-, medium-, and long-toothed, plain, DeBakey, Adson, and Russian forceps. Handheld retractors include Army-Navy, Richardson, Deaver, malleable, or rake, and selected self-retaining retractors. Accessory instruments may include but are not limited to various grooved and nontraumatic curved, straight, and angled bowel clamps. Suction tips may include Yankauer tonsil suction, Frazier tip, cardiac suction tip, or a Poole, intestinal sump suction. Protective nontraumatic covers or shods may be slipped over the jaws of selected clamps to protect and stabilize tissue during dissection or suturing. Longer versions of many of the basic instruments will be required for low abdominal procedures, obese patients, and thoracoabdominal approaches.

Laparoscopic surgery of the GI tract requires laparoscopic instruments intended for abdominal surgery. These instruments may be disposable, reusable, hybrid "reposables" (reusable instruments with disposable cutting or coagulation tips), or a combination. Laparoscopic instruments have operating tips that function similarly to the basic laparotomy instruments but are designed to fit through a narrow trocar and extend into all quadrants of the abdominal cavity from the skin surface. Several laparoscopic dissectors and scissors have electrosurgical capability. Bipolar or monopolar electrosurgery may be used, with bipolar considered the safer alternative (Risk Reduction Strategies). Accessories for laparoscopic instruments, telescopes, and trocars include a light cord, insufflation tubing, camera and cord, suction-irrigation tubing, ultrasonic dissection handpiece with cord, and thermal plasma coagulation devices. Safe practices when using devices that generate surgical smoke require the use of a smoke evacuation system and accessories in both open and laparoscopic procedures (see Chapter 7). When laparoscopic procedures necessitate extracorporeal (outside the abdomen) assistance for inspection, dissection, anastomosis, or specimen manipulation, a hand-assisted port may be used to offer the surgeon a sterile, protected entry into the abdomen for his or her nondominant hand, while maintaining pneumoperitoneum. Referred to as hand-assisted laparoscopic surgery (HALS), the hand-assisted port is suitable for laparoscopic surgeries that require a minilaparotomy to remove an organ or specimen or for extracorporeal anastomoses. A primary advantage with HALS is tactile sensation. These devices have an adhesive base to attach the sleeve and a protractor to expose the wound and to protect against contamination. Additional small incisions, or port sites, are made to introduce standard laparoscopic instruments.

RISK REDUCTION STRATEGIES

Monitoring Integrity of Laparoscopic Instrument Insulation

Laparoscopic injury can result from electrical and thermal burns when the integrity of an instrument's insulation coating is defective. Electrosurgery has been a standard surgical tool since the 1930s and most laparoscopic procedures employ electrosurgical energy for tissue cutting and coagulation. Minimally invasive surgery provides a moist environment and limited access for visualization. Current leakage while using monopolar laparoscopic electrosurgery can occur within the trocar cannula or outside the trocar cannula, and capacitive leakage can occur from the active electrode shaft to the cannula. Significant injury can result from such stray current. Even a slight tear in the insulation can produce a power density of current and high-voltage waveform to create a larger opening in the insulation. The surgeon may not notice the change in current and the patient may not present with symptoms for several days after the procedure. Perioperative team members must continually monitor the functioning of equipment and instruments to prevent hazards and injury. The following are recommendations for care and handling of laparoscopic instruments and accessories:

- Use active electrode monitoring (AEM) devices with electrosurgery during patient care.
- Use active electrode insulation integrity testing devices before transfer to the surgeon at the sterile field and/or during instrument processing.
- Inspect instruments for small visible breaks in the insulation before use.
- Handle instruments so as to protect them from sharp objects during use, transport, and processing.
- Inspect insulation with a magnifying lens after decontamination.
- Conduct stray leakage testing with an insulation testing device after each decontamination.
- Remove damaged instruments from service for repair or replacement.
- Comply with all manufacturer care and handling instructions.

Modified from Association of PeriOperative Registered Nurses (AORN): Recommended practice for cleaning and care of surgical instruments and powered equipment. In *Perioperative standards and recommended practices,* Denver, 2009, The Association; Dennis A: Laparoscopic electrosurgical complications: stay informed, *Endonurse* 46-56, 2008; ECRI Institute: Safety technologies for laparoscopic monopolar electrosurgery: device for managing burn risks, *Health Devices* 34:259-271, 2005.

Robotic or telerobotic surgical systems have advanced laparoscopic surgery, enhancing the surgeon's performance and precision by promoting an ergonomically comfortable hand position, visualizing a three-dimensional virtual field, replacing the camera holder with a stable platform, and providing unlimited motion of instrumentation (Ewing et al, 2004). Magnification and full-field lighting enhance the surgeon's orientation. Since 1997 robotic systems have been successfully employed in a broad range of GI procedures of the esophagus, stomach, and bowel, including fundoplication and bariatric procedures.

A tall, multishelf video cart, primary tower, or ceiling-mounted boom contains the primary video monitor, light source, video camera, DVD, printer, insufflator, and directed energy generators. The tower may also contain a bipolar electrosurgical unit (ESU), pulsed irrigation system, or ultrasonic dissection unit. A second tower, cart, or boom displays a second monitor, allowing the surgical team on the other side to view the procedure. The surgeon may prefer to use one monitor, placed between the patient's legs, when lithotomy position is used.

Meticulous planning ensures that all equipment is in working order. Equipment may have to be positioned after the patient is transferred to the OR bed; it is done quickly and quietly to expedite the procedure, without provoking anxiety in the patient. Place the insufflator unit on a tower shelf above the level of the patient's abdomen. This precaution prevents backflow of gas, fluid, and organic debris if the unit is turned off before the tubing is disconnected from the patient. Run electrical cords and tubing from all equipment to the nearest outlet, with consideration for staff and patient safety. Avoid areas that may be wet. Secure cords to the floor to prevent falls. Do not overload an outlet with plugs from several units that each draws considerable current, such as units that produce heat. Be prepared to connect all equipment cords and tubing after the patient is draped, and white-balance the camera. Provide a source of light for the anesthesia provider and the scrub person when the overhead room lights are turned off.

It is prudent to have an open laparotomy set with instruments and accessories available, should conversion to an open laparotomy or laparoscopic-assisted procedure be necessary. The laparotomy instruments may be opened and counted on the laparoscopy back table or a separate sterile table as per institutional protocol. All sharps must be counted or inventoried before the incision is made regardless of approach or size of incision (AORN, 2009c).

The surgeon may request ureteral catheters to be placed by a urologist before a GI procedure is begun. The catheters enable the surgeon to see and palpate the ureters during the procedure. A basic cystoscopy setup with sterile ureteral catheters, two of each size, will be needed.

Intraluminal examination of the bowel may be necessary during the procedure. The surgeon may request a sterile colonoscope or sigmoidoscope to insert into an opening made through the bowel wall, after the abdomen is open. Set up the scopes and accessories on a separate sterile table. This table will be considered contaminated after the scope is removed. Team members who have directly participated in the endoscopic procedure must change gown and gloves before proceeding with the remainder of the surgical intervention.

Additional accessory instruments or devices may include a sterile plastic drawstring intestinal bag to confine loops of normal bowel from the operative segment, sterile counted radiopaque surgical towels, combination suction-irrigator, or irrigator-bipolar coagulation. Ultrasound-guided probes and ultrasonic dissection instruments are commonly used in GI surgery. Automatic stapling devices streamline the processes of ligating tissue, cross-clamping, and creating anastomoses and reservoir pouches. These instruments deliver single staples and single or double rows of closely staggered linear and circular rows of inert staples. The staple appliers may be single-fire or accept multiple cartridges for successive use. They may be designed for open laparotomy or endoscopic use. The B-shaped design of the implanted staple does not compromise the vascularity of the approximated tissue edges. These devices are available in reusable and disposable units. Personnel must be

familiar with the types of available stapling equipment, applications, assembly if indicated, and proper loading.

Electrosurgery is critical to achieve and maintain hemostasis. Optimal dispersive pad sites include the thigh, flank, shoulder, upper arm, and buttocks. The pad is placed over a fleshy muscular site as close as possible to the incision, yet out of the prep area. Avoid dependent areas that may have a bony prominence or affinity for pooled solution. Choose power settings that achieve the best tissue response at the lowest setting. The smoke evacuation apparatus should be utilized. Provide long and angled ESU tips. Other hemostatic and dissection equipment and devices may include the argon beam coagulator, ultrasonic tissue dissector, radiofrequency ablation, and laser (see Chapter 7).

Suture materials used on GI tissue were traditionally chromic gut and silk. With the increased number of synthetic absorbable and nonabsorbable suture materials available, surgeons have a variety of materials from which to choose. Polyester fiber sutures and polyglycolic acid sutures are frequently employed on GI tissue. Generally, 3-0 and 4-0 sutures on a semicircular taper needle are used on intestinal tissues. Ligatures for small vessels usually require a 3-0 or 4-0 braided material, whereas 0 or 2-0 braided ligatures are used for larger vessel occlusion. For closure or anastomosis of GI layers, 3-0 or 4-0 synthetic absorbable suture with a curved intestinal needle is commonly used on the mucosa. A 3-0 or 2-0 continuous synthetic absorbable suture and 4-0 or 3-0 nonabsorbable suture with curved or straight intestinal needles may be used for the seromuscular layer. Some surgeons may prefer interrupted silk sutures on intestinal (semicircular taper) needles for anastomosis procedures. For abdominal closure 1 or 0 braided or monofilament suture is commonly used. Retention sutures may be indicated when there is potential for compromised tissue or wound healing. Checking the surgeon's preference/procedure card or pick list for appropriate suture materials not only ensures the availability of necessary supplies but also is cost-effective.

Sponges used in open laparotomy procedures include large packs (18 × 18 inches), large laps (12 × 12 inches), or small elongated tape sponges (4 × 18 inches). Sponges vary in size according to product availability. Gauze dissectors (referred to variously as "Kittners," "peanuts," or "pushers") on a Kelly clamp or right angle clamp may be used for blunt tissue dissection. Meticulous vigilance prevents the incidental misplacement of these items. Larger gauze sponges are not recommended for use in the abdominal cavity. In the case of significant bleeding or isolation of bowel during anastomosis, lint-free radiopaque cloth towels can be used. Towels are counted, as are all sponges.

Bowel technique, also referred to as *contamination* or *isolation* technique, prevents cross-contamination of the wound or abdomen with bowel organisms. This technique is also employed during cancer procedures to prevent mechanical metastasis, or "seeding" of malignant cells throughout the abdomen. Bowel technique begins as soon as the GI tract is clamped and transected, and proceeds through wound irrigation, before wound closure. The wound edges and surrounding drapes are protected with extra drapes, while instruments used for GI tract resection and anastomosis are sequestered and used only for this part of the procedure. The rest of the sterile back table remains untouched throughout the anastomosis. Separate instruments and drapes are used for the closure. Gowns, gloves, and drapes are changed before closure. The contaminated GI tract instruments are handed off or left on a separate Mayo stand. Preplanning during preoperative setup includes extra and separate instruments ready for anastomosis and closure. These must all be included in the instrument count with provision for a closing count of the contaminated set. There is also a provision for containment and display of needles used for the anastomosis. Surgeon preference and institutional protocol determine details of bowel technique.

Specimens are handled carefully and prepared for examination by the pathologist. The specimen may be contaminated with microorganisms or malignant cells and no contamination of the sterile field and instruments can occur. The surgeon usually determines how the specimen is handled before examination. It may be sent to the pathology department fresh, in saline, or in a preservative solution. Tissue also may be sent for frozen-section examination to verify pathologic condition and to determine if tissue margins are free of malignant cells. Specimens may also be entered into research protocols, which will require further special handling, storage, and transport.

The surgical department has procedures for correct patient and specimen identification that are followed each time a specimen is collected. Accuracy is verified with the surgeon by reading back (referred to as "write down, read back") the label and pathology form before removing the specimen from the room or before the surgeon leaves the room, and documented according to institutional protocol.

Drains may be used to evacuate gastric secretions or serosanguineous fluid. A closed suction wound drain may be used. A Malecot, Pezzer, or Foley catheter in desired size may be inserted as a gastrostomy tube for drainage until normal bowel peristalsis returns. A jejunostomy tube may be placed in the jejunum after gastric resection to provide access for enteral nutrition.

Determination and documentation of wound classification are done at the end of the procedure. If the GI tract has been entered or transected, the wound class will be considered "clean-contaminated" as long as no breaks in technique have occurred or signs of infection have been discovered in the surgical wound.

Evaluation

Evaluation of nursing care is ongoing throughout the procedure and before the patient is transported to the postanesthesia care unit (PACU) or a surgical intensive care unit (SICU). The dressing, drains, and any pain management pump tubing are secured so as to avoid damage during transfer to the PACU stretcher or SICU bed. Skin is assessed for reddened or bruised areas; if such areas are present, they are documented and treatment initiated immediately. The ESU dispersive pad is removed, the site inspected, and the condition of the skin documented. Ensure that the patient is covered with a clean, warm blanket before being transported to PACU or SICU. Any variances are reported to the surgeon, documented in the patient's record, and included in the hand-off report given to the nurse in the PACU, SICU, or nursing unit. Patient outcomes, based on the perioperative nursing diagnoses, will be reviewed. Postoperative documentation reflects and measures how each outcome was met and notes significant variations from the desired expectation.

Patient and Family Education and Discharge Planning

Patients undergoing surgical intervention for GI disorders vary greatly in the length of time and complexity of their recovery. Recovery and convalescence depend on the type of procedure, surgical approach, site of surgery, type of anesthesia, pain management, and individual health of the patient. GI structures may have varying degrees of edema, decreased peristalsis, and alterations in tissue oxygenation and lymphatic drainage; these all depend on the amount of manipulation, resection, and trauma suffered by the anatomic structures of the GI tract. The patient usually experiences decreased peristalsis for 3 to 5 days after open laparotomy or laparoscopy. Postoperative ileus, commonly called paralytic ileus, is a condition of delayed GI motility that extends beyond 3 days, causing bloating, pain, nausea, emesis, and general feeling of fullness that could progress to bowel obstruction (Carter, 2006). Causes are varied (Box 10-4) and can arise from neurogenic, inflammatory, hormonal, pharmacologic, or mechanical effects of surgery, including manipulative handling of the intestines during surgery (Kulaylat and Dayton, 2008). In the absence of risk factors for delayed peristalsis, motility of the small intestines returns to normal first, within several hours after surgery. Stomach motility returns to normal within 24 to 48 hours and the large bowel, the final GI segment, returns to normal within 48 to 72 hours (Bisanz et al, 2008). Identifying early bowel sounds through abdominal auscultation may signal return of small intestinal motility while the remaining segments may not be ready for return to regular feedings and full diet. The return of motility of the entire GI tract, or resolution of ileus, is evidenced by the first passage of flatus or stool (Bisanz et al, 2008).

Diet is introduced only after evidence of GI motility returns (Research Highlight). The patient may experience nausea and vomiting if food or drink is introduced too early for the GI system to function with normal absorption and motility. Postoperative outcomes are improved when nutritional status is maximized. When GI motility returns, the patient will receive nutritional support as tolerated: by oral feeding, total enteral nutrition (TEN), or total parenteral nutrition (TPN).

Coughing and deep breathing help the patient to recover from general anesthesia. Splinting of the abdominal muscles and the use of incentive spirometry assist with postoperative coughing and deep breathing and move pooled secretions. Early ambulation aids in regaining overall muscle tone and strength, supports cardiac and pulmonary function, prevents DVT in the lower extremities, and boosts a sense of well-being.

Pain management is critical for the patient's recovery. An epidural catheter may be placed immediately before surgery for postoperative pain control. For most major GI procedures, patient-controlled analgesia (PCA) or patient-controlled epidural analgesia (PCEA) is used for consistent control of pain and discomfort in the first 1 to 3 postoperative days of hospital recovery. Narcotics may increase the time for normal bowel peristalsis to return and require close monitoring after the third postoperative day.

The patient with a new ostomy will need consultation with the WOCN so that both patient and family can learn to care for and manage the ostomy and surrounding skin. Many lifestyle changes occur with an ostomy. The WOCN first teaches the

BOX 10-4

Risk Factors for Postoperative Ileus

- Intraabdominal infection
- Intraabdominal inflammation
- Lengthy surgical procedure
- Prolonged exposure of abdominal organs
- Opioid and psychotropic drugs
- Inhaled anesthetics
- Electrolyte imbalance
- Retroperitoneal hemorrhage
- Pancreatitis

RESEARCH HIGHLIGHT

Early Feeding After Abdominal Surgery

Traditionally, postoperative fluid and food intake was delayed until evidence of bowel function returned; early feeding, however, may stimulate GI activity and return of motility, decreasing length of stay (LOS). Oral intake of nutrition as early as 4 to 12 hours postoperatively may stimulate reflexes that produce coordinated propulsion activity and release of GI hormones (Bisanz, 2008). Several recent studies investigated if a routine of permitting patients to eat normal food after major abdominal surgery would affect the return of GI motility. In one randomized controlled study (N = 447), one group of patients (227) was assigned to "nil per os" (NPO) and enteral tube feeding, while another group (220) was permitted to eat-at-will from their first day after surgery. A total of 76 NPO patients had complications compared with 62 of the eat-at-will group. Return of motility, LOS, total number of complications, and post discharge complications significantly favored the eat-at-will group (Lassen et al, 2008).

A smaller study of 128 patients separated into 2 equal groups compared the traditional progression from clear liquids to full diet over 4 days to early eat-at-will feeding. The endpoint indicators were the need to reinsert an NG tube, LOS, and postoperative complications. This study also included pain scale ratings and several quality of life criteria. There were no differences in outcomes between the two groups, including pain and quality of life indicators (Han-Geurts et al, 2007).

Gum chewing following surgery has been associated with enhanced recovery of GI function. A study of 158 patients who chewed gum had return of motility evidenced by passing of flatus and bowel movement sooner than the average of 1.10 days. It is possible that gum chewing represents a type of sham feeding that stimulates the digestive nerves and GI hormones (Purkayastha et al, 2008).

Early nutrition increases wound healing, enhances return of GI motility, shortens LOS, and decreases some postsurgical complications. For most patients, progressive feeding according to the GI tract's capability to tolerate food immediately after surgery is likely to result in significant positive outcomes.

Modified from Han-Geurts et al: Randomized clinical trial of the impact of early enteral feeding on postoperative ileus and recovery, *Br J Surg* 94: 555-561, 2007; Lassen et al: Allowing normal food at will after major upper gastrointestinal surgery does not increase morbidity: a randomized multicenter trial, *Ann Surg* 247:721-1140, 2008; Purkayastha S et al: Chewing gum associated with enhanced bowel recovery after colon surgery, *Arch Surg* 143(8):788-793, 2008.

patient and family to accept the ostomy. Skin care, appliance application, ostomy irrigation, diet, bowel training, and quality of life strategies are but a few of the topics that must be presented for care and management of an ostomy. Clothing, self-esteem, body image, sex and intimacy, travel, public toileting, and odor control are some of the key issues the WOCN helps the patient and family to face with useful strategies and resources to ensure quality and fulfillment in their lives (Carmel and Goldberg, 2004).

Patients with resected small bowel may require TPN because their ability to absorb nutrients from ingested food is compromised. Referral to home care agencies expert in administering TPN is essential for this patient population.

General discharge instructions for the patient undergoing GI surgery include both verbal and written instructions. They are provided with the name and phone number of the healthcare provider to call if questions or concerns arise (Patient and Family Education). Procedure-specific instructions are necessary to fully assist the patient and caregivers with recovery and rehabilitation at home (Canobbio, 2006).

PATIENT AND FAMILY EDUCATION

General Discharge Instructions for GI Surgery Patients

General discharge instructions for the GI surgery patient should include the following:

- Swelling inside the GI tract may produce a feeling of tightness that should dissipate in 6 to 8 weeks.
- Solid foods should be added to the diet gradually. Chew solid foods well, and avoid gulping, eating fast, or swallowing large bulk portions.
- Avoid carbonated beverages for 3 to 4 weeks to help prevent gas bloating.
- Plan small, frequent meals because a feeling of fullness will occur quickly.
- Keep the incisional area clean and dry. Check the site daily for redness, swelling, bruising, tenderness, and drainage.
- Expect itching and prickly sensations around the incision as these are normal during healing.
- Observe dressing and perform ostomy care as instructed.
- Increase exercise gradually to return to activities of daily living. Exercise regularly.

The perioperative nurse should also review the following with the patient and family. Where appropriate, have the patient repeat back, in his or her own words, information provided. Allow time for questions. Use the patient's preferred language, and consider ramifications of culture, any hearing or visual impairments, health literacy, cognitive impairments, or disability:

- Pain management strategies.
- Reconcile and explain all discharge medications (purpose, dose, schedule, route of administration, side effects to report). The patient should be provided with a copy of these.
- When to make an appointment for follow-up care with the surgeon (provide phone number).
- When to call a physician or nurse practitioner. Generally, this call should be made if any of the following develop: persistent fever (38.4° C [101° F] or higher), bleeding, increased abdominal swelling or pain, persistent nausea or vomiting, chills, persistent cough or shortness of breath, changes in bowel habits, diarrhea, constipation, flatulence.

AMBULATORY SURGERY CONSIDERATIONS

Preprocedural Instructions for Esophagogastroduodenoscopy (EGD) and Colonoscopy

The perioperative nurse caring for patients undergoing esophagogastroduodenoscopy (EGD, upper endoscopy) and colonoscopy may include the following activities as part of preprocedure care:

- Using simple language, review explanation of procedure, postprocedure expectations, and recovery. Use patient's preferred language; obtain services of a translator if necessary.
- Verify written consent; patient should be able to state name of planned surgical procedure. Secure advance directives according to facility policy.
- Discuss oral intake restrictions, including medications to be taken the morning of procedure with sips of water.
- Provide special instructions for patients taking insulin (who may need to consult primary health provider for dosing adjustment).
- Remind patient not to take anticoagulants, herbal supplements, aspirin, or ibuprofen 1 week before procedure (patient may need alternative blood thinners ordered).
- Remind patient not to use bulk-forming agents, iron-containing supplements, or synthetic dietary fat products as they may impair visualization of colonic mucosa.
- Review any skin cleansing recommendations, including showering with an antibacterial soap according to facility policy.
- Describe need to remove all jewelry, including body jewelry, and removable prostheses or devices. Advise patient to wear comfortable loose clothing that is easy to remove and redress.
- Require a responsible adult to accompany the patient to the facility, drive them home, and remain with the patient for 24 hours.
- Review instructions for bowel prep and/or cleansing enema for colonoscopy.
- Review institutional criteria for discharge, including return of gag reflex and oral fluid intake for EGD.
- Provide directions on when and where to report for procedure.
- Review situations for procedure cancellation or delay: failed bowel prep, oral intake, sickness the morning of procedure.
- Give contact information for who and where to call if issues with preprocedure instructions arise or if patient is unable to arrive for procedure.

Modified from Canobbio MM: *Mosby's handbook of patient teaching,* ed 3, St Louis, 2006, Mosby.

Ambulatory procedure considerations are based on patient, procedure, and anesthesia selection. Patient instructions before and at discharge are critical, and depend on the patient's ability, self-efficacy, and family support for home care (Ambulatory Surgery Considerations).

Surgical Interventions

ABDOMINAL INCISIONS

The abdominal cavity is surgically entered more than any other anatomic region. The site of the incision (Figure 10-8) is chosen to gain quick, easy access and exposure to underlying

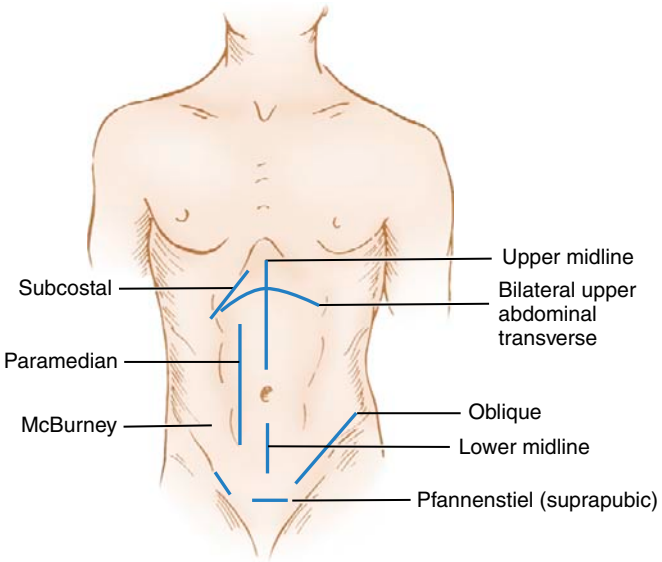


FIGURE 10-8 Incisions made through the abdominal wall.

pathology; to minimize trauma, bleeding, and postoperative discomfort; to maximize wound strength; and to afford ample room to accomplish the surgery. Each incision has advantages and disadvantages as to adequacy of exposure, length of time required for closure, disruption of surrounding blood and nerve supply, underlying muscles that must be cut or split, incidence of postoperative wound hernia, effect on pulmonary function, and cosmesis. Abdominal incisions permanently change the blood supply of the anterior abdominal wall and impact future surgeries and reconstructive options available to the patient. Any compromise of the skin, muscle, or blood supply by prior incision may preclude the use of an otherwise optimal tissue flap for reconstruction after radical thoracic, breast, or GI surgery. Minimally invasive approaches decrease the use and extent of abdominal incisions and preserve the integrity of the abdominal wall.

The abdominal wall consists of various tissue layers (Figure 10-9). Beneath the skin and subcutaneous fat are the fascia, muscles (internal and external oblique, rectus abdominis, transverse abdominis), preperitoneal fat, and peritoneum. The fascia, consisting of bands of tough fibrous connective tissue, surrounds the muscle anteriorly and posteriorly (Figure 10-10). The peritoneum is a serous membrane that lines the abdominal cavity (parietal peritoneum) and surfaces of the abdominal organs (visceral peritoneum).

Vertical Midline Incisions

The vertical midline incision is the simplest abdominal incision to perform. It is an excellent primary incision and offers good exposure to any part of the abdominal cavity. Hemostasis is easily achieved, and fewer layers are traversed. The incision can be extended from just below the sternal notch, distally around the umbilicus (which is avascular, tough connective tissue), back to the midline, and down to the symphysis pubis. The peritoneum is incised, and the round ligament of the liver may be divided. Postoperative hernias are more common above the umbilicus than below it. The midline crossover vasculature is permanently altered with this incision.

The paramedian incision, also called a *rectus* incision, is a vertical incision placed approximately 4 cm (2 inches) lateral to the midline on either side of the upper or lower abdomen. This incision is used infrequently because it adds little to the exposure obtained by way of a midline vertical incision. Paramedian incisions take longer to create and close and are more prone to herniation; this is especially true when they are more lateral.

Closure of the paramedian and midline incisions begins with the peritoneum. The peritoneum and posterior fascia may be sutured as a single layer in a continuous stitch with an absorbable suture material. The suture line may be supported with retention sutures when outward abdominal pressure on the suture line is anticipated, which raises the risk for herniation, dehiscence, or evisceration. Retention sutures are placed through all layers of the wound, using a heavy #2-gauge nylon, polypropylene, or wire suture material. Wound dehiscence, a risk of abdominal surgery, is separation of the unhealed incision. When dehiscence is severe, bowel or other abdominal structures may protrude (evisceration). Dehiscence and evisceration are most common with midline vertical incisions. Risk factors include serious nutritional deficiencies, diabetes, steroid use, obesity, infection, and improper surgical closure.

Anterior fascia, subcutaneous tissue, and skin are closed as separate layers. Anterior fascia and muscle are closed with interrupted nonabsorbable synthetic sutures. The subcutaneous layer may be closed with an absorbable interrupted suture. Skin edges are approximated and secured with interrupted nonabsorbable sutures, skin staples, subcuticular continuous closure with an absorbable suture material, skin-bonding adhesive, or sterile skin tape strips. There are many alternatives and variations to abdominal incision closure, based on the individual patient's need and surgeon preference.

Oblique Incisions

McBurney Incision. The McBurney muscle-splitting incision is commonly used for open appendectomy. It is an 8-cm oblique incision that begins well below the umbilicus, goes through McBurney point (two thirds of the distance from the umbilicus to the anterior iliac spine in the right lower quadrant), and extends upward toward the right flank. The external oblique muscle and fascia are divided bluntly (split in the direction of their fibers) and are retracted. The internal oblique muscle, transverse muscle, and fascia are also split and retracted. When muscles are divided in line with their direction of pull, as is the case with muscle-splitting incisions, there is less chance of postoperative herniation or disruption. The peritoneum is incised transversely. This incision is quick and easy to close and allows a firm wound closure. However, it does not permit good exposure and is difficult to extend. To extend the incision medially, the inferior epigastric vessels are ligated and the rectus sheath incised transversely.

Lower Oblique Inguinal Incision. An oblique right or left inguinal incision extends from the pubic tubercle to the anterior iliac crest, slightly above and parallel to the inguinal crease. This is the standard incision for open inguinal herniorrhaphy. Incision through the external oblique muscle provides access to the cremaster muscle, inguinal canal, and cord structures. This incision does not typically interrupt major abdominal arteries.

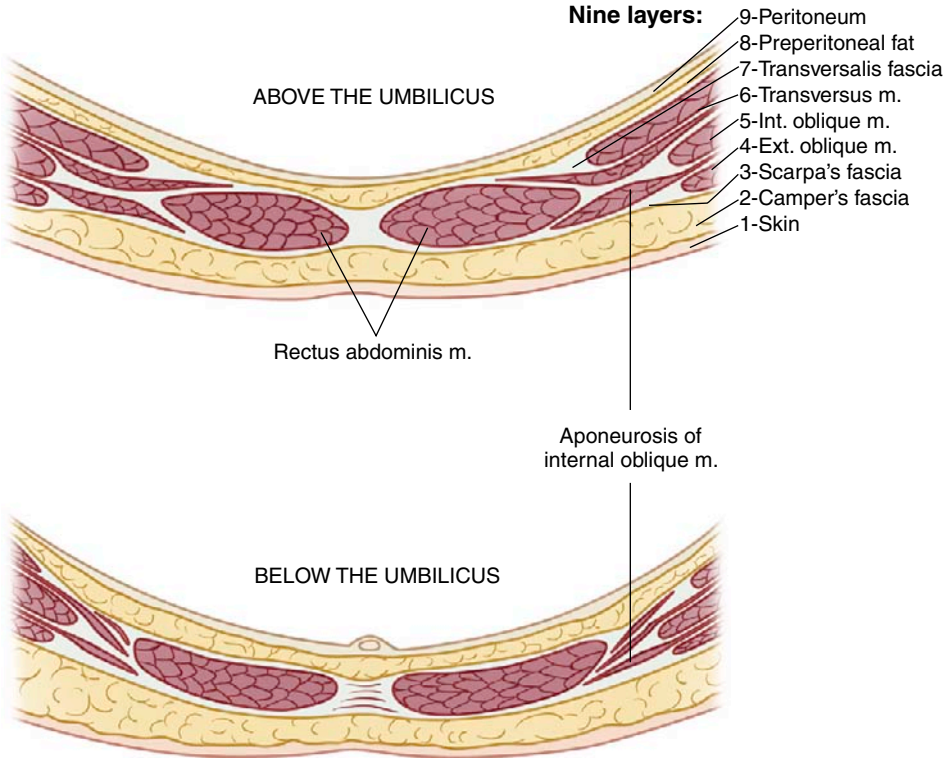


FIGURE 10-9 Horizontal section of abdominal wall. Aponeurosis of internal oblique muscle splits into two sections, one lying anterior and the other posterior to rectus abdominis muscle, thereby forming an encasing sheath around muscle above umbilicus. Below umbilicus, aponeuroses of all muscles pass anterior to rectus. *m.*, Muscle; *Int.*, internal; *Ext.*, external.

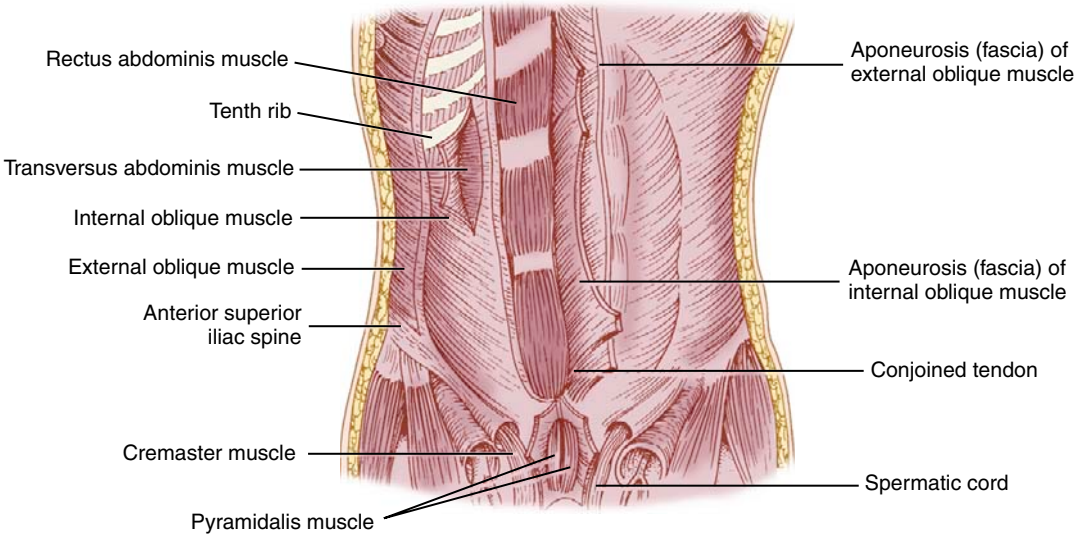


FIGURE 10-10 Superior muscles of abdominal wall.

Long, lower abdominal oblique incisions are used for transplant, urologic, and vascular procedures. These incisions require transection of the abdominal wall and flank musculature. They may require ligation of the deep inferior epigastric artery.

Subcostal Incision. The subcostal incision is made on the right side (Kocher incision) when used for open procedures of the gallbladder, biliary system, and pancreas (Figure 10-11). A left subcostal incision is used for surgery of the spleen. This incision provides limited exposure unless the patient is short with a wide abdomen and wide costal margins. It provides good cosmetic results because it follows the skin lines and nerve damage is minimal. Tension on the skin edges is less than that of a vertical incision, permitting wider retraction and exposure with less respiratory impairment during the procedure.

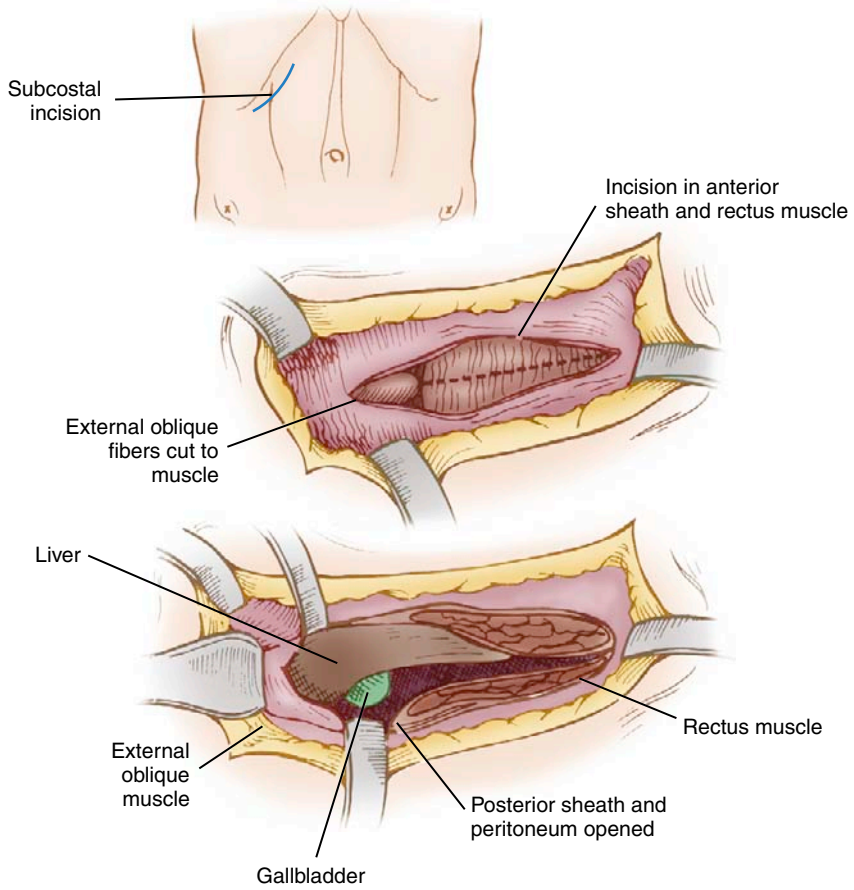


FIGURE 10-11 Subcostal incision in upper right quadrant. Anterior sheath has been divided transversely, and muscle is exposed. Posterior sheath and peritoneum have been opened transversely.

This oblique incision begins in the epigastrium and extends laterally and obliquely downward to just below the costal margin. It continues through the rectus muscle, which is retracted or transversely divided. The superior epigastric artery is occasionally sacrificed. A chevron incision (joined right and left subcostal incisions) provides excellent exposure for gastric, duodenal, pancreatic, and portal system procedures. This incision, however, interrupts lateral blood supply and innervation to the rectus muscle and postoperative muscle atrophy may occur.

Closure of this incision includes approximation of the falciform ligament, peritoneum, posterior rectus sheath, and anterior rectus sheath. Postoperatively, this is a strong but painful incision.

Transverse Incisions

Pfannenstiel Incision. The Pfannenstiel incision is used for pelvic surgery. It is a curved transverse incision across the lower abdomen through the skin, subcutaneous layer, and rectus sheath, approximately 1 cm (½ inch) above the symphysis pubis, usually within the pubic hairline (Figure 10-12). This is the standard incision for open obstetric and gynecologic procedures. The rectus muscles are separated along the midline, and the peritoneum is entered through a midline vertical incision. This incision does not alter vascular supply to the abdominal wall if the deep inferior epigastric artery is left intact. It provides good exposure and a strong postoperative scar that is cosmetically acceptable.

Midabdominal Transverse Incision. The midabdominal transverse incision is used on the right or left for a retroperitoneal approach. The incision begins slightly above or below the umbilicus on either side, extends laterally to the lumbar region at an angle between the ribs and the iliac crest, follows Langer's lines of tension of the abdominal wall, and runs parallel to vessels and nerves, rarely causing permanent damage. It is a standard incision for transverse colectomy or colostomy and choledochojejunostomy. The skin and subcutaneous tissue are incised, the anterior sheath split, the rectus muscle divided, and vessels within the rectus clamped and ligated. The posterior rectus sheath and peritoneum are cut in the direction of the fibers, preserving intercostal nerves. The peritoneum is incised along the midline, and the incision extended laterally to the oblique muscle.

Thoracoabdominal Incision. The thoracoabdominal incision is the standard incision for surgery of the proximal stomach, distal esophagus, and anterior spine. The patient is placed in a lateral position. The incision begins at a midpoint between the xiphoid and umbilicus and extends posteriorly, across the seventh or eighth interspace and the midscapular line into the chest. The rectus, oblique, serratus, and intercostal muscles are

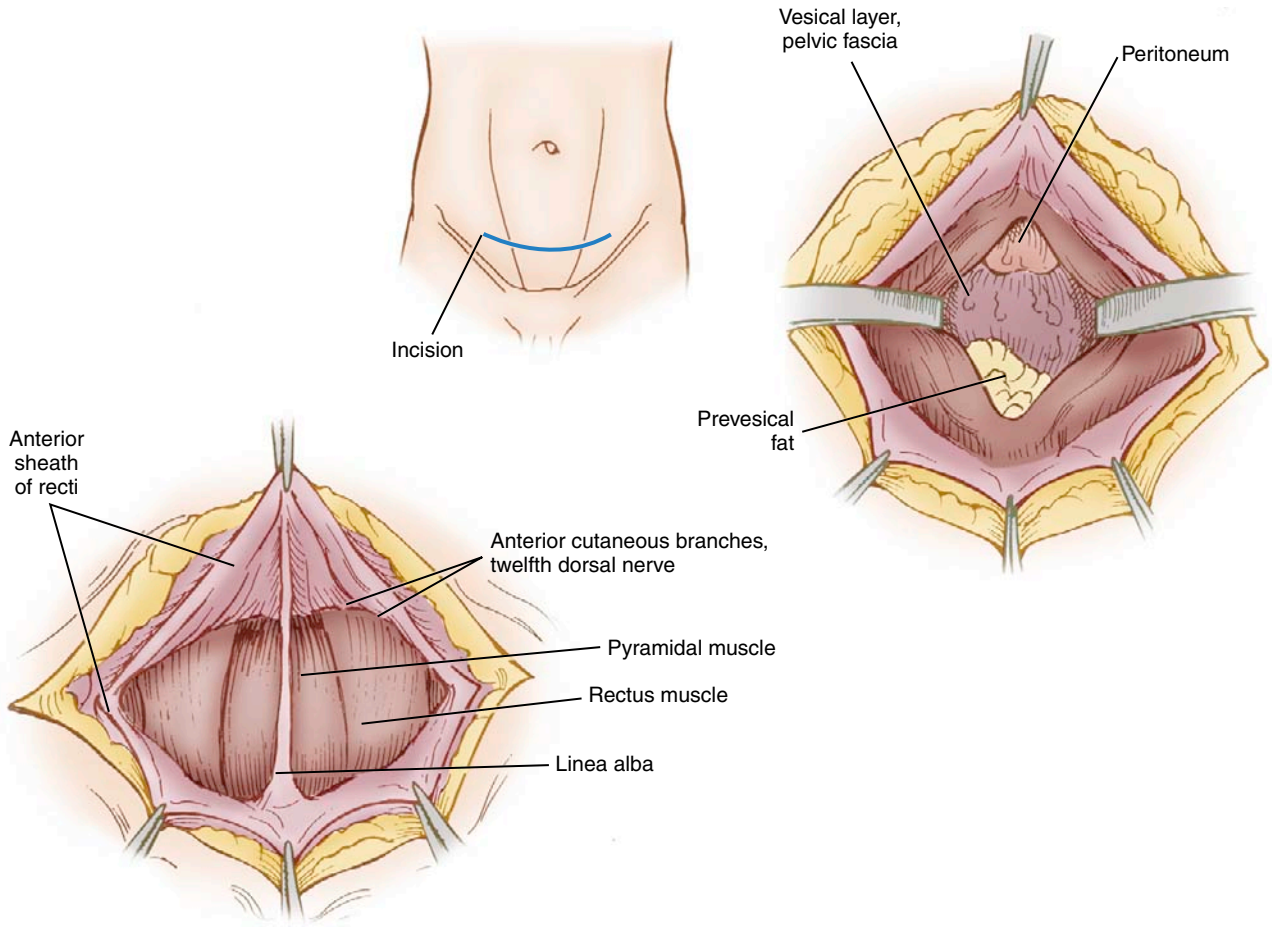


FIGURE 10-12 Pfannenstiel incision (suprapubic).

divided down to peritoneum and pleura. The costal cartilage and diaphragm are then divided (Figure 10-13). This incision sacrifices the superior epigastric artery.

Wound closure occurs in layers with an interrupted suture technique. The peritoneum and pleura may be closed with an absorbable suture material, whereas the muscle and fascia layer may be closed with either an absorbable or a nonabsorbable synthetic suture material. Skin edges are approximated and secured with suture, staples, skin bonding adhesive, or skin tape strips.

LAPAROTOMY

An opening made through the abdominal wall into the peritoneal cavity is called a *laparotomy*. Surgical intervention may be necessary to repair or remove traumatized tissue, to cure disease processes by organ removal, or to examine by biopsy or otherwise visualize internal organs for diagnosis. Surgery may be indicated for diagnostic, therapeutic, palliative, or prophylactic reasons. Most procedures requiring a laparotomy involve the organs of the GI tract.

Procedural Considerations

A basic laparotomy set with long and short soft tissue instruments and various shallow and deep retractors is used. An ESU, smoke evacuator, and suction are basic to performing laparotomy. The patient is positioned supine with arms extended on locked armboards at less than a 90-degree angle. General anesthesia with endotracheal intubation is usual, although spinal or epidural anesthesia may be used. An indwelling urinary catheter may be inserted before the abdominal prep, which extends from above the nipple line to above the symphysis pubis. A forced-air warming blanket may be applied over or under the patient's upper body, arms, and head for thermoregulation. SCDs are applied before induction to prevent deep venous blood pooling in the lower extremities.

In select patients, laparotomy leads to the formation of adhesions and the consequent likelihood of chronic pain, infertility, painful intercourse, and small bowel obstruction. Adhesions are fibrous bands of filamentous protein tissue that form a network of fibers, causing separate tissues and organs to adhere to one another in the abdominal cavity (Porth and Gaspard, 2004; The Surgical and Clinical Adhesions Research [SCAR]-3 study, 2005). Adhesions are caused by a defect in the process of normal tissue healing, prompted by tissue injury, inflammation, infection, or ischemia. The peritoneum is most associated with abdominal and pelvic adhesions. Introduction of microscopic particles, such as glove powder talc or starch, gauze fibers, and suture materials, seems to promote adhesion development.

Surgical separation of individual adhesions, called *adhesiolysis,* is not always effective, with adhesions re-forming, causing a cycle of symptoms and recurrent adhesive disease. Adhesive

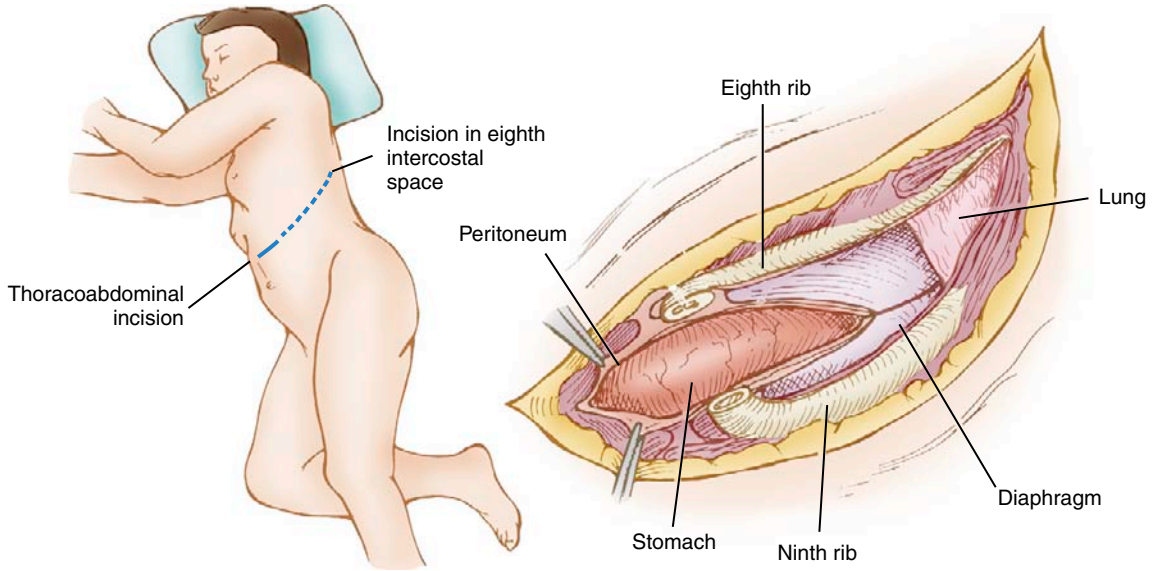


FIGURE 10-13 Thoracoabdominal incision. Patient is placed on unaffected side. Incision is usually made from point midway between xiphoid process and umbilicus to costal margin at site of eighth costal cartilage. Dissection is carried down to peritoneum and pleura. Costal cartilage and diaphragm are divided, and stomach is exposed.

tissues have increased levels of growth factors, which suggest a greater probability of re-formation. Adhesions may also develop as a result of radiation-induced endarteritis, endometriosis, pelvic inflammatory disease (PID), or Crohn's disease.

Adhesion-related disorder (ARD) is a chronic condition of pain, constipation, and cramping. Patients often describe substantial psychologic burdens and disability. Because adhesions are not evident on x-ray unless they present with bowel obstruction, torsion, or volvulus, many patients are misdiagnosed initially.

Pharmacologic agent interventions aimed at treating adhesions are limited. Systemic administration is essentially ineffective since surgical sites typically interrupt blood supply. Further, rapid absorption via the peritoneal membranes removes most of the agent within 24 hours after surgery. Most of the promising lytic-acting agents that interfere with production of hyperplastic adhesive fibrous tissue also interfere with normal wound healing. Historically, surgeons have tried many experimental substances and methods to delay adhesion development, such as mineral oil, animal biomembranes, silk, rubber, Teflon, gold foil, and amniotic membranes. Adhesions are best divided with sharp dissection.

Preventive measures include the following:

- Minimizing tissue trauma and inflammation with meticulous surgical technique
- Utilizing laparoscopic approach when indicated
- Reducing the time that the abdomen is open
- Minimizing use of electrosurgery
- Applying meticulous hemostasis
- Minimizing infection risk
- Avoiding gastrointestinal contamination
- Irrigating the abdomen with copious amounts of warmed solution before closure
- Administering antiinflammatory drugs such as corticosteroids and nonsteroidal antiinflammatory drugs (NSAIDs)
- Limiting suture use and using fine, nonreactive suture materials
- Mechanically separating the organs before closure with physical barriers such as omentum, polytetrafluoroethylene (PTFE), cellulose, sodium hyaluronate membrane, bioresorbable polymer films, gels, and water-soluble glucose polymer or polyethylene glycol (PEG) solution
- Using hydroflotation with saline, lactated Ringer's, or Hartmann's solution
- Using alternative therapies such as deep tissue massage, biofeedback, acupuncture, and hypnosis

Operative Procedure

Laparotomy Opening

1. The skin incision is made and carried to the fascia (Figure 10-14, *A*).
2. Bleeding is controlled with hemostats and vessels ligated with fine nonabsorbable ligatures (ties), or electrocoagulated.
3. The wound edges are retracted with small retractors.
4. With tissue forceps and scalpel, the external fascia is incised (Figure 10-14, *B*).
5. With Metzenbaum, curved Mayo scissors, electrosurgery, or a knife, the external oblique muscle is split the length of the incision. Bleeding vessels are controlled with hemostats, ligating clips, medium or fine ligatures, or electrocoagulating current.
6. The external oblique muscle is retracted.
7. The internal oblique and transverse muscles are split, parallel to the fibers, up to the rectus sheath with a scalpel or scissors. These muscles are then retracted.
8. The peritoneum is exposed, grasped with smooth tissue forceps, and nicked with a #10 blade.
9. Sponges, laparotomy pads, and suction are used as needed. Culture samples may be taken at this time.

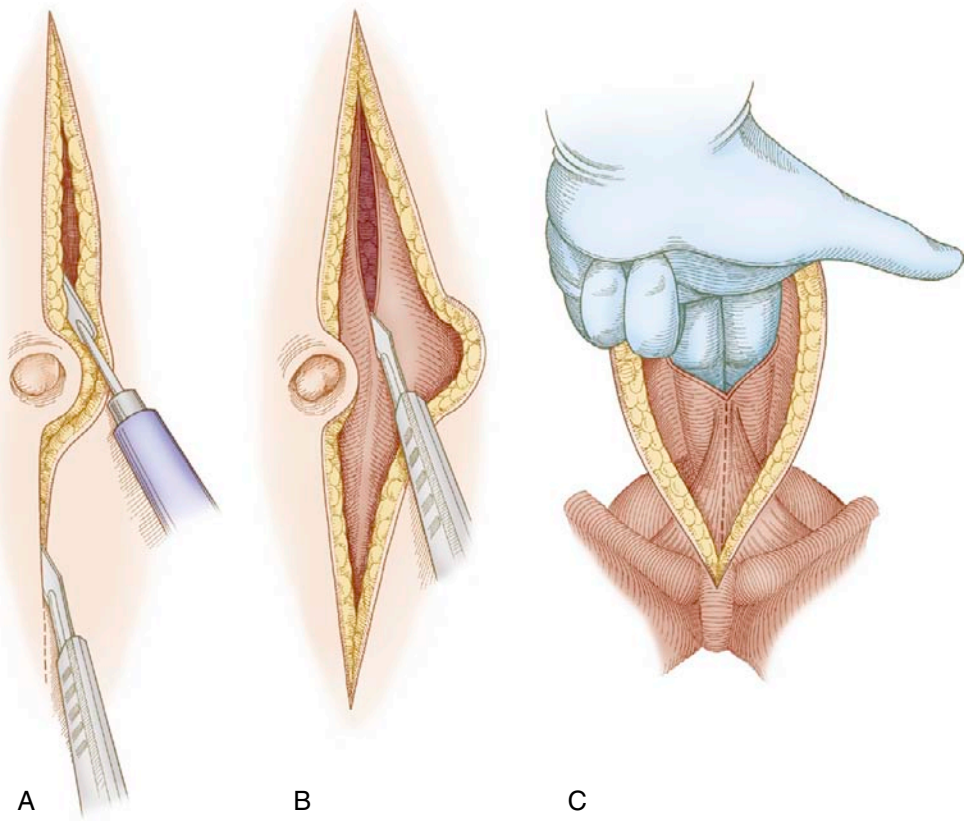


FIGURE 10-14 **A**, Midline laparotomy incision around the umbilicus. **B**, External fascia is incised. **C**, Entry into the peritoneal cavity.

10. The peritoneal incision is extended the length of the wound with Metzenbaum or Mayo scissors (Figure 10-14, *C*).
11. The peritoneum is retracted with large Richardson retractors for initial exploration.
12. Once the affected organs are identified, a self-retaining retractor, such as a Balfour or Bookwalter retractor system, may be used to establish hands-free exposure.

Laparotomy Closure

1. Two tissue forceps or clamps are used to approximate peritoneal edges, and the peritoneum closed with a continuous synthetic absorbable suture or interrupted nonabsorbable sutures. The internal oblique fascia is usually closed with the peritoneum. Muscle tissue is approximated and may or may not be sutured.
2. The external oblique fascia is closed with interrupted sutures, staples, or both. Retraction is necessary as the various layers are closed. Richardson retractors are commonly used.
3. Fine (3-0 or 4-0) absorbable sutures are usually employed to close the subcutaneous or subcuticular tissue. Retraction is provided with laparotomy pads or small retractors.
4. Skin edges are held with Adson, Russian, or medium-toothed forceps and approximated with interrupted 3-0 or 4-0 silk, nylon, or other nonabsorbable sutures on a cutting needle. A cosmetically aesthetic wound closure is achieved in patients with limited tension on the incision by using a subcuticular closure with a 3-0 or 4-0 nonabsorbable suture. Skin staples or clips, sterile adhesive strips, or skin-bonding adhesive is often used to approximate skin edges. Retention sutures of #1 or #2 nonabsorbable suture material may be used. Prepackaged retention bridges or flexible tubing bolsters are used to protect the incision site.

LAPAROSCOPY

Laparoscopy is an approach to abdominal surgery for minimal access into the abdomen to achieve the same surgical result as open laparotomy. Laparoscopic surgery is often referred to as minimally invasive surgery (MIS), wherein the surgery is performed with instruments (rather than the surgeon's hands) inside the body, yet manipulated from outside the body (Box 10-5 describes terms used in laparoscopic gastrointestinal surgery). The first generation of modern laparoscopic surgery began in the early 1970s in the GYN specialty; it was used primarily for diagnostic direct (eye on the telescope eye piece) visualization of endometriosis, ectopic pregnancy, and uterine fibroids, and later, laparoscopic tubal ligation with electrosurgery was performed. These procedures were originally called Band-Aid, keyhole, or belly button procedures.

Traditional laparoscopic port placement, via triangulation, is the fundamental concept of laparoscopic surgery. It places the instruments on planes where they meet to effectively support dissection with adequate visualization and identification of anatomy and pathology. Incorrectly placed ports can cause sword-fighting instruments and indirect access to the operative

BOX 10-5

Laparoscopic Terminology

MAS/MIS—Minimal Access Surgery/Minimally Invasive Surgery
SPA—Single Puncture Access
SPS—Single Port Surgery
SILS—Single Incision Laparoscopic Surgery
OPUS—One Port Umbilical Surgery
NOTES—Natural Orifice Transluminal Endoscopic Surgery
NOSCAR—Natural Orifice Surgery Consortium for Assessment and Research
TOGA—Trans Oral GAstroplasty

target. Challenges also exist in delivering intact specimens through small ports. The increased intra-abdominal pressure from the insufflation of CO_2 into the peritoneal cavity applies pressure on the diaphragm and femoral vessels. This can compromise patients with cardiac and respiratory disease and cause deep vein thrombosis. The venting of CO_2 at the end of the procedure is believed to have the potential of "blowing" cancer cells into the layers of the port site, causing later cancer recurrence of the skin and subcutaneous layers of the abdomen. This is a very rare event and probably not a concern that should eliminate laparoscopic approaches for cancer patients. Less invasive approaches to surgery are less stressful to the patient. Traditional laparoscopic surgery has many other advantages over traditional open surgical approaches (Box 10-6). These advantages, however, do not exist without technical challenges and cost concerns.

Procedures described as "laparoscopically assisted" combine laparoscopic surgical manipulation of tissue with enlargement of one of the port incisions, permitting the surgeon direct access, or hand contact, on the operative tissue. The surgeon may transfer a portion of the surgical tissue onto the abdominal surface to achieve repair outside the body (*extracorporeal* repair). *Intracorporeal* refers to inside the abdomen. Laparoscopically assisted surgery may also refer to laparoscopic dissection and resection with an open approach to remove the surgical specimen.

Laparoscopy is usually contraindicated in patients with extensive adhesions from prior surgeries. Patients with bleeding disorders or pregnancy also pose a risk. Advanced cardiac or pulmonary disease may preclude the option of a minimal access approach. Potential complications include trocar site bleeding (Patient Safety), vascular injury, hemorrhage, perforation or laceration of organs, infection, anastomotic leaks, ileus, strictures, accidental electrosurgical injury, and pulmonary problems. The surgeon may have to convert to an open procedure in the presence of adhesions, hemorrhage, fixed small bowel, unusual anatomy, unexpected findings, or instrument failure. The potential for conversion to an open approach is discussed with the patient before surgery and documented on the consent form by the surgeon.

Single port access laparoscopy entails entry through the abdominal cavity via one port placed through the umbilicus. This approach is also called "radical endoscopy" or "stealth surgery" (surgery that takes place without leaving a trace that it occurred, since there is no scar). Access is gained through the Hasson cutdown technique with a small scalpel and bladeless dissecting-tip trocar. The port maintains pneumoperitoneum and retracts the incision. Instruments are curved and flexible to accommodate space restrictions and afford range of motion that follows the surgeon's hand movements. Multiple instruments can be used via one port with standard digital technology (video systems and processors).

Single port/puncture laparoscopy offers considerable advantages over traditional laparoscopy. The high-dexterity instrumentation that is used bends and flexes to provide manipulative options not available with traditional laparoscopy. It does so essentially with three or four instruments: a combined telescopic light/camera and two working tools. At the end of the procedure, the port is removed and the umbilicus is gently folded back into its original shape. Many procedures that can be accomplished via laparoscopic access are now approached

PATIENT SAFETY

Perioperative Considerations in Trocar Safety

Trocar and insufflation needle–associated insertion mishaps can result in major vascular injury and death. The aorta and right common iliac artery are the most often injured vessels because of the right handedness of most operators. Trocars may be bladed, bladeless, or blunt-tipped. To gain access to the abdominal cavity, the selected trocar must pass through the abdominal wall layers without injuring blood vessels or internal organs. Although the surgeon has primary responsibility for preventing these and other trocar injuries, the perioperative nurse should understand the risks related to such instrumentation, as well as have a basic understanding of the techniques for trocar insertion. The perioperative nurse's review of the patient's history should focus on previous surgeries that might have contributed to the formation of adhesions, patient weight (in thin patients, the distance between vascular structures and the abdominal wall is comparatively short; in obese patients, more force may be required), and patients with enlarged livers or spleens. Of special concern is any trocar with a shield. With this device, the scrub person and surgeon must ensure that the shield is retracted before insertion and kept retracted. If it is not, too much force is required. Further, the shield itself may lock into place prematurely when pressure is reduced before full penetration into the abdomen.

Another important safety issue with trocars is the distance they extend into the abdomen. Registered nurse first assistants (RNFAs) assisting in access procedures during minimally invasive surgery (MIS) should develop the skill to detect passage of the trocar tip through the peritoneum, but still avoid possible injury to internal organs. When working in the upper abdomen, the RNFA should use maximum countertraction when inserting a trocar toward the diaphragm. This assists in avoiding major blood vessels. Often, aiming the trocar parallel to the spine and off midline helps to avoid vascular injury. Injury prevention will benefit from a systems' approach with a focus on training, technique, and equipment design. Operators must be aware of the spatial relationships within the abdomen and the tactile senses of force and resistance. They must comply with the technical aspects of proper protocol, and pay attention to potential hazards of blind insertion.

Adapted from Laparoscopic access, *Point View* 44(1):20-26, 2005; Rad BN, Beart RW: Minimally invasive surgery—laparoscopic colectomy. In Souba WW et al: *ACS surgery—principles and practice,* New York, 2005, WebMD; Girard NJ: Perioperative grand rounds: procedural mishap: learning curve, *AORN J* 89(2): 468, 333, 2009.

BOX 10-6

Advantages and Disadvantages of Laparoscopic Surgery

BENEFITS FOR THE PATIENT
- Minimal blood loss
- Reduced risk for infection
- Rapid return of GI function
- Less small bowel obstruction
- Less risk for incisional hernia with smaller incisions
- Less immune suppression than open techniques
- Less postoperative pain and reduced analgesia use
- Adjunct to preoperative staging
- Application of chemotherapy and brachytherapy

DRAWBACKS FOR THE PATIENT
- Less capacity for intraabdominal inspection and large specimen removal
- Potential for port-site recurrence
- Potential for DVT
- Decreased venous return
- Decreased vital capacity
- Increased peak airway pressure, cardiac volume, systemic vascular resistance (SVR) (50%), systolic pressure
- Risk for pleural or peritoneal seeding of malignant cells

BENEFITS FOR THE SURGEON
- Enhanced imaging resolution
- Image/video-recording option
- All team members see same image
- Abundant light
- Magnification

DRAWBACKS FOR THE SURGEON
- Ergonomically challenging
- Instruments move in opposition—fulcrum effect
- Loss of haptic sensation and tactile feedback
- Critical moves necessary with nondominant hand
- Sees two dimensionally but must perceive three dimensionally
- Significant learning curve to competence

via single puncture as well. Contraindications include multiple prior abdominal surgeries because of adhesions or altered anatomy, and morbid obesity because of decreased visibility and difficult movement inside the cavity (Curcillo, 2007; Fowler, 2008; Pasricha, 2005).

Because the umbilicus has no muscle or fascia layer, umbilical incisions are safe and less painful than other incision sites. With only one incision site, there is less risk of penetration injuries, infection, and hernia. The growing capabilities of therapeutic flexible endoscopy have ushered in a new era in treatment of GI conditions. Refinements in laparoscopic surgery have progressed to the point that complex surgical procedures, such as gastric bypass, are performed in a minimally invasive fashion.

These trends have set the stage for the development of even less invasive methods to treat conditions both in the gut lumen and in the peritoneal cavity. Major intraperitoneal surgery is being performed without skin incisions. The natural orifices may provide the entry point for surgical interventions in the peritoneal cavity, thereby avoiding abdominal wall incisions. Natural orifice transluminal endoscopic surgery (NOTES) is performed by a team that has the skills of an advanced therapeutic endoscopist and a laparoscopic surgeon. Advantages for the patient include decreased pain, blood loss, and morbidity; absence of a scar; and earlier return to activities of daily living (ADLs). Advantages for the surgeon include increased visibility with light and magnification, larger field of view, flexible tips that eliminate the need to change instruments frequently, and easy transition to traditional laparoscopy (Lucile Packard Children's Hospital, 2008). Operative costs are similar to those for traditional laparoscopy.

While single port laparoscopy was developed from the platform of traditional laparoscopic surgery, new instrumentation is advancing the ergonomics and precision of dissection (Barclay et al, 2008; Cleveland Clinic, 2008; Raman et al, 2008). Laparoscopy offers advantages over the conventional open approach in many GI procedures. Success of surgical repair, postoperative recurrence of disease, and overall survival are similar between open and laparoscopic approaches for the same surgery. Operative times vary according to many variables, including unusual occurrences, the surgeon's skill and technique, and instrumentation. Postoperative analgesia needs are the same or may be less than in the open laparotomy approach. Patients typically report less postoperative discomfort because of the absence of a large abdominal incision. Nonetheless, many do report muscle discomfort in the area of a working-port incision where significant manipulation of instruments occurred. Postoperative flatus and first bowel movement may occur a day sooner than for conventional surgery patients. Resumption of oral intake may also be sooner in this group (see Research Highlight, Early Feeding after Abdominal Surgery, p. 310). Minimal access approaches also result in faster recovery of pulmonary function, fewer postoperative complications, less potential for surgical site infections, improved cosmesis, shorter recovery period, and quicker return to former activities of daily living.

Procedural Considerations

Minimal access surgery requires specially designed instruments, telescopes, trocars with cannulae, suction and irrigation devices, retractors, electrosurgery, CO_2 introduction devices, stapling instruments and appliers, and video image equipment. The video camera, light source, and monitors provide indirect visualization of the surgical site, enhanced with magnification and bright illumination.

Operative Procedure

1. Initial entry is made in the periumbilical region with percutaneous puncture with an insufflation (Veress) needle (closed technique) or a sharp trocar in a sheath (direct technique). A cutdown technique (Hasson technique) may be used with a small incision through to the fascia with a #15 blade. The trocar is then introduced through and into the peritoneal cavity. In the direct technique, an optical trocar is inserted to visualize trocar placement before insufflation.
2. Pneumoperitoneum is established with insufflation of 3 to 4 liters of CO_2 into the peritoneal cavity to achieve an intraabdominal pressure of 12 to 15 mm Hg.
3. The needle is removed and replaced with a 10-mm or 11-mm trocar. The rigid laparoscope, with video camera and cord coupled to the telescope eyepiece end, is inserted into the port for visualization. Two to six more ports may be created to facilitate use of an endoscopic fan retractor; various grasping, dissection, cutting, and electrosurgery instruments;

ultrasonic scalpel dissector; suction-irrigation devices; laser fibers; endoscopic clip and staple appliers; and specimen retrieval graspers. Port sites are selected to permit all instrument tips to converge at the primary surgical work site.

4. Surgical exploration, dissection, resection, anastomosis, inspection, and irrigation then follow.
5. CO_2 is exhausted and ports removed. The umbilical incision is closed with 3-0 or 4-0 nonabsorbable synthetic suture. Remaining port incisions are closed with the same suture, adhesive strips, or skin-bonding adhesive. A small dressing or bandage is applied.

INTRAOPERATIVE INTRAPERITONEAL CHEMOTHERAPY

Patients who undergo abdominal surgery for GI and peritoneal cancers may benefit from intraoperative hyperthermic intraperitoneal chemotherapy (HIPEC) to remove or to reduce the burden of tumor or diseased organs, often called cytoreductive (removing as much tumor tissue as possible) (also referred to as "debulking") surgery. HIPEC may take place while the abdomen is still open or after it is closed (referred to as the "closed" technique). The abdominal cavity is connected to an extracorporeal fluid circuit for instillation and continual perfusion of heated chemotherapeutic agents (Pappas et al, 2008). Access may be created with a peritoneal port such as a Tenckhoff catheter or with separate inflow and outflow catheters. Tissue contact can be maintained with perfusion pump–directed flow or by manually rocking the abdominal cavity (by a sterile team member) to agitate fluid around and about the abdominal organs. The procedure may take up to 2 hours. This therapy allows for a high concentration of chemotherapy to have direct contact with the tumor, surrounding organs, and visceral and parietal peritoneum. Heating the fluid increases topical absorption. Contraindications to intraperitoneal chemotherapy include adhesive disease, hypovolemia, massive ascites, malnutrition, GI dysfunction, or postoperative infection (Marin et al, 2007). Complications may include wound infection, abdominal wound dehiscence, anastomotic leak sepsis, and enterocutaneous fistula (Marin et al, 2007).

Proper personal protective equipment (PPE) must be worn and safe medication handling practices must be employed to protect all team members and the patient from accidental injury from hazardous cytotoxic drugs (Risk Reduction Strategies). HIPEC has been shown to increase survival in select patients when combined with cytoreductive surgery (Pappas et al, 2008).

ENDOSCOPIC PROCEDURES

GI endoscopy has transformed the diagnosis and treatment of patients with GI diseases. Endoscopic procedures permit direct or video visual inspection of the contents and walls of the esophagus, stomach, duodenum, and colon. Endoscopy provides significant tools for routine screening of individuals at risk for GI disease (Ransohoff, 2005), for establishing a diagnosis, for determining preferred treatment of a disease process, and for follow-up after a treatment regimen or surgery. GI endoscopy, enhanced by advances in imaging, instrumentation, and accessory devices, has evolved into an interventional discipline, offering nonsurgical approaches to cure and palliation of symptoms of selected GI diseases and conditions. Common GI endoscopy procedures include esophagogastroduodenoscopy (EGD) (also referred to as gastroscopy or upper endoscopy), small bowel endoscopy (also referred to as push enteroscopy or double-balloon enteroscopy), colonoscopy (also referred to as lower endoscopy), and sigmoidoscopy (also referred to as a "flex sig").

Endoscopic procedures are performed with local anesthetics, IV moderate sedation/analgesia, or general anesthetics, all of which ensure a safe and complete examination. Smaller caliber flexible endoscopes have evolved so that they can be passed easily without the need for sedation (Research Highlight). IV moderate sedation provides a depressed level of consciousness and tolerance of a potentially uncomfortable procedure, yet patients retain their ability to maintain their airway and respond appropriately to physical and verbal stimuli. It is administered by the attending physician/interventionalist, anesthesia provider, or a registered nurse competent to monitor the patient's heart rate and rhythm, oxygen saturation, blood

RISK REDUCTION STRATEGIES

Safe Care and Handling of Cytotoxic Drugs

Safe work practices, engineering controls, and proper use of approved protective equipment can minimize potential health effects from occupational exposure to cytotoxic, antineoplastic drugs, and other hazardous drugs. Cytotoxic drugs are pharmaceutical compounds that are destructive to cells within the body. Antineoplastic agents control or kill cancer cells. They are cytotoxic but generally more damaging to dividing cells than to resting cells. Safe work practices include:

- Personal protective equipment (PPE) must be used whenever there is a risk of exposure to cytotoxic or other hazardous drugs; PPE includes nonpermeable gowns, latex or nitrile chemo gloves changed every 30 minutes or when torn, masks, and eye protection whenever there is risk for splash or eye exposure.
- PPE is worn whenever preparing, transferring, spiking, changing, priming, and disposing of chemotherapeutic agents (chemo).
- Always work below eye level.
- Have a chemo spill kit available wherever chemo is prepared, administered, stored, or disposed.
- Have yellow chemo waste containers available in the work area for contaminated sharps, linen, and trash.
- PPE is worn during chemo spill cleaning and when handling and disposing of patient body fluids. Wear the N95 NIOSH certified respirator mask when cleaning cytotoxic spills.
- Unused medication vials, bags, or syringes must be returned to the pharmacy or placed in chemo waste containers in the work area.
- Place needles, syringes, broken glass, empty vials, and tubing in the sharps containers labeled for chemotherapy waste.
- Place used PPE in yellow chemo waste container. Wash hands.
- If exposed, wash affected area with soap and water for 15 minutes. Flush eyes with normal saline for 15 minutes. Report to employee health or appropriate healthcare provider.

Modified from National Institute for Occupational Safety and Health: *Preventing occupational exposure to antineoplastic and other hazardous drugs in the health care setting,* available at www.cdc.gov/niosh/docs/2004-165. Accessed June 14, 2009.

RESEARCH HIGHLIGHT

The Body Pillow as a Tool for Upper Endoscopy

This small study investigated use of a large body pillow as a comfort and positioning tool for unsedated upper endoscopy (EGD); 177 healthy patients who had previously undergone upper endoscopies in a medical facility in Japan were followed. The procedure was performed with the patient positioned on the left side, hugging the pillow to the chest and abdomen with knees flexed. No sedation was given. After the procedure, the patients were interviewed about their current distress levels in comparison with their former procedure without the pillow. A total of 60% stated that the pillow procedure was less stressful than their prior procedure. Another 29% claimed no change. Of the remainder, 8% claimed more distress and 3% had no answer. The researchers concluded that the pillow should be recommended as a tool for upper endoscopy, as it is safer than sedation and contributed to alleviation of patient stress during the procedure.

From Matsuda R et al: Body pillow: an extremely useful tool for an upper endoscopy examination, *Gastroenterol Nurs* 32(1):53-54, 2009.

pressure, respirations, level of consciousness, and comfort during and immediately after the procedure until the patient is stable and ready for discharge or transfer. Preprocedure preparation for elective procedures limits ingestion of solid foods and liquids for a prescribed period. Bowel preparation with diet limitation, bowel cleansing preparations, and sometimes enemas is prescribed before lower endoscopy procedures.

Flexible endoscopes are semicritical patient care devices that must undergo high-level disinfection before each use. They are easily damaged by misuse and should be handled according to the manufacturer's recommendations. They must be leak-tested, decontaminated, reprocessed, and dried after each use. They must be stored in an appropriate secure and ventilated endoscope closet. Endoscopic accessories, such as biopsy forceps, snares, cytology brushes, and fine-needle aspiration (FNA) catheters, must be sterile because they are considered critical devices that invade the mucosal barrier.

Esophagogastroduodenoscopy (EGD) (Upper Endoscopy)

EGD visualizes the esophagus, stomach, and proximal duodenum. It is used for diagnosis, treatment, and documentation of abnormalities with biopsy, brush cytology, polypectomy, electrosurgery, thermal coagulation, laser therapy, dilation, banding or sclerosing of esophageal varices, removal of foreign bodies, insertion of an esophageal prosthesis, and other interventional procedures for gastroesophageal reflux disease (GERD), Barrett's esophagus, and percutaneous endoscopic gastrostomy (PEG) tubes. When an EGD is performed with a local anesthetic or sedation, the patient is usually permitted no solid food for 6 to 8 hours before the procedure but may drink liquids up to 2 hours before the procedure.

Procedural Considerations. The patient's position for EGD depends on the areas to be visualized, but a left lateral supine or low Fowler's position is commonly used. For inspection of lesions in the gastric fundus and cardia, an upright sitting position may be used. A protective bite-block is placed in the patient's mouth to protect the scope and the patient's teeth from injury. Instrumentation includes a gastroscope and video system (optional), biopsy forceps, suction, water-soluble lubricant, saline and water for irrigation, and electrosurgery capability.

A topical local anesthetic (applied to the posterior pharynx) along with IV moderate sedation is the most common technique. A perioperative or endoscopy nurse skilled and credentialed in moderate sedation and advanced cardiac life support (ACLS) or an anesthesia provider monitors the airway, vital signs, and oxygenation.

A light source with air and water infusion capability and a water bottle for irrigation are required. Suction, aspiration tubes, and a cup of saline for the biopsy specimen should be available. Lubricating jelly is placed over the sheath of the gastroscope for ease in placement. An ESU and cord are available for fulgurating a lesion or coagulating a bleeding site.

Operative Procedure

1. The gastroscope tip is completely covered with a thin coat of water-soluble lubricating jelly.
2. During introduction of the gastroscope, the patient's head and neck must remain in the sagittal plane of the spine so that the axis of the mouth is in line with the esophagus.
3. The gastroscope is slowly passed through the nasopharynx into the esophagus, stomach, and duodenum.
4. The mucosal surface is inspected and contents may be aspirated for cytologic analysis. A biopsy may be performed.
5. After the procedure, the patient is monitored and must have a gag reflex before fluids are offered.

Small Bowel Enteroscopy

The small bowel has traditionally been a difficult segment of the GI tract to reach for endoscopic visualization. Enteroscopy can be approached orally or through the anus using an adult or pediatric colonoscope, or a push enteroscope that measures 200 to 250 cm in length. Push enteroscopy advances the scope far into the small bowel. A balloon on the tip of the scope permits it to be held in place. The patient receives IV metoclopramide (Reglan), promoting peristaltic advancement of the scope. The small bowel is examined as the scope is slowly withdrawn. This procedure may take 6 to 8 hours (Society of Gastroenterology Nurses and Associates [SGNA], 2004). Push enteroscopy is useful for examining areas of bleeding and strictures.

Double-balloon enteroscopy employs an enteroscope with a balloon on its end and on the end of the overtube, which creates a traction system that permits the small bowel to pleat itself onto the overtube, and prevents overstretching of the small intestine. This technique also permits visualization and therapeutic measures such as biopsies, coagulation of small bleeders, and lysis of strictures (Lewis, 2005; Sunada et al, 2005).

Colonoscopy and Sigmoidoscopy (Lower Endoscopy)

Colonoscopy is endoscopic examination of the colon from the rectum to the ileocecal valve. The bowel wall is inspected for abnormalities such as bleeding, polyps, inflammation, ulceration, or tumors during both insertion and withdrawal of the colonoscope. Colonoscopy facilitates biopsy, removal of polyps,

electrocoagulation or laser treatment of tumors or bleeders, dilation, decompression, and provision for a video and photographic record of the procedure and findings. Sigmoidoscopy, both flexible and rigid, provides access and visualization of the sigmoid or descending colon to the level of the splenic flexure. Colonoscopy or sigmoidoscopy may be performed before colon or sigmoid resection for surgical localization of the tumor site with india ink tattooing or clip placement. This permits the surgeon to identify the tumor site, viewing the marked site from the serosal side of the colon by laparotomy or laparoscopy access.

Endoscopy can also be performed through an ostomy stoma to inspect an anastomosis site or identify recurrence of disease or bleeding. Reservoir pouches can also be inspected after surgical healing for anastomosis integrity, inflammation, bleeding, and other abnormalities. The patient must receive a clear liquid diet the day before colonoscopy and sigmoidoscopy and may receive bowel-cleansing agents such as citrate of magnesia or a commercial bowel prep solution. Enemas may be necessary before the procedure.

Procedural Considerations. The instruments and equipment that must be available to perform colonoscopy and sigmoidoscopy include a colonoscope or flexible sigmoidoscope, video camera and monitors (optional), a light source, an air-insufflation device with water bottle for irrigation, a biopsy forceps, snares, cytology brush, electrosurgical-fulguration-desiccation unit and appropriate accessories, lubricating jelly, and suction.

Operative Procedure

1. The patient is positioned on the left side with knees bent.
2. The well-lubricated colonoscope is passed slowly into the anal canal and advanced continuously until it reaches the cecum in colonoscopy. The endoscopist or surgeon may ask the nurse or surgical technologist to apply gentle abdominal pressure to assist advancement of the scope around the splenic or hepatic flexures. With sigmoidoscopy, only the left colon is examined. Flexible sigmoidoscopy may be accomplished in a cooperative patient without sedation.
3. After the endoscopic examination, the patient is observed for postprocedural bleeding, pain (Rapid Response Team box), signs of perforation, or reaction to medications.

Procedures for Gastroesophageal Reflux Disease (GERD)

GERD is described as a condition of backflow of gastric or duodenal contents into the distal esophagus, causing pain, heartburn, coughing, and respiratory distress. GERD may also present with incompetence of the distal esophageal valve to the stomach or lower esophageal sphincter (LES). Chronic GERD can lead to erosive esophagitis, asthma, dysphagia, aspiration pneumonia, and Barrett's esophagus. Several innovative, nonsurgical interventional endoscopic techniques now can minimize or prevent the reflux of stomach acid into the esophagus, controlling GERD symptoms by enhancing the competency of the LES. These procedures, accomplished through an EGD, or upper endoscopy, reinforce the LES by plicating and sewing the inner lumen of the esophageal junction to re-fashion the valve, tightening the tissue above the LES to create a stricture, or implanting devices to narrow the LES lumen. The American Gastroenterological Association's guidelines address management and treatment of GERD according to evidence-based medical literature. Recommended practice includes the use of proton pump inhibitor (PPI) medications as the first line of therapy followed by antireflux surgery only when the patient can no longer tolerate acid suppression therapy (Barclay et al, 2008).

Several antireflux procedures can be performed endoscopically in an endoscopy procedure room using moderate sedation or general anesthesia. The Stretta (Curon Medical) procedure is radiofrequency heat energy delivered through an endoscopically-introduced balloon catheter to the distal esophagus, creating thermal lesions that tighten the tissue.

The EndoCinch (Bard Medical) technique dilates the lumen of the esophagus before passing the EndoCinch device through

RAPID RESPONSE TEAM

In phase II PACU, while recovering from colonoscopy under moderate sedation, the patient described vague generalized abdominal pain, increasing in intensity. He had nausea and vomiting, low-grade fever, abdominal tenderness, guarding, and muscle rigidity on palpation. Respirations were shallow and he was tachycardic and anxious. The gastroenterologist had left the building. The nurse, concerned about his increasing distress and delay in normal recovery after colonoscopy, summoned the hospital rapid response team, using the SBAR format in her call for assistance:

Situation—"I have a patient with increasing abdominal distress, tachycardia, and shallow respirations."

Background—"The patient is a 53-year-old normally healthy man post screening colonoscopy. The procedure was unremarkable; however, he has complained of increasing vague abdominal pain, nausea, and vomiting."

Assessment—"He has abdominal tenderness, guarding, and rigidity on palpation. He is tachycardic with shallow respirations and a low-grade fever, which he did not have before the procedure. He states that he has never felt like this before and is afraid something is seriously wrong. His wife is very concerned. He has emerged from the moderate sedation; however, this is not a normal recovery from a routine colonoscopy."

Recommendation—"His condition is deteriorating and he must be seen now. I am concerned he may have a perforation of the colon. He is in Endoscopy recovery bed 4."

The rapid response team consisted of an ICU nurse, respiratory therapist, and critical care hospitalist. They performed a focused assessment and review of the medical record, placed an additional IV line and administered fluids, ordered a stat abdominal CT scan and pain medication, and called the surgeon on-call. The CT revealed free air in the abdomen and perforation at the splenic flexure of the colon. The patient had emergency surgery for repair of the perforation and recovered without incident.

Adapted from O'Brien D: Postanesthesia complications. In Drain CB, Odom-Ferren J, editors: *Perianesthesia nursing: a critical care approach,* ed 5, St Louis, 2009, Saunders.

an EGD scope. The device is a sewing capsule that pinches or pleats mucosal folds and anchors them in place with a suture. Several plications are placed in a circumferential or staggered vertical pattern.

The Wilson-Cook sewing system (Wilson-Cook Medical) is another submucosal plication device that suctions a small fold of tissue into the lumen of the scope accessory, and then plicates, sutures, and knots the tissue pleat.

Procedures for Barrett's Esophagus

Cellular changes, or dysplasia, of the mucosa of the distal esophagus is called Barrett's esophagus, a precursor for cancer of the esophagus. A significant percentage of patients with GERD may develop Barrett's. Patients who show progressive dysplasia in spite of medical therapies, such as histamine blockers and proton pump inhibitors, may be treated with one of several endoscopic techniques targeted to eliminate dysplastic tissue, prevent or eliminate strictures, and promote regrowth of normal esophageal mucosa.

Endoscopic mucosal resection (EMR) is an interventional technique to remove submucosal flat or depressed lesions. EUS is used to determine depth of invasion into the esophageal wall, and the lesion or dysplastic tissue is then injected with isotonic saline, hypertonic saline, or saline with epinephrine to lift the lesion away from the muscle layer, creating a polyp-like lesion. This tissue bulge is then suctioned into a cap secured to the end of the scope, resected with a rigid wire snare, and removed. The saline creates a cushion to protect the muscle wall from perforation and facilitates snare resection. This technique also provides a tissue specimen for histologic examination. Areas of bleeding can be endoscopically electrocoagulated (Ransohoff, 2005).

Photodynamic therapy (PDT) is a technique using laser light ablation. Dysplastic tissue uptakes a photosensitizer drug, Photofrin II (sodium porfimer), which is activated by the laser. The drug is administered 48 hours before the procedure to allow for tissue uptake. Normal tissue excretes the drug sooner than abnormal or dysplastic tissues. The drug is retained in the mucosal layer, which limits the depth of the laser effect. After 48 hours, the patient returns for the endoscopic procedure. The laser fiber is introduced through the scope channel and laser light is directed toward the mucosa, causing tissue destruction and cell death of those areas identified by the uptake of the photosensitizer drug. The patient may continue to be sensitive to light for 60 to 90 days following the injection and must take precautions to prevent cutaneous burns (Wang, 2005). Unlike EMR, PDT does not provide a tissue specimen. PDT is often combined with endoscopic mucosal resection. PDT and EMR can also be used to treat the gastric and colonic mucosa.

Self-Expanding Metal Stents

Self-expanding metal stents (SEMSs) expand within a lumen to maintain patency in an area constrained by stricture or tumor. They are used in the esophagus or colon, advanced across the obstruction, and released to remain in place. They are preloaded in a closed position on a delivery catheter, introduced through an endoscope with fluoroscopy guidance, and deployed, applying radial force that holds them in place. Stents may also be made of silicone. Although initial complications are low, stents may migrate, perforate, become impacted with food, cause bleeding or fistula development, or become obstructed with tumor overgrowth. Stent placement is frequently a palliative procedure.

SURGERY OF THE ESOPHAGUS

Esophagectomy

Esophageal cancer is the sixth most common cancer worldwide and is notorious for aggressive progression of intramural invasion of the esophageal wall and lymphatic metastasis (Edmondson and Schiech, 2008). Esophageal cancer may be adenocarcinoma or squamous cell, each with an equally poor prognosis when treated in late stages. As many as 50% of patients with esophageal cancer are ineligible for surgery because of late-stage diagnosis, debilitating multisystem conditions, infection, or malnutrition.

Esophagectomy can be performed by several different approaches and procedures: transthoracic, transhiatal, video-assisted thoracotomy surgery (VATS), or laparoscopic-assisted approach. A segment of the colon or jejunum may be used as a reconstructive conduit in the patient with prior partial or total gastrectomy.

Procedural Considerations. Instrumentation includes a basic thoracotomy set, basic laparotomy set, vascular instruments, and a GI instrument set. Long versions of basic instruments, deep retractors, linear stapling devices, and vascular ligating clips should also be available. Laparoscopic and thoracoscopic instrumentation and video equipment is used in the VATS approach. The surgeon may perform an EGD before the surgical prep. The patient is positioned and secured in the preferred position for the intended surgical approach after induction of general anesthesia. A double-lumen endotracheal tube is placed in order to deflate the lung for a thoracotomy approach. Critical monitoring devices, such as arterial lines and pulmonary artery catheters, are placed. An indwelling urinary catheter is inserted. Measures are taken to ensure that the patient's body temperature is maintained in normothermia. Any of these procedures may be modified with laparoscopic, thoracoscopic, mini-laparotomy, or mini-thoracotomy access. Postoperative pain management may be augmented with interscalene perineural blockade for shoulder pain. Patients undergoing esophagectomy usually are transferred to the intensive care unit (ICU).

Transhiatal Esophagectomy

1. Transhiatal esophagectomy removes from 67% to 100% of the thoracic esophagus through an upper midline abdominal incision and an incision in the neck above the left clavicle. The abdominal component may be approached laparoscopically. Thoracotomy is avoided.
2. Accessible lymph nodes are removed for staging purposes. Not all lymph nodes can be accessed.
3. The stomach is mobilized and fashioned into a tubular shape at the greater curvature with surgical staples.
4. The tubular stomach segment is tunneled up through the posterior mediastinum to the left cervical incision. This procedure is often called a gastric pull-up.
5. The stomach is reconstructed with the fundus attached to the remaining cervical portion of the proximal esophagus using an end-to-side anastomosis. The fundus is also sutured to the cervical prevertebral fascia.

6. A pyloromyotomy or pyloroplasty then follows to increase stomach emptying. This often results in postoperative "dumping syndrome" and reflux.
7. A jejunostomy tube is placed for postoperative enteral nutrition.
8. Postoperative hoarseness and dysphagia are common because of ipsilateral nerve damage.

Transthoracic Esophagectomy

Transthoracic esophagectomy is indicated for disease of the middle third of the esophagus and high-grade dysplasia in Barrett's esophagus. This approach permits complete lymph node dissection under direct vision and combines a left-sided thoracoabdominal incision or separate right posterior lateral thoracotomy and midline abdominal incision. The latter describes the traditional Ivor Lewis approach. Another variation, sometimes called the "three-hole esophagectomy," combines a cervical, right thoracotomy, and midline laparotomy approach for proximal tumors. The single incision thoracoabdominal incision provides the best exposure for low gastroesophageal junction tumors and is indicated for patients with cardiac and pulmonary disease.

Operative Procedure

1. The skin incision is carried downward, midway between the vertebral border of the scapula and the spinous processes to the eighth rib and then forward along this rib to the costochondral junction. The extent of the vertical portion of the incision depends on the tumor's location.
2. The wound is retracted, and bleeding vessels are ligated or coagulated.
3. The chest cavity is opened, and the rib spreader is placed. Moist packs are placed, and the lung is retracted with a Deaver or Harrington retractor.
4. The mediastinal pleura is incised with long Metzenbaum scissors and long plain forceps in line with the esophagus and the lesion.
5. The esophagus is dissected free from the aorta with dry gauze dissectors.
6. Suture ligatures of 2-0 and 3-0 nonabsorbable material are used to control bleeding vessels.
7. The diaphragm is opened, and a series of traction sutures are placed.
8. The stomach is mobilized by dissection of its ligamental attachment with long scissors and curved thoracic clamps.
9. The left gastric artery is clamped, cut, and doubly ligated with 2-0 nonabsorbable suture and a suture ligature of 3-0 nonabsorbable material. The sterile field is prepared for the open method of anastomosis.
10. The stomach is transected well below the lesion with selected resection instruments.
11. Closure of the stomach is completed with two rows of intestinal sutures of 2-0 synthetic absorbable suture and sometimes with an additional row of 3-0 nonabsorbable sutures for reinforcement. A linear stapling device may be used as well.
12. A separate circular opening is usually made in the upper portion of the stomach for anastomosis to the esophagus.
13. Two Allen clamps or a stapler type of clamp is applied above the stricture, and the freed esophagus is divided.
14. The circular opening in the stomach and the transected end of the esophagus are anastomosed. The mucosal layers are approximated. The muscular layers of the esophagus and stomach are closed by two rows of interrupted sutures. A mechanical end-to-end anastomosing (EEA) surgical stapling device may also be used to accomplish the gastroesophageal anastomosis.
15. The stomach is anchored to the pleura, and the edges of the diaphragm are sutured to the wall of the stomach with interrupted sutures of 3-0 or 2-0 nonabsorbable material.
16. The pleura is cleansed with warm normal saline irrigation, which is then removed by suctioning.
17. A thoracic catheter is inserted for closed drainage. The chest wall is closed as described for thoracotomy.

Video-Assisted Thoracotomy Surgery (VATS)

1. VATS is accomplished in three stages beginning with thoracoscopic dissection and mobilization of the esophagus.
2. The second stage is the laparoscopic dissection, mobilization, and tubular construction of the stomach. Pyloroplasty is also performed laparoscopically.
3. The third stage is the open cervical incision anastomosis.

Excision of Esophageal Diverticulum

Excision of an esophageal diverticulum, sometimes called *Zenker's diverticulum,* is removal of a weakening in the wall of the esophagus that collects small amounts of food and causes a sensation of fullness in the neck. Diverticula usually occur in the cervical portion of the esophagus, and excision usually relieves symptoms completely.

Procedural Considerations. Instrumentation includes a thyroid set with the addition of Pennington clamps, curved mosquito hemostats, 5-inch Adson forceps, and lateral retractors. The patient is positioned supine with a shoulder roll placed to assist with hyperextension of the neck. The head may be turned to the side and supported with a padded headrest. This procedure may be done endoscopically.

Operative Procedure

1. An incision is made over the inner border of the sternocleidomastoid muscle and is extended from the level of the hyoid bone to a point 2 cm above the clavicle.
2. The sac of the diverticulum is freed and ligated.
3. The pharyngeal muscle and surrounding tissues are closed.
4. In conjunction with this procedure, an esophageal myotomy is often performed distal to the diverticulum to minimize likelihood of recurrence.

Esophageal Hiatal Hernia Repair and Antireflux Procedure

Hiatal herniorrhaphy restores the LES to its correct anatomic position in the abdomen, secures it firmly in place, and corrects GERD. A hiatal hernia (also called a *diaphragmatic hernia*) is a defect, either congenital or acquired, in the diaphragm through which a portion of the stomach protrudes up into the thoracic cavity.

Hiatal hernias are usually of two types—paraesophageal and sliding. Symptoms vary from none to severe heartburn, reflux (backward flow), regurgitation, and dysphagia. When symptoms are severe, a repair of the hernia is done, usually through a transabdominal approach. A transthoracic approach is used

for patients with prior left upper quadrant surgery and for those who are extremely obese.

An antireflux procedure, to prevent reflux of gastric juices into the esophagus, is also done when the hernia is repaired. The three most frequently performed antireflux procedures are the Nissen, Hill, and Belsey Mark IV.

Procedural Considerations. The patient is positioned supine but may need to be repositioned to lateral if the gastroesophageal sphincter cannot be accessed through a high midline position. An indwelling urinary catheter is inserted after induction of general anesthesia.

Instrumentation includes a basic laparotomy set, Maloney or Hurst dilators in sizes 32 French (32F) to 42F, a self-retaining retractor system, and a 1-inch Penrose drain. If a transthoracic approach is planned, a basic thoracic set is required.

Operative Procedure

1. Through a transabdominal incision, the hernia is located and a crural repair is done.
2. The fundus of the stomach is wrapped around the lower 4 to 6 cm of the esophagus and is sutured in place (Nissen fundoplication); the upper part of the lesser curvature of the stomach and the cardioesophageal junction are sutured to the median arcuate ligament (Hill procedure); or the stomach is plicated approximately 270 degrees around the esophageal circumference (Belsey Mark IV procedure). The Nissen fundoplication procedure is illustrated in Figure 10-15.
3. Vagotomy, pyloroplasty, or both may be performed at the same time.
4. The wound is closed.

Laparoscopic Nissen Fundoplication

The Nissen-Rossetti fundoplication and several other laparoscopic procedures have been developed for GERD management. Nissen fundoplication is also used in the following ways: to reduce the hernia, to eliminate the hernia sac, and to repair the large defect in the diaphragm hiatus. GERD may also be treated with a silicone prosthetic implant placed around the distal esophagus under the diaphragm and above the stomach. The prosthesis, a small donut-shaped device with an open end that is sutured to be continuous, allows food to pass but prevents the stomach from sliding into the chest cavity. This procedure may also be performed as an open laparotomy.

The patient undergoing a laparoscopic Nissen fundoplication is usually admitted the day of surgery. Surgery is performed through five trocar sites in the abdomen, which greatly reduces postoperative recovery. The patient is typically discharged by the second postoperative day if there are no complications. A postoperative upper GI series verifies functioning of the newly constructed antireflux valve.

Procedural Considerations. Surgery is performed using a general anesthetic to anesthetize the patient. A nasogastric (NG) tube and urinary drainage catheter are placed after induction and intubation. The patient is positioned supine or in the modified lithotomy position.

Instrumentation and supplies include a basic laparotomy set, laparoscope, laparoscopic camera, five trocars (trocar size or sizes depend on the surgeons' preference), a light cord, filtered insufflation tubing, and an ESU cord. Laparoscopic instruments

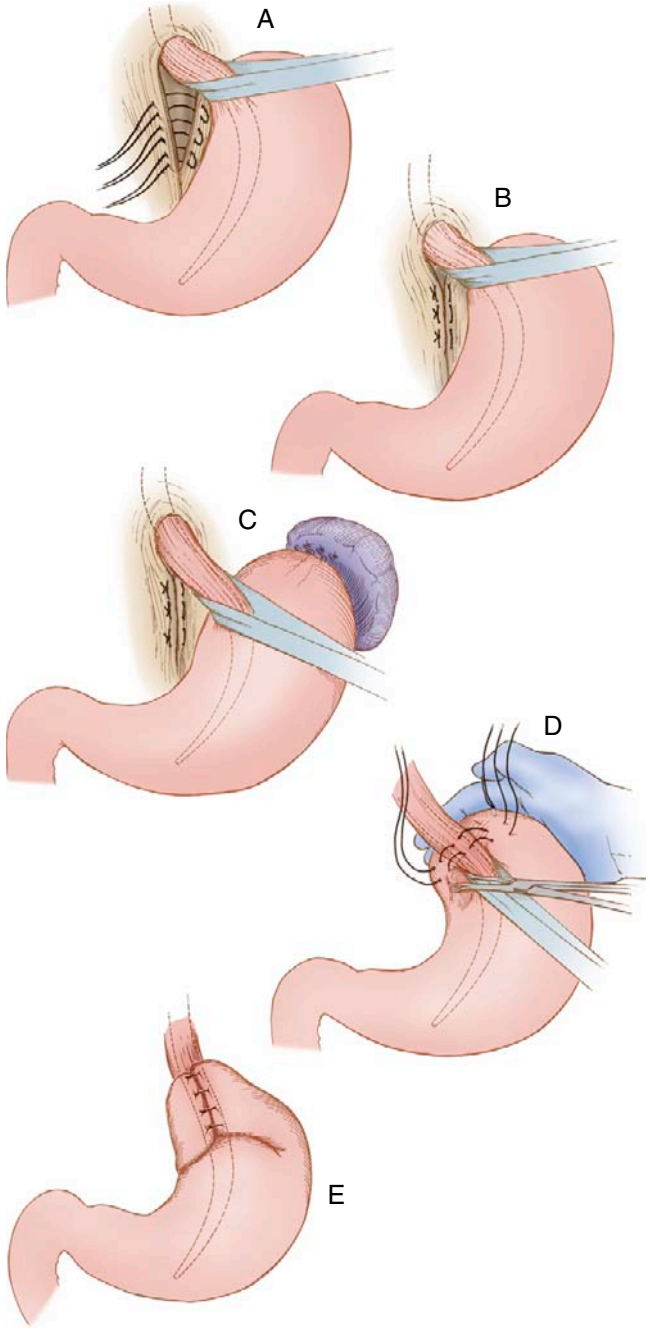


FIGURE 10-15 The Nissen fundoplication procedure begins with oral passage of a Maloney dilator (40F to 48F) into the lumen of the stomach. **A**, The esophagus is then mobilized. A Penrose drain is placed around the gastroesophageal junction to pull the esophagus down and out of the hernia. **B**, Shown are three heavy sutures (#0 braided absorbable) placed to narrow the hiatal aperture but not so tight as to constrict the esophagus, thus the purpose of stenting the esophagus with the Maloney dilator. **C**, Further traction is applied to the distal esophagus while the proximal stomach and fundus are freed from all peritoneal attachments. **D**, The posterior wall of the stomach is relocated around the distal esophagus. **E**, The stomach walls are wrapped and sutured around the intraabdominal esophagus, with the Maloney stent in place.

commonly used include grasping forceps, endoscissors, endo-Babcock forceps, endodissecting forceps, endoclip appliers, an endosuturing device, and endoretractors, such as the fan retractor. Suction and a suction-irrigator are commonly used. A Penrose drain or a 12F red Robinson catheter is used to assist in isolating and retracting the distal esophagus. Bougie dilators (large sizes, such as 40F to 60F) may be used as an esophageal stent by which to secure the fundoplication. A water-based lubricating jelly is used to assist the anesthesia provider in placing the bougie. Equipment needed for the procedure includes an ESU, an insufflation unit with CO_2 gas, and two video monitors (one placed on each side of the patient).

Operative Procedure

1. A stab wound is made with a #11 blade for insertion of the first trocar.
2. The trocar is placed, and insufflation achieved. This may be performed before placing the trocar by inserting a *Veress* needle for insufflation.
3. The laparoscope is placed through the port, and the camera attached to the laparoscope.
4. Two trocars are placed below the xiphoid process, in the right upper quadrant of the abdomen, high in the costal margin, about 5 to 6 mm to the right and left of the midline. Another trocar is placed on the lateral plane to the midline in the left abdomen (left midclavicular). The last trocar is placed in the lateral abdominal wall for use by the assistant.
5. A fan-shaped endoretractor is inserted through the right midclavicular port site and used to retract the left lobe of the liver to expose the gastroesophageal junction.
6. An endo-Babcock forceps is inserted through the left midclavicular port and is used to grasp the upper aspect of the fundus of the stomach. The stomach is retracted laterally and downward. This port site is also used for insertion of a grasper to hold the Penrose drain, clip applier, and ultrasonic coagulating shears.
7. The surgeon mobilizes the distal esophagus by opening the hiatus and employs an endodissector forceps to bluntly dissect the tissue along the right and left crura.
8. Endoclips are used to ligate the most distal portion of the pericardiophrenic vessel before it is divided.
9. The posterior vagus is identified but left intact.
10. Dissection is continued to expose the posterior esophagus.
11. The upper aspect of the greater curvature of the stomach is mobilized, and dissection continues to the posterior esophagus.
12. The Penrose or Robinson catheter is inserted through a sheath and is passed behind the gastroesophageal junction. The ends are united and secured with an endoclamp that is then locked and used as a traction retractor during the procedure.
13. Another grasping forceps is used to grasp the apex of the gastric fundus and retract it downward to expose the short gastric vessels. The vessels are ligated with endoclips and divided with endoscissors.
14. The upper portion of the mobilized greater curvature is grasped and passed through the opening that has been created at the hiatus.
15. Tension and adequate mobilization of the greater curvature of the stomach are assessed. The portion of the greater curvature of the stomach that has been moved around the posterior esophagus at the proximal part of the gastroesophageal junction is then manipulated over the anterior distal esophagus.
16. A nonabsorbable endosuture is passed through a 5-mm port and used to place a row of interrupted sutures to join the aspects of the greater curvature of the stomach in a 2-cm to 3-cm "wrap" around the esophagus.
17. The anesthesia provider passes a large bougie down the lumen of the esophagus. The sutures are secured with the bougie in place.
18. The catheter (or drain) and bougie are removed. The abdomen is deflated.
19. Final inspection is completed, hemostasis obtained, and the instruments and ports removed under direct vision so that any bleeding from the abdominal wall can be readily detected. The trocar sites are then closed and dressings applied.

Esophagomyotomy (Heller Procedure)

Esophagomyotomy (Heller cardiomyotomy) is myotomy of the esophagogastric junction to correct esophageal obstruction resulting from achalasia, a motility disorder of aperistalsis of the esophagus and elevated LES pressure. These patients have dysphagia, esophageal fullness, regurgitation, and weight loss (SGNA, 2004).

Procedural Considerations. Selection of a transthoracic or transabdominal incision depends on the patient's general condition and other existing pathologic factors. The surgeon may elect to perform a pyloroplasty to prevent reflux by promoting stomach emptying. Instrumentation includes a basic laparotomy set and instruments to enter and retract the thorax if necessary. Laparoscopic and VATS approaches are safe and effective alternatives to the open procedure. The laparoscopic approach offers the advantage of adding fundoplication (Lee et al, 2004). Potential postoperative complications include esophageal perforation and reflux.

Operative Procedure

1. A midline abdominal incision is made from the xiphoid process to the umbilicus.
2. After exposure of the esophagogastric junction, a Maloney dilator is inserted through the patient's oral cavity to distend the esophagus.
3. A scalpel with a #15 blade is used to make a longitudinal incision through the muscular wall of the distal esophagus and proximal stomach, leaving the mucosa intact.
4. A small portion of the fundus of the stomach may be plicated to the lateral wall of the esophagus.
5. The wound is closed.
6. VATS is approached with the patient positioned and secured in a right lateral position.
7. A 30-degree thoracoscope is inserted in the left eighth intercostal space along the left posterior axillary line.
8. The lung is retracted through a working port placed in the left anterior axillary line of the fifth space.
9. Dissection is done through a mini-thoracotomy in the left ninth intercostal space to sweep the muscular layer from the mucosa from 6 cm above and 1 cm below the gastroesophageal junction. This dissection is made halfway around the circumference of the esophagus.
10. A chest tube is placed and the incision and port sites closed.

Esophageal Dilation

Esophageal dilation may be indicated in patients who have an esophageal stricture related to past surgery, chemical or thermal injury, or anatomic anomalies. An upper GI series is required before the procedure to locate the stricture.

Procedural Considerations. Esophageal dilation is a clean procedure performed in the OR or endoscopy unit. General anesthesia or moderate sedation is usually indicated. An esophageal perforation is a complication that could require open repair. The patient is positioned supine.

A flexible gastroscope and light source with video camera and monitor, bougie dilators (Hurst or Maloney dilators are commonly used) in graduated sizes, water-soluble lubricant, gauze sponges, and gloves are required to perform the procedure. An esophageal stent that can be inserted through a large-channel gastroscope or along a guidewire may be requested. The surgeon may use fluoroscopy to demonstrate that the dilation site is accurate by combining esophagoscopy with fluoroscopy and marking the site of stricture distally and proximally with radiopaque markers taped to the patient's skin.

Operative Procedure

1. The bougies are arranged in graduated order beginning with the smallest size (24F) and progressing to the largest size (60F).
2. The surgeon may first perform gastroscopy and pass a guidewire through the esophageal stricture.
3. The bougies are then passed one at a time gently but firmly through the stricture in an attempt to dilate the esophageal lumen.
4. Continuation of the dilation to the largest bougie depends on ease of passage and the patient's tolerance.
5. Laser therapy may be indicated for palliation if a tumor mass is causing the stricture. The neodymium:yttrium-aluminum-garnet (Nd:YAG) laser energy may be delivered to the mass or stricture by way of a flexible quartz fiber passed through the operative channel of the gastroscope.
6. An esophageal stent may be placed at the stricture site to decrease the chance of recurrence.

SURGERY OF THE STOMACH

Vagotomy

Truncal vagotomy is identification of the two vagal trunks on the distal esophagus and resection of a segment of each, including any additional nerve fibers running separately from the trunks. By interrupting parasympathetic innervation, this procedure reduces gastric acid secretion in patients with duodenal ulcers. When truncal vagotomy was initially performed alone, a high incidence of gastric stasis resulted from the loss of cholinergic innervation to the smooth muscle of the stomach; thus pyloroplasty or another gastric drainage procedure almost always accompanies truncal vagotomy. Truncal vagotomy deprives not only the stomach but also the liver, gallbladder, bile duct, pancreas, small intestine, and half of the large intestine of parasympathetic nerve supply (Figure 10-16). Truncal vagotomy with antrectomy or a drainage procedure is the most common operation for duodenal ulcers.

Selective vagotomy is transection of each abdominal vagus at a point just beyond its bifurcation into gastric and extragastric divisions. Thus the hepatic branch of the anterior vagus and the celiac branch of the posterior vagus are preserved. Selective vagotomy has theoretical advantages over truncal vagotomy because vagal innervation of the viscera other than the stomach is preserved. However, selective vagotomy also denervates the entire stomach, so that addition of a drainage procedure is still necessary. Selective vagotomy may cause less postvagotomy diarrhea than truncal vagotomy does, but the incidence of dumping syndrome is probably the same or even higher. Both procedures are about equally effective in controlling duodenal ulcers.

Parietal cell vagotomy is the vagal denervation of only the parietal cell area of the stomach. The technique spares the main nerves of Latarjet, but divides all vagal branches that terminate on the proximal two thirds of the stomach. The operation has also been called *proximal gastric vagotomy* (Figure 10-17) and highly selective vagotomy. Because antral innervation is preserved, gastric emptying is unimpaired and a drainage procedure is unnecessary. The incidence of dumping and diarrhea after *parietal cell vagotomy* is much lower than that after truncal or selective vagotomy.

Procedural Considerations. Instrumentation for vagotomy includes a basic thoracotomy set (if a thoracoabdominal incision is to be used), a laparotomy set, a GI instrument set, blunt nerve hooks (Smith-Wick), 10-inch vessel clip appliers with clips, and 10-inch Metzenbaum dissecting scissors. A 1-inch Penrose drain is used to retract the esophagus. After receiving a general anesthetic, the patient is positioned supine. A laparoscopic approach may also be used.

Operative Procedure

1. A midline incision is made, and the esophagus identified and retracted with a 1-inch wide Penrose drain.
2. The vagus nerves or their branches, depending on which type of vagotomy is being done, are identified, clamped with either a ligature or a hemostatic clip, and resected.
3. The wound is closed in layers.

Pyloroplasty (Pyloromyotomy)

Pyloroplasty is the formation of a larger passageway between the prepyloric region of the stomach and the first or second portion of the duodenum. A pyloroplasty may be performed for treatment of a peptic ulcer under selected conditions but is more frequently employed to remove cicatricial bands in the pyloric ring, thus relieving spasm and permitting rapid emptying of the stomach. In adults, a vagotomy is usually performed with a pyloroplasty.

Procedural Considerations. A laparotomy set and GI instrument set are required. The patient is positioned supine, and a general anesthetic is administered. An NG tube is placed and an indwelling urinary catheter inserted.

Operative Procedure

1. The abdominal cavity is opened through a midline incision.
2. The pylorus of the stomach is isolated.
3. An incision is made through the stomach and the duodenum.

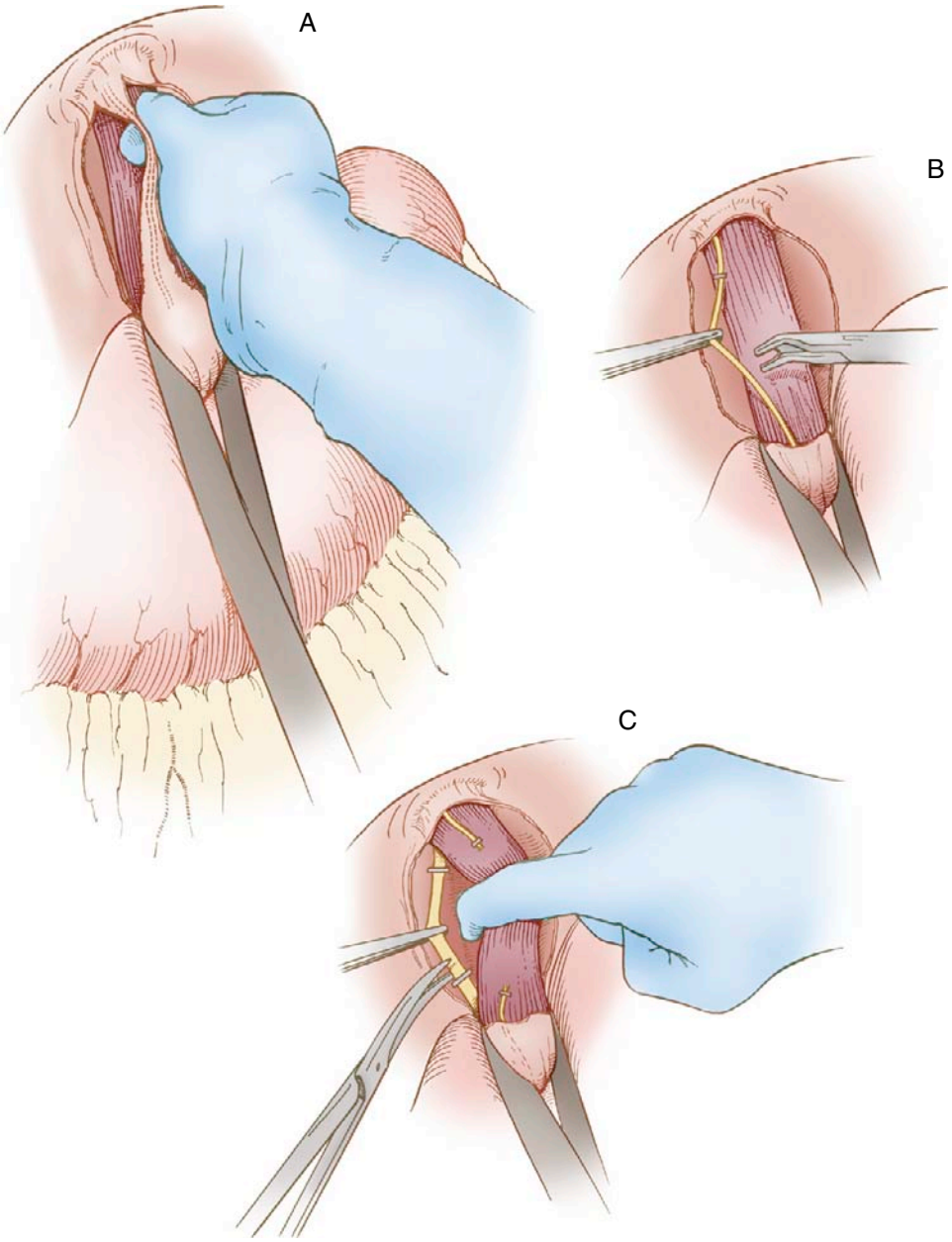


FIGURE 10-16 Truncal vagotomy. **A**, The phrenoesophageal ligament is lifted from the surface of the esophagus, and the vagal trunks are identified. **B**, Ligating clips are applied to the vagus nerve. **C**, Ligating clips have been applied to the larger posterior nerve in preparation for resecting a 2-cm segment between the clips.

4. The pyloroplasty is closed with nonabsorbable or synthetic absorbable intestinal sutures.
5. The abdominal wound is closed in layers, and a dressing is applied.

Percutaneous Endoscopic Gastrostomy (PEG)

PEG is now the most popular gastrostomy tube placement approach. After administration of a local anesthetic or induction of moderate sedation/analgesia, the tube is placed endoscopically. It can be used for gastric decompression and enteral feedings. PEG uses a flexible gastroscope and a uniquely designed gastrostomy tube for placement through the abdominal wall; it requires a push-pull technique to insert. This procedure may be done in the endoscopy suite, in the OR, or at the bedside in a critical care unit if necessary.

Procedural Considerations. A PEG tube kit containing the following is required: a percutaneous needle, a long silk suture with one end strengthened for feeding it down the lumen of the needle, a percutaneous gastrostomy tube, and a bolster. A flexible gastroscopy system is also required as well as snare forceps.

The patient is positioned supine after being anesthetized with IV moderate sedation. A bite-block is inserted into the patient's mouth.

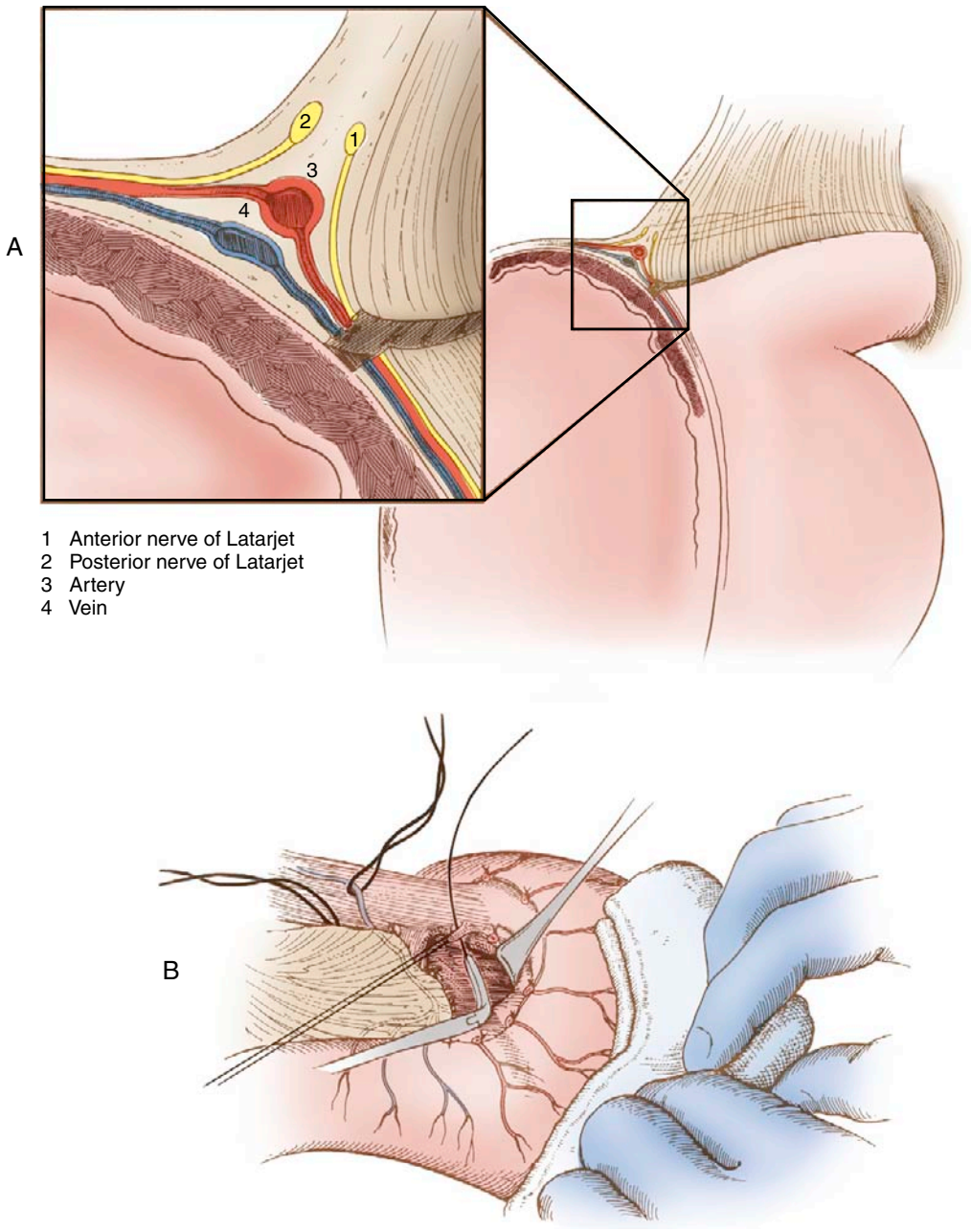


FIGURE 10-17 Selective proximal vagotomy. **A**, Illustrates the junction of the gastrohepatic ligament with the lesser curve of the stomach and demonstrates the anterior (*1*) and posterior (*2*) nerves of Latarjet, along with the artery (*3*) and vein (*4*). **B**, The lesser curve is lifted with a vein retractor to facilitate serial ligation of the intermediate and posterior neurovascular attachments.

Operative Procedure

1. The gastroscope is passed.
2. The end of the scope is angled anteriorly to the left anterolateral wall of the stomach's fundus so that the light from the gastroscope can be seen through the abdominal wall.
3. The stomach is insufflated with air through the gastroscope.
4. A local anesthetic is injected at the site of the intended gastrostomy if the patient is awake.
5. A small stab wound is made with a #11 blade.
6. The percutaneous needle is inserted into the abdominal wall and into the stomach lumen under direct visualization of the gastroscope.
7. The long silk suture is threaded into the lumen of the needle and passed into the stomach, where it is snared with the forceps.
8. A clamp is applied to the exterior distal end of the suture after the needle is removed.
9. The gastroscope is removed, and the suture extends out of the patient's oral cavity.

10. The suture is then attached to the tapered end of the gastrostomy tube.
11. The gastrostomy tube is gently guided into the patient's oral cavity, down the esophagus, and into the lumen of the stomach and pulled through the abdominal wall ("push-pull" technique).
12. The tube is secured with an internal bolster by reinserting the gastroscope and snugging it close to the gastric wall under direct visualization.
13. An external bolster is applied over the tube and snugged to the abdominal wall. Care is taken to ensure the bolsters do not compress the tissues because such compression might compromise tissue integrity and perfusion.
14. The distal end of the tube is cut, and a connector is applied.
15. The patient's stomach is deflated, and the procedure is complete.

Closure of Perforated Gastric or Duodenal Ulcer

Closure of a perforation in the stomach or duodenum is performed through a high right rectus or midline abdominal incision.

Procedural Considerations. A perforated gastric or duodenal ulcer is treated as a surgical emergency, and the operation is performed as soon as the diagnosis is made. The patient is typed and crossmatched so that an adequate supply of blood is available. A gastric lavage is not performed, but continuous suction is used. A laparotomy set and a GI instrument set are required. Linear stapling instruments should be available.

Operative Procedure

1. Through a right rectus or midline abdominal incision, the perforation is located.
2. Suction is used to remove exudate in the peritoneal cavity.
3. The perforation is closed with a purse-string suture by inverting the raw edges and suturing a piece of omentum over the closure.
4. The ulcerated area may be resected using linear stapling devices.
5. The abdomen is copiously irrigated with warm saline, which may contain a broad-spectrum antibiotic.
6. The abdominal wound is closed in layers, and a dressing applied.

Gastrojejunostomy

Gastrojejunostomy establishes a permanent communication between the proximal jejunum and either the anterior or the posterior stomach, without removing any segment of the GI tract (Figure 10-18). It is accomplished through a midline or paramedian abdominal incision.

Gastrojejunostomy is performed to treat a benign obstruction at the pyloric end of the stomach or an inoperable lesion of the pylorus when a partial gastrectomy is not feasible. It also provides a large opening without sphincter obstruction.

Procedural Considerations. Laparotomy and GI instrument sets are required. Linear stapling instruments should be available. The patient is positioned supine after induction of general anesthesia. The anesthesia provider inserts an NG tube after intubation. An indwelling catheter is placed into the urinary bladder before the abdominal skin prep.

Operative Procedure

1. Through an upper midline or paramedian abdominal incision, exploration of the peritoneal cavity is completed, as described for routine laparotomy.
2. The pathologic condition is confirmed.
3. Warm, moist packs are placed, and a self-retaining retractor is positioned.
4. A loop of proximal jejunum is grasped with a Babcock forceps and freed from the mesentery.
5. The loop of jejunum is approximated to either the anterior or the posterior stomach wall several centimeters from the greater curvature of the stomach.
6. Nonabsorbable 2-0 traction sutures are placed through the serosal layers at each end of the selected portion of the jejunum and stomach.
7. Gastroenterostomy clamps may be placed before insertion of the posterior interrupted 3-0 or 2-0 nonabsorbable serosal sutures.
8. The field is draped for open anastomosis (bowel technique).
9. The jejunum and stomach are opened.
10. Bleeding points are clamped with mosquito or Crile hemostats and ligated with 3-0 synthetic absorbable sutures.
11. The inner posterior row of sutures is placed, using atraumatic intestinal needles with 2-0 or 3-0 synthetic absorbable suture, and continued for the first anterior row.
12. The anastomosis is completed with anterior serosal sutures of 3-0 or 2-0 nonabsorbable material.
13. Traction sutures are removed.
14. Interrupted 4-0 nonabsorbable sutures may be used for reinforcement.
15. Contaminated instruments are discarded into a basin.
16. The abdominal wound is closed in layers, and a dressing applied.

Partial Gastrectomy—Billroth I and Billroth II

A Billroth I gastrectomy is resection of a diseased portion of the stomach through a right paramedian or midline abdominal incision and establishment of an anastomosis between the stomach and duodenum. It is performed to remove a benign or malignant lesion located in the pylorus, or upper half of the stomach. One of several techniques may be followed to establish GI continuity, including the Schoemaker, the von Haberer-Finney, and other modifications of the Billroth I procedure (Figure 10-19).

Procedural Considerations. Laparotomy and GI instrument sets are required. Linear stapling instruments should be available. The patient is positioned supine after induction of general anesthesia. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter is inserted before the abdominal skin prep.

Operative Procedure

1. The abdominal wall is incised, and the peritoneal cavity is opened and explored.
2. Bleeding vessels are clamped and ligated or coagulated.
3. The abdominal wound is retracted, and the surrounding organs are protected with warm, moist packs.
4. The gastrocolic omentum is freed from the colon mesentery to prevent injury to the middle colic artery.

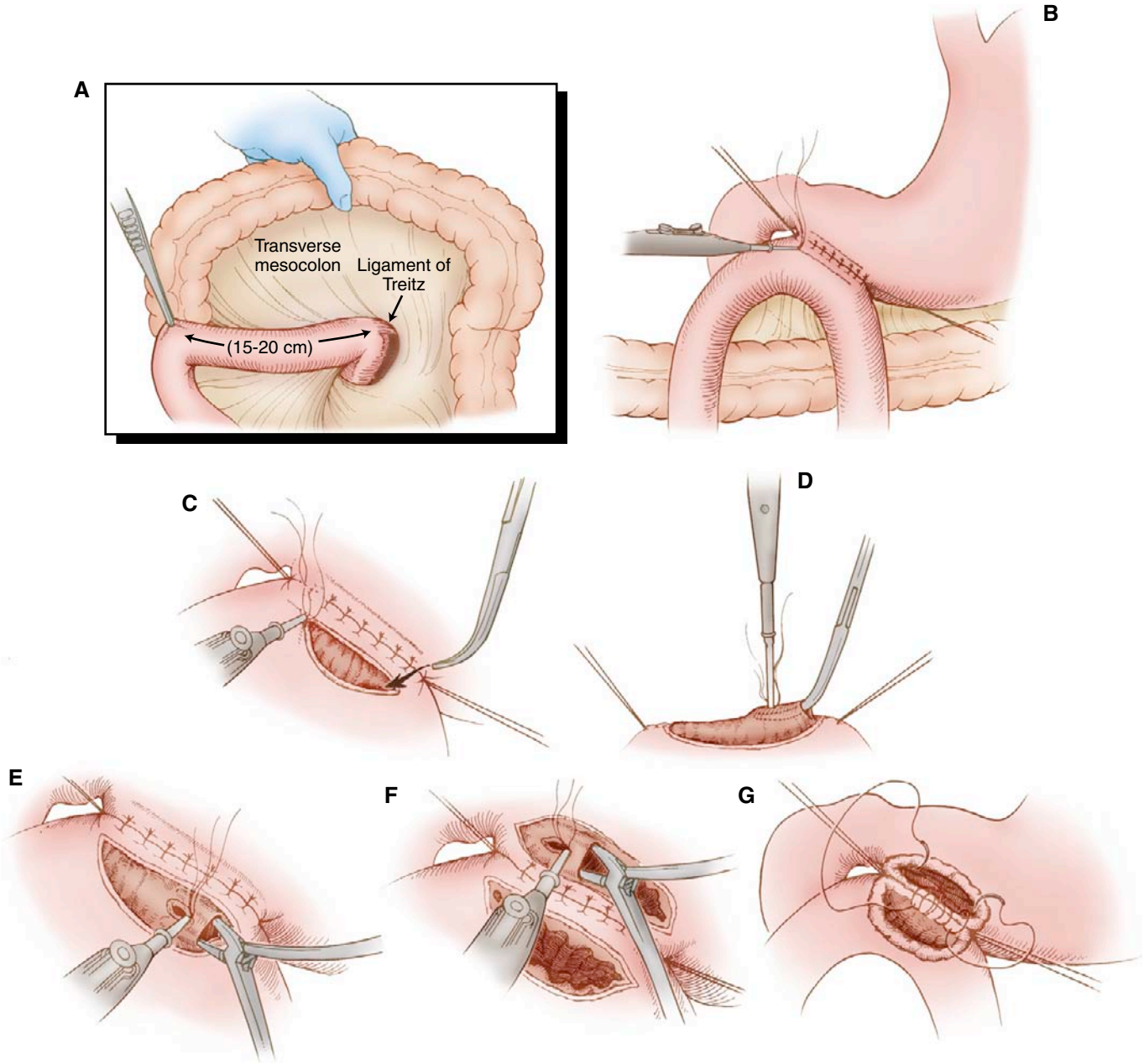


FIGURE 10-18 Gastrojejunostomy. **A**, Illustrates the selection of a segment of jejunum that will be anastomosed to the stomach; the distance between the ligament of Treitz and the anastomosis should not be excessively long or under any tension. **B**, A posterior row of interrupted sutures is placed between the gastric and jejunal serosae, and the sites of the gastric and jejunal stomas are scored with the electrosurgical pencil. **C**, The jejunal stoma is created by dissecting through the serosa and muscularis with the electrosurgical pencil. An opening is made in the mucosa, and a right-angled clamp is inserted into the lumen. **D**, The clamp is opened and elevated. **E**, Electrosurgery is applied between the two jaws of the clamp. **F**, The procedure is repeated for creating the gastric stoma. **G**, Full-thickness anastomosis is begun posteriorly.

5. With hemostats and Metzenbaum scissors, the right and left gastroepiploic arteries and veins are clamped, divided, and ligated with 2-0 nonabsorbable sutures and 2-0 and 3-0 suture ligatures, thereby freeing the greater curvature of the stomach.
6. The gastric vessels are clamped, divided, and ligated to free the diseased portion of the stomach.
7. The operative field is prepared for open anastomosis (bowel technique).
8. After sectioning the stomach from the greater to lesser curvature, two Allen intestinal anastomosis clamps or other suitable clamps, or linear stapling device, are placed on the upper portion of the duodenum just distal to the pylorus.

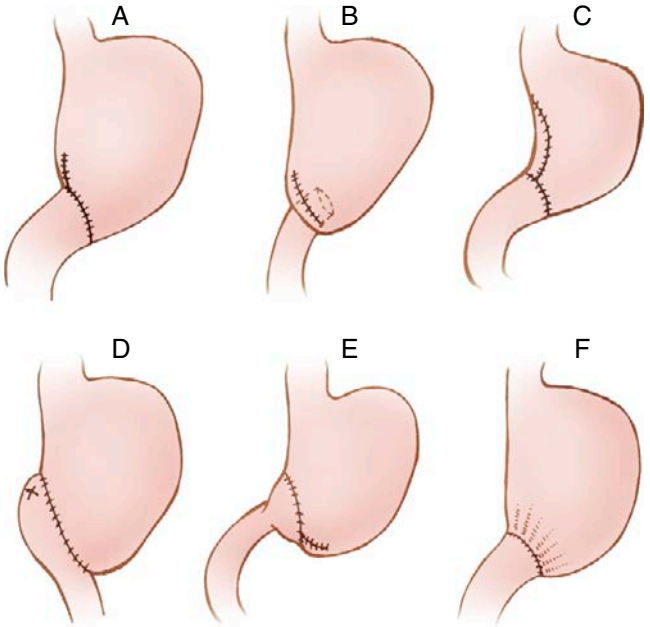


FIGURE 10-19 Diagrams illustrating resections of stomach with anastomosis of stomach and duodenum (gastroduodenal anastomosis). All are modifications of the Billroth I technique, in which the stomach is moved to the duodenum. **A**, Billroth I: after pylorus is removed, lesser curvature is partially closed and duodenum is sutured to open end of stomach at its lower margin. **B**, Kocher: distal end of stomach is closed, and duodenum is transferred up to posterior margin of closed stomach. **C**, Schoemaker: lesser curvature of stomach is sutured closed and and brought down to same size as duodenum, and end-to-end anastomosis is done. **D**, von Haberer-Finney: side of duodenum is transferred up to end of stomach so that entire end of stomach is open for direct anastomosis. **E**, Horsley: lesser curvature end of stomach is used to suture to duodenum and closes greater curvature end. **F**, von Haberer: modification of operation shown in **D**. Stomach is, so to speak, narrowed or puckered so that it fits end of duodenum. Modification of this is done by some surgeons as follows: duodenum is split longitudinally, and its ends are flared open so that opening is large enough to fit open end of stomach.

9. The duodenum is divided by scalpel, electrosurgery, or a linear cutting and stapling device (e.g., gastrointestinal anastomosis [GIA]).
10. Additional moist packs are placed for protection, and two sets of anastomosis clamps are placed across the stomach.
11. Division of the stomach is completed.
12. At the lower margin, the opened stomach is approximated to the duodenum by a series of interrupted sutures placed in the serosal layers. An atraumatic intestinal needle with 3-0 nonabsorbable suture is used. Suture ends are held with hemostats, and the intestinal clamps are removed.
13. Stumps of the stomach and duodenum are cleansed with moist sponges, and bleeding vessels are ligated with fine suture or coagulated.
14. During anastomosis of the stomach and remaining duodenum, the involved segments may be held with rubber-shod clamps. The excess of the lesser curvature of the stomach is closed on completion of the anastomosis.
15. Instruments used in the open portion of the GI tract are discarded into a separate basin.
16. Routine laparotomy closure is completed.

A Billroth II gastrectomy is resection of the distal portion of the stomach through an abdominal incision and establishment of an anastomosis between the stomach and jejunum. It is performed to remove a benign or malignant lesion in the stomach or duodenum. This technique and modifications are selected because the volume of acidic gastric juice will be reduced and the anastomosis can be made along the greater curvature or at any point along the stump of the stomach. Modifications of the Billroth II procedure include the Polya and Hofmeister operations, which also establish GI continuity by duodenal bypass.

After surgery, duodenal and jejunal secretions empty into the remaining gastric pouch.

Procedural Considerations. Laparotomy and GI instrument sets are required. Linear stapling instruments should be available. The patient is positioned supine after induction of general anesthesia. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter is inserted before the abdominal skin prep.

Operative Procedure

1. The abdominal wall is incised and the peritoneal cavity opened and explored.
2. Bleeding vessels are clamped and ligated or coagulated.
3. The abdominal wound is retracted, and the surrounding organs are protected with warm, moist packs.
4. The gastrocolic omentum is freed from the colon mesentery to prevent injury to the middle colic artery.
5. With hemostats and Metzenbaum scissors, the right and left gastroepiploic arteries and veins are clamped, divided, and ligated with 2-0 nonabsorbable suture and 2-0 and 3-0 suture ligatures, thereby freeing the greater curvature of the stomach.
6. The distal portion of the stomach is isolated.
7. Moist packs are placed for protection of the viscera, and two sets of anastomosis clamps are placed across the distal stomach.
8. The stomach is resected just distal to the pylorus using a scalpel, electrosurgery, or a linear stapling and cutting device (GIA) (Figure 10-20, *A*).
9. A proximal loop of jejunum is positioned for anastomosis to the posterior wall of the remaining stomach.
10. An anastomosis is established between the stomach and jejunum using mechanical linear stapling devices (GIA and thoracoabdominal [TA] instruments) (Figure 10-20, *B, C*).
11. The abdomen is closed.

Total Gastrectomy

Total gastrectomy is complete removal of the stomach and establishment of an anastomosis between the jejunum and esophagus (esophagojejunostomy) (Figure 10-21). It includes an enteroenterostomy if indicated. Total gastrectomy is done with curative intent or as a palliative procedure to remove a malignant lesion of the stomach and metastases in the adjacent lymph nodes.

Procedural Considerations. The incision may be bilateral subcostal, long transrectus, long midline, or thoracoabdominal. Thoracotomy, GI, and laparotomy sets are necessary. Mechanical linear stapling devices should be available. In addition, two

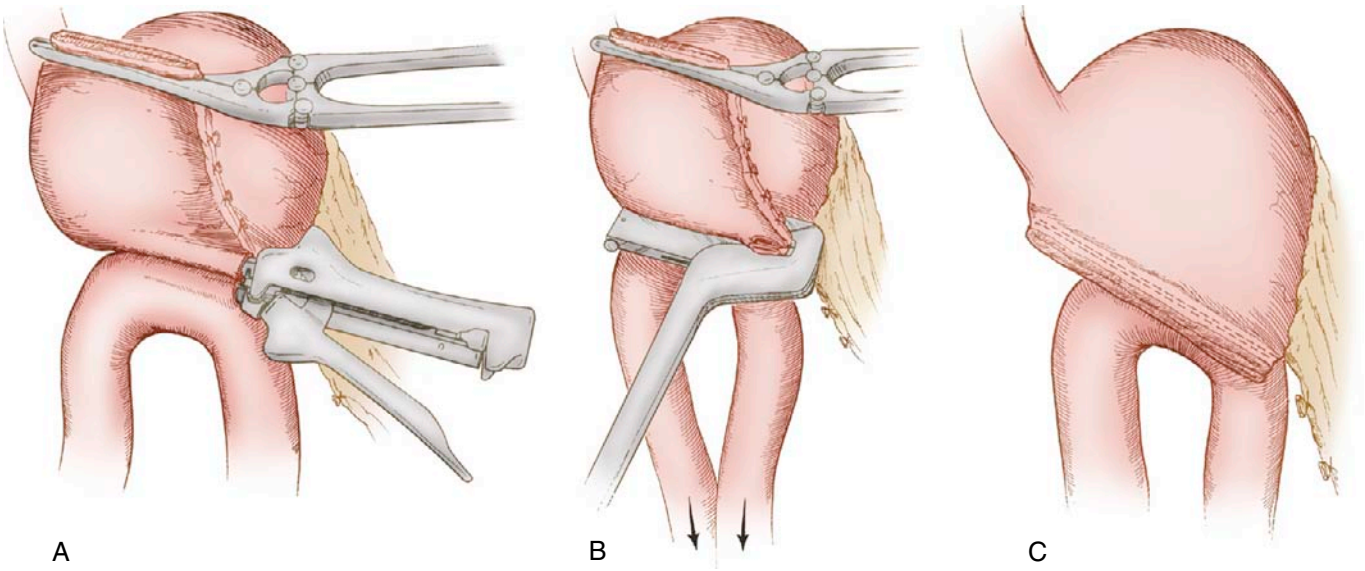


FIGURE 10-20 Subtotal gastrectomy with stapled Billroth II anastomosis. **A**, The distal stomach has been dissected free and resected just distal to the pylorus. A proximal limb of jejunum is transferred up to anastomose to the posterior wall of the stomach with a linear stapling instrument that transects between two parallel staple lines. **B**, The stomach is elevated, and a 90-degree mechanical stapling device is placed across the distal stomach. **C**, Illustration of the completed subtotal gastrectomy with stapled antecolic gastrojejunostomy.

long, blunt nerve hooks and two 10-inch needle holders are required. The patient is positioned supine after induction of general anesthesia. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter is inserted before the abdominal skin prep.

Operative Procedure

1. The abdomen is opened through an incision of choice.
2. The wound edges are protected and retracted.
3. Complete exploration for metastasis is performed.
4. The omentum is freed from the colon, using sharp dissection; vessels are ligated with 2-0 nonabsorbable suture.
5. The splenic vessels are ligated and transfixed with 2-0 and 3-0 nonabsorbable suture at the tail of the pancreas; the spleen is left attached to the omentum.
6. The duodenum is mobilized, intestinal clamps or linear stapler is applied, and the operative field is protected for transection and closure of the distal duodenum (bowel technique).
7. The right gastric artery is ligated and transfixed with 2-0 and 3-0 nonabsorbable suture, and the gastrohepatic omentum is separated from the liver.
8. After ligation of the left gastric artery, the mobilized stomach, spleen, omentum, and lesser and greater curvature ligamentous attachments are delivered into the wound.
9. The coronary ligament of the left lobe of the liver is divided, exposing the diaphragmatic peritoneum over the esophagogastric junction.
10. The liver is protected by moist packs, and gentle retraction is maintained with a Harrington, Deaver, or malleable retractor.
11. A flap of peritoneum is freed from the diaphragm, and branches of the vagus nerves are divided.
12. A loop of jejunum is selected and delivered antecolic to the esophagogastric junction for anastomosis.
13. Traction is placed on the specimen, and the posterior row of interrupted 3-0 nonabsorbable sutures is placed, or a stapling device is used.
14. As the jejunum and esophagus are incised, mosquito or Crile hemostats and ligatures of 3-0 synthetic absorbable suture control bleeding.
15. The posterior row is reinforced with 3-0 intestinal synthetic absorbable sutures or a linear staple line.
16. Division of the esophagus is completed, and the entire specimen is removed.
17. The mucosal anterior wall of the anastomosis is approximated with 4-0 interrupted synthetic absorbable sutures; an end-to-end anastomosis circular stapling device may be used to anastomose the esophagus and jejunum.
18. A second layer of sutures, 3-0 nonabsorbable or synthetic absorbable, is placed anteriorly in the seromuscular and muscular coat of the intestine.
19. A flap of the peritoneum is attached to the jejunum with interrupted 3-0 nonabsorbable sutures to relieve traction on the anastomosis.
20. A lateral jejunojejunal anastomosis is completed to permit irritating bile and pancreatic fluids to bypass the anastomosis line, thereby preventing esophageal regurgitation.
21. The abdominal wound is closed in layers. If retention sutures are used, they must be placed extraperitoneally because of the absence of omentum to protect the small bowel.

An alternative to using suture materials is the use of mechanical stapling devices. Another method of establishing continuity is a combination of a Roux-en-Y jejunojejunostomy and a jejunoesophagostomy. A Roux-en-Y, also written RNY, is any Y-shaped anastomosis in which small bowel is included.

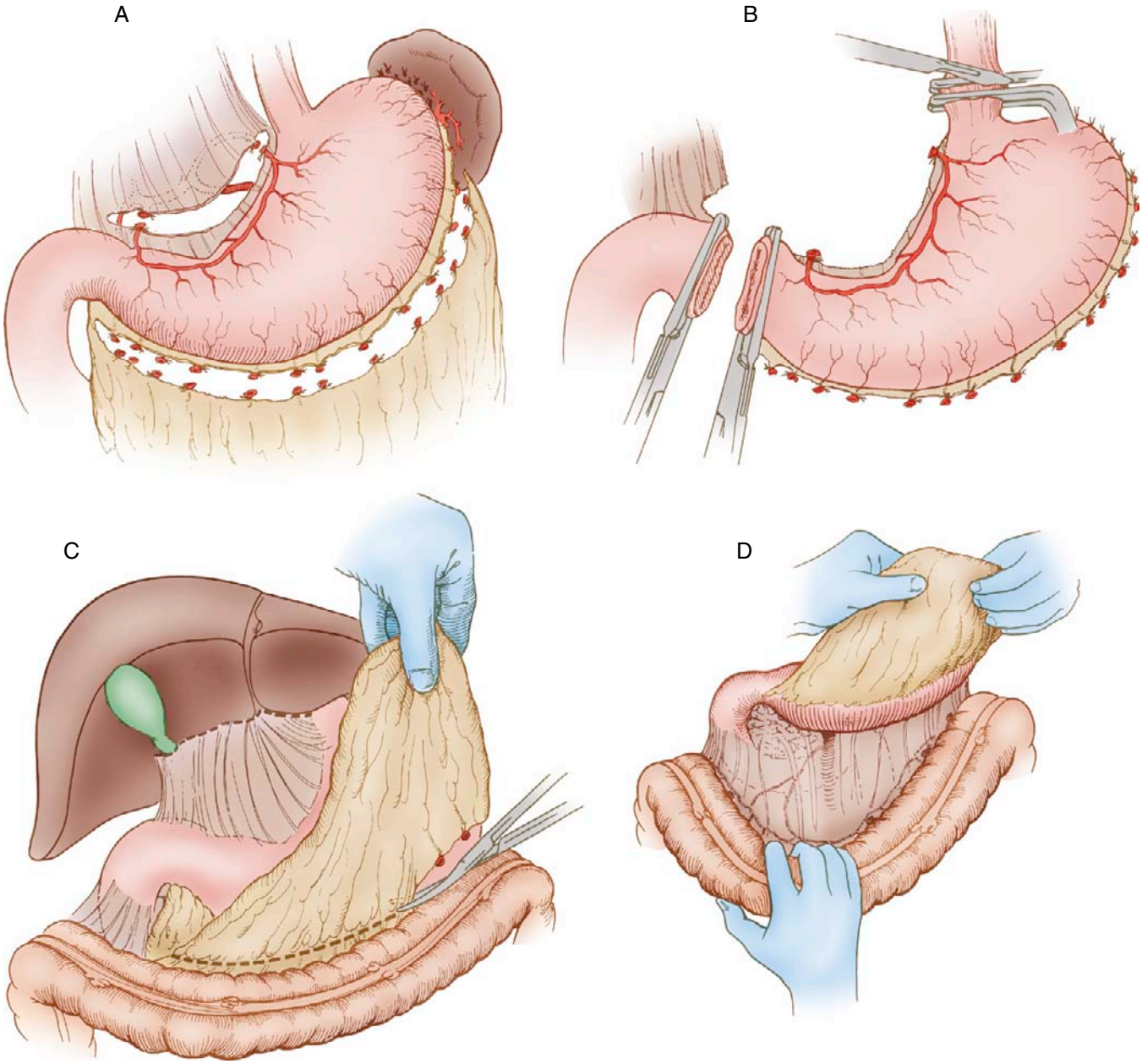


FIGURE 10-21 Total gastrectomy may be performed for benign or malignant disease. **A**, Demonstrates the mobilization of the stomach for benign disease. Serial division of the vessels in the gastrocolic ligament and gastrohepatic ligament is performed to free the greater and lesser omentum. The short gastric vessels connecting the stomach to the spleen are divided, and the spleen is preserved. **B**, The duodenum is divided distally to the pylorus, and the proximal line of division is at the distal intraabdominal esophagus. **C**, For malignancies, the line of resection includes both the lesser and the greater omentum. **D**, The retrogastric area is inspected for tumor involvement. The spleen and tail of the pancreas may be included in the resection.

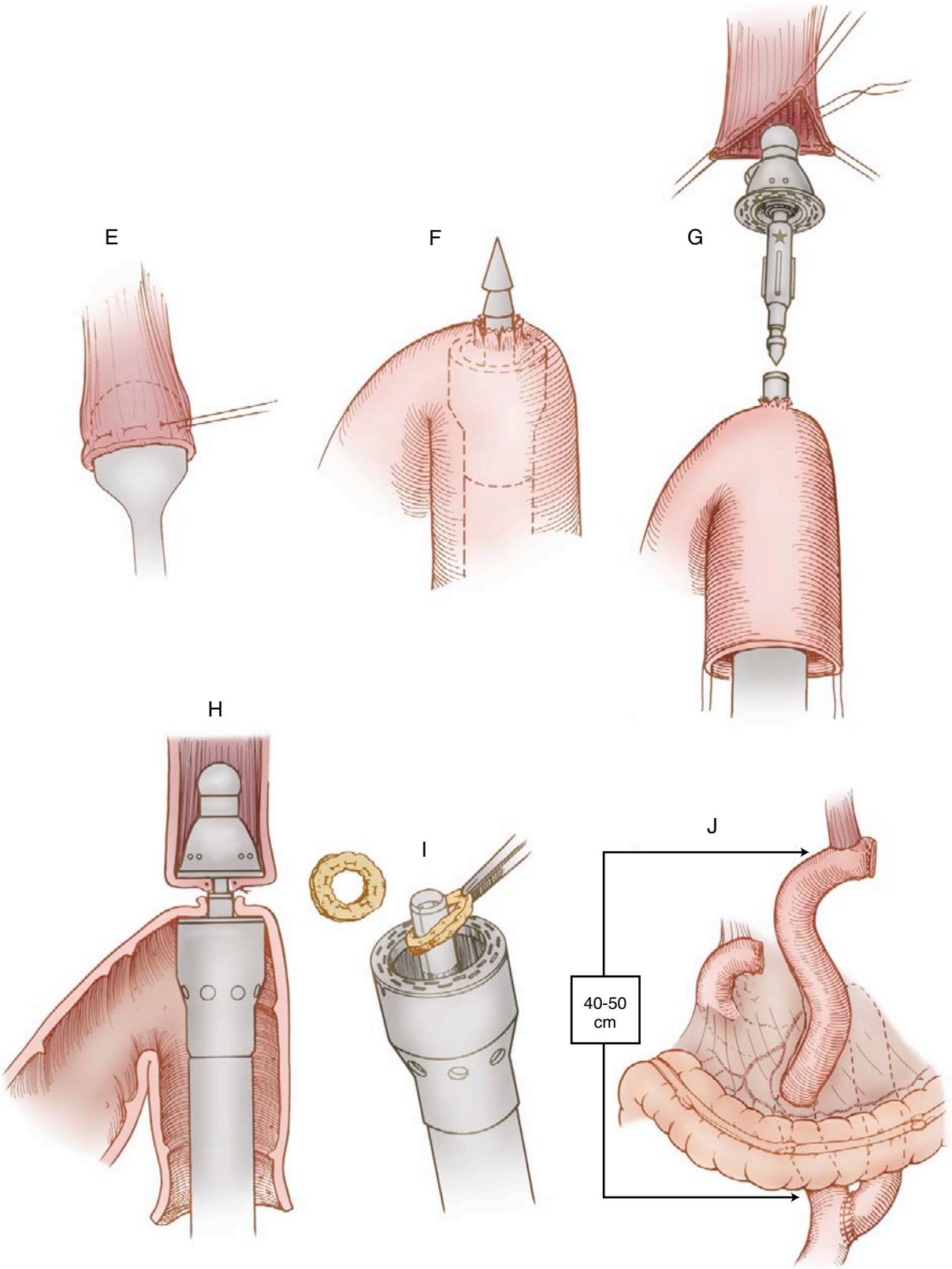


FIGURE 10-21, cont'd **E**, A sizer is inserted into the lumen of the distal esophagus. **F**, The EEA or intraluminal anastomosis (ILA) is inserted into the lumen of the jejunum to facilitate esophagojejunostomy. **G**, The anvil is inserted into the distal esophagus where purse-string sutures will be snugged around the protruding arm of the anvil. **H**, The distal esophagus and the jejunum are united by the mechanism of the stapling device, and the interluminal anastomosis will be performed. **I**, The "donuts," distal esophagus and jejunal tissues, are examined for integrity and completeness. **J**, Illustration of the esophagojejunostomy completed.

BARIATRIC SURGERY

Bariatric surgery, also termed *weight loss or weight reduction surgery,* is surgical treatment of obesity (History box). Morbid obesity is a disease affecting more than 20 million people in the United States. Morbid obesity (also referred to as clinically severe obesity or extreme obesity) is defined as a body mass index (BMI) of 40 kg/m^2 or more, the equivalent of about 45 kg (100 lb) over ideal body weight (AORN, 2009d) (Box 10-7). Obese patients typically present with serious co-existing health conditions, such as diabetes, cardiopulmonary disease, obstructive sleep apnea (OSA), gallstone disease, hypertension, hyperlipidemia, respiratory problems, or joint disease.

Eligibility criteria for patients seeking bariatric surgery include morbid obesity complicated by medical conditions secondary to obesity, history of failed dietary therapy, psychologic stability and motivation, acceptable operative risks, and a patient who is well-informed about the procedure, recovery, and postsurgical lifestyle modifications.

Contraindications are not easily generalized because morbidly obese patients are typically at greater risk for surgery. Patients at greatest risk are those with end-stage heart and lung function, inability to ambulate, weight more than 272 kg (600 lb), age younger than late teens or older than 65 years, and presence of Prader-Willi syndrome (SGNA, 2004).

There are three categories of bariatric procedures: restrictive, malabsorptive, or a combination of both. Restrictive procedures reduce the size of the stomach. When the patient eats, food is digested and absorbed normally, but the smaller capacity of the stomach gives the feeling of fullness, and the patient eats less. In malabsorptive procedures, surgery reduces the absorptive capacity of the small intestine with a bypass of a segment or segments of the proximal small bowel.

Adjustable gastric banding is a restrictive procedure. Adjustable band surgery uses a silicone strip and elastic ring called the adjustable *LAP-BAND* (INAMED Health). The band is placed laparoscopically around the top of the stomach. A fold of stomach is sutured around the band to secure it in place (Figure 10-22). The band has a port that is inflated with saline 4 weeks postoperatively. The constriction created by the inflated band restricts the amount of ingested food that can enter the stomach, preventing overeating. This procedure is adjustable and reversible (laparoscopic adjustable gastric banding, or LAGB) (Research Highlight).

HISTORY

Bariatric Surgery

Year	Breakthrough
1950s	J. Kremen, MD, performs jejunoileal bypass. It is recognized that patients with short-bowel syndrome lose weight because of impaired absorption. Similar procedure is performed in Sweden, excising redundant portion of intestine.
1960s	Ten jejunocolic shunt procedures are reported. Shunts are eventually converted to jejunoileostomies to control diarrhea, electrolyte imbalance, and dehydration. Patients continue to experience postoperative anemia, cholelithiasis, vitamin depletion, and renal and liver disease. E. Mason, MD, performs partial gastrectomy with staples, creating a pouch anastomosed to small intestine. Early complications promote refinement of gastroplasty.
1970s	E. Mason, MD, develops vertical-banded gastroplasty (VBG). L. Wilkinson, MD, uses mesh strip for the band to reduce size of gastric reservoir. Biliopancreatic diversion is developed in Italy.
1980s	Gastric banding is refined to limit food intake. L. Kuzmak, MD, develops first adjustable gastric band and later a hollow band with inflatable ring. American Society for Bariatric Surgery (ASBS) is formed in 1983.
1990s	Laparoscopic access becomes approach of choice. Some procedures move to ambulatory surgery units.
2000s	Bariatric becomes common medical terminology. Many institutions develop interdisciplinary programs specifically for weight loss surgery. Bariatric boutique surgery centers enter surgical market. Long-term studies begin to evaluate surgery results over time. Insurance reimbursement continues to evolve as studies evaluate risks, complications, rehospitalization rates and costs. Laparoscopic-adjustable gastric band (LAGB) approved by the Food and Drug Administration. Sleeve gastrectomy evolves as primary alternative for those not candidates for other procedures. Gastric and vagal pacing developed. Endoscopically accessed interventions evolve with implanted balloon and stapling delivery devices. Bariatric surgery viewed as significant treatment and resolution for type 2 diabetes.

Modified from Association of periOperative Registered Nurses: Bariatric surgery guideline. In *Perioperative standards and recommended practices,* Denver, 2009, The Association; Ide P et al: Perioperative nursing care of the bariatric surgical patient, *AORN J* 88(1):30-54, 2008; Adams TD et al: Long term mortality after gastric bypass surgery, cardiosource 2007, *Am Coll Cardiol,* available at www.medscape.com/viewarticle/562298. Accessed June 14, 2009; Study shows potential for resolving type 2 diabetes with bariatric surgery, *Back to EurekAlert 2009,* http://eurekalert.org/pub_releases/2009-03/ehs-ssp022709.php. Accessed June 14, 2009.

BOX 10-7

Calculating a Patient's Body Mass Index

Obesity is defined in terms of body mass index (BMI), which is a measure of the weight-to-height ratio to gauge total body fat. BMI is expressed as kilograms per square meter and calculated by the following formula: BMI = (weight in pounds ÷ height in inches^2) × 703. Obesity levels are characterized as follows:

- Obese: BMI of 30-39.9 kg/m^2
- Extremely (also referred to as "morbidly") obese: BMI of 40-49 kg/m^2
- Super obese: BMI greater than 50 kg/m^2

Modified from Association of periOperative Registered Nurses: Bariatric surgery guideline. In *Perioperative standards and recommended practices,* Denver, 2009, The Association; Pelczarski KM: Take a proactive approach to bariatric patient needs, *Mater Manag Health Care* 16(6), 2007, available at www.ecri.org/Documents/News/20070601_MaterialsManagementinHealthCare_Bariatric.pdf.

RESEARCH HIGHLIGHT

Bariatric Surgery Outcomes

In this study, researchers from the Department of Health and Human Services' Agency for Healthcare Research and Quality (AHRQ) reviewed insurance claims for 9582 bariatric surgeries at 652 hospitals to determine how 6-month complication rates after bariatric surgery improved between 2001 and 2006. The 6-month complication rate for bariatric surgery in 2001 was 40%. However, surgical advances, including laparoscopic approaches, contributed to a 21% drop in complication rates for bariatric surgery by 2006. Readmissions with complications declined 31%, and surgical infection rates dropped 58%. Improvements in complication rates and readmission rates were associated with increases in surgical volume (within-hospital volume), which accounted for more surgical experience in performing bariatric procedures. Interestingly, the use of laparoscopy reduced costs by 12%, and gastric banding decreased costs by 20%. Although laparoscopy had no impact on readmissions, gastric banding did reduce readmissions.

Modified from Encinosa WE et al: Recent improvements in bariatric surgery outcomes, *Med Care* 47:531-535, 2009.

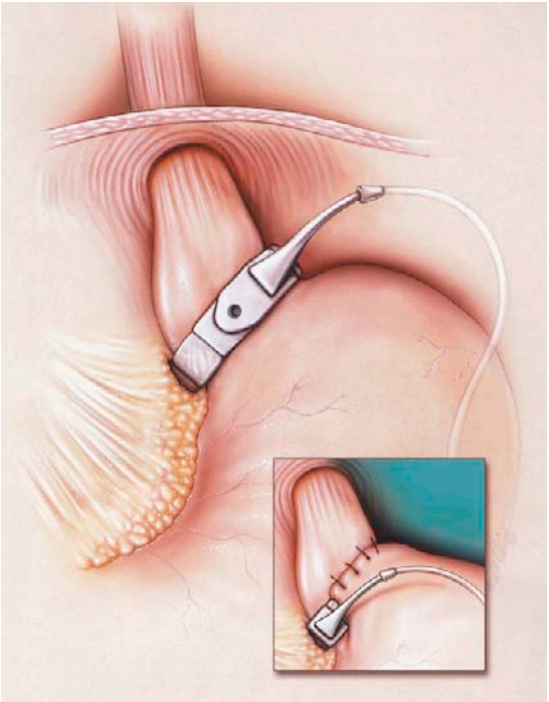


FIGURE 10-22 Proper position of the LAP-BAND. The silicone band around the fundus of the stomach creates a small gastric pouch. The inner lining of the band contains an inflatable balloon that is connected to a subcutaneous port on the patient's abdomen (not shown). The band can be inflated or deflated, adjusting the stomach size as needed.

Bariatric procedures have been shown to improve long-term health, including reducing the risks of cardiovascular disease and type 2 diabetes (Adams et al, 2007; Beauchamp-Johnson, 2007; Hager, 2007).

Laparoscopic Roux-en-Y Gastric Bypass

Roux-en-Y gastric bypass (RYGB) is a largely restrictive and mildly malabsorptive procedure that reroutes the passage of ingested food and fluid from a small pouch created with surgical staples or sutures in the proximal stomach to a segment of the proximal small bowel. The jejunum or ileum is used as described under Gastrojejunosotomy. Laparoscopic RYGB is commonly performed in the United States. Postoperatively, changes in lifestyle are required for fully successful weight loss (Chambers, 2009).

Procedural Considerations. All patients undergoing bariatric surgery need special consideration, because they usually have associated serious co-morbidities that place them at risk during the procedure. A special OR bed is required that can accommodate patients who weigh more than 350 lb (159 kg). In addition to laparoscopic instrumentation and accessory supplies, extralarge blood pressure cuffs and extra-long trocars are required. Positioning requires additional padded safety restraints, pressure-reduction devices to reduce the risk of pressure injury, and properly fitting SCDs. The perioperative nurse should anticipate the potential for anesthesia assistance during intubation and airway management.

Operative Procedure

1. Five trocars are placed above the umbilicus: two on the midline, two in the left upper quadrant, and one in the right upper quadrant; an incision is made for the liver retractor (Figure 10-23).
2. The omentum is mobilized and the ligament of Treitz identified.
3. The jejunum is divided 40 cm distal to the ligament of Treitz with a vascular stapler (Figure 10-24). The proximal jejunum is left to lie in the patient's right side and the Roux limb lifted superiorly and passed through the transverse colon mesentery (Figure 10-25).
4. A gastric pouch is created with several loads of a linear stapler.
5. The Roux limb is anastomosed to the proximal gastric pouch. Methylene blue is used to check for leaks. The gastrojejunostomy may be accomplished with either traditional suturing technique or a circular EEA stapler.
6. Mesenteric defects are closed, the abdomen is inspected, and the port sites are closed.

With RYGB, a critical segment of the calorie- and nutrition-absorbing mucosal surface is avoided. The gastric pouch is generally less than 30 ml in volume. This procedure results in considerable weight loss for the patient. Serious complications may include hemorrhage, anastomotic leaks, pulmonary embolism, pneumonia, infection, small bowel obstructions or stenosis, and incisional hernia. Nutritional deficits, nausea, flatus, diarrhea, and dumping syndrome are other common complications.

Biliopancreatic diversion (Figure 10-26) and duodenal switch (Figure 10-27) procedures are largely malabsorptive and mildly restrictive. In both procedures, both the Roux limb and the biliopancreatic limb are long in length, leaving a shortened common channel where digestion and absorption of proteins, fats, and carbohydrates can occur. These procedures present more risk of complications, nutritional deficiencies, liver abnormalities, anemia, and lactose intolerance.

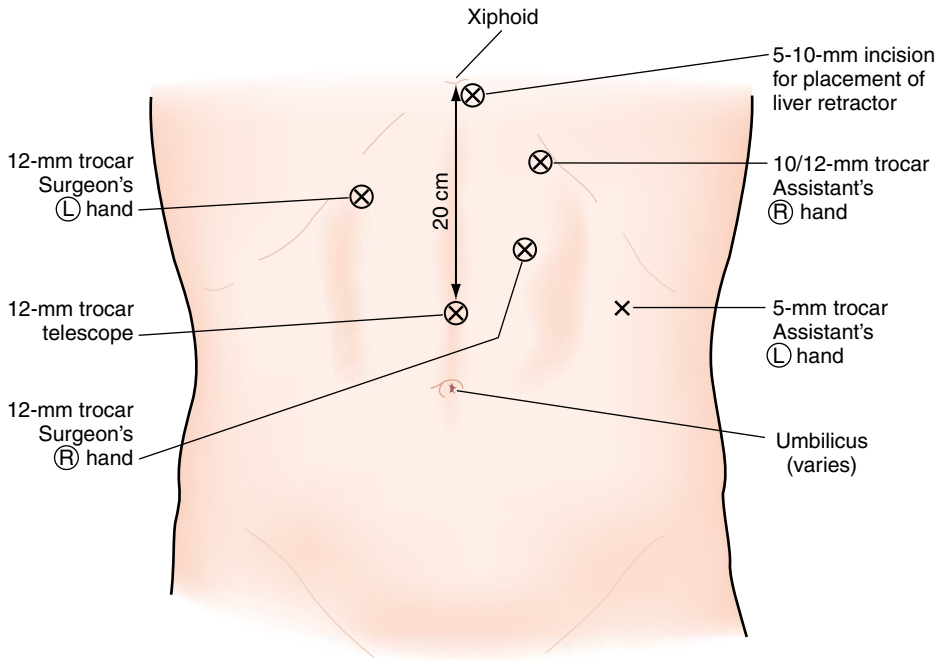


FIGURE 10-23 Trocar configuration for laparoscopic Roux-en-Y gastric bypass.

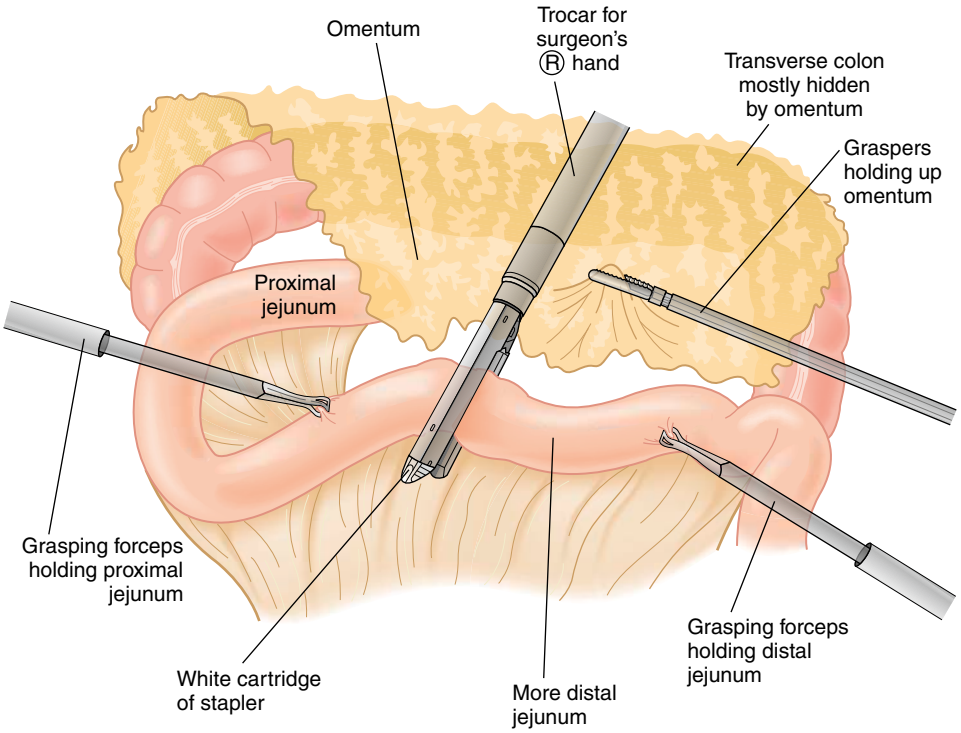


FIGURE 10-24 Placing stapler to divide jejunum to create Roux limb.

SURGERY OF THE SMALL BOWEL

Meckel's Diverticulectomy

Meckel's diverticulum is removed to prevent inflammation and obstruction from intussusception of the diverticulum, which consists of an unobliterated congenital duct at the umbilicus that is attached to the distal ileum. The diverticulum may contain gastric mucosa, which can ulcerate, perforate, or bleed.

Procedural Considerations. Laparotomy and GI sets are required. Linear stapling devices should be available. The patient is positioned supine after induction of general anesthesia. The

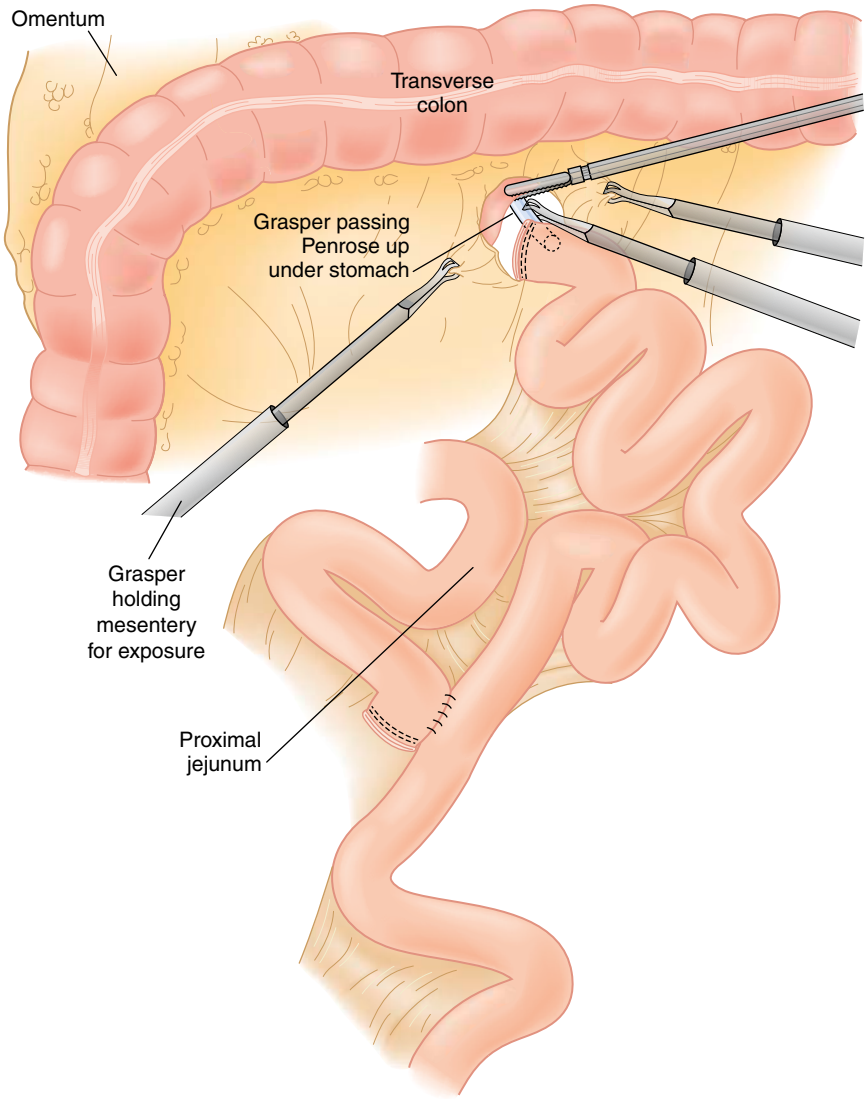


FIGURE 10-25 Passing the Roux limb into a retrocolic and retrogastric position.

anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter is inserted before the abdominal skin prep.

Operative Procedure

1. The abdomen is opened through a midline incision or laparoscopically accessed, and the diverticulum is identified.
2. If the diverticulum is long and narrow with a narrow base, the procedure is similar to that of an appendectomy (see the following discussion). If the base is broad, the loop of bowel containing the diverticulum is isolated from the mesentery and a limited small bowel resection is performed.
3. An anastomosis of the divided ends is completed with an inner continuous layer of 3-0 synthetic absorbable suture and an interrupted outer layer of 4-0 nonabsorbable sutures.
4. The abdominal wound is closed.

Appendectomy (Open Approach)

Appendectomy is severance and removal of the appendix from its attachment to the cecum through a right lower quadrant muscle-splitting incision (McBurney). This procedure is performed to remove an acutely inflamed appendix, thereby controlling the spread of infection and reducing the danger of peritonitis (Research Highlight).

Procedural Considerations. A basic laparotomy instrument set is used. The patient is positioned supine after induction of general anesthesia. Culture tubes should be available.

Operative Procedure

1. A right lower quadrant muscle-splitting (McBurney) incision is usually made.
2. Muscles are retracted with Richardson or Parker retractors to expose the peritoneum.
3. The peritoneum is grasped with tissue forceps or Allis forceps, and a small incision is made with a #15 blade.
4. A culture sample is taken.
5. The incision is completed with Metzenbaum scissors.
6. The mesoappendix is grasped near the tip with Babcock forceps or a hemostat for gentle traction.
7. The mesoappendix is dissected from the appendiceal wall and ligated with 3-0 nonabsorbable suture. If a suture

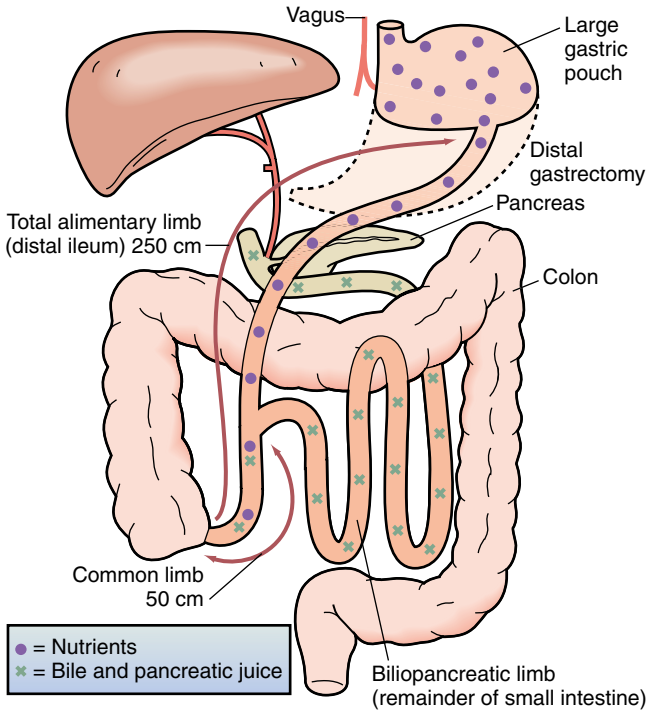


FIGURE 10-26 Configuration of the biliopancreatic diversion (BPD), which is transection of the stomach with anastomosis of the duodenum to the distal ileum. In this malabsorptive procedure, the pancreatic enzymes and bile enter near the ileum, allowing nutrients to pass from the stomach to the distal ileum without being digested. Weight loss occurs because of the partial gastrectomy, which restricts intake, and because of the shortened alimentary canal, which causes malabsorption.

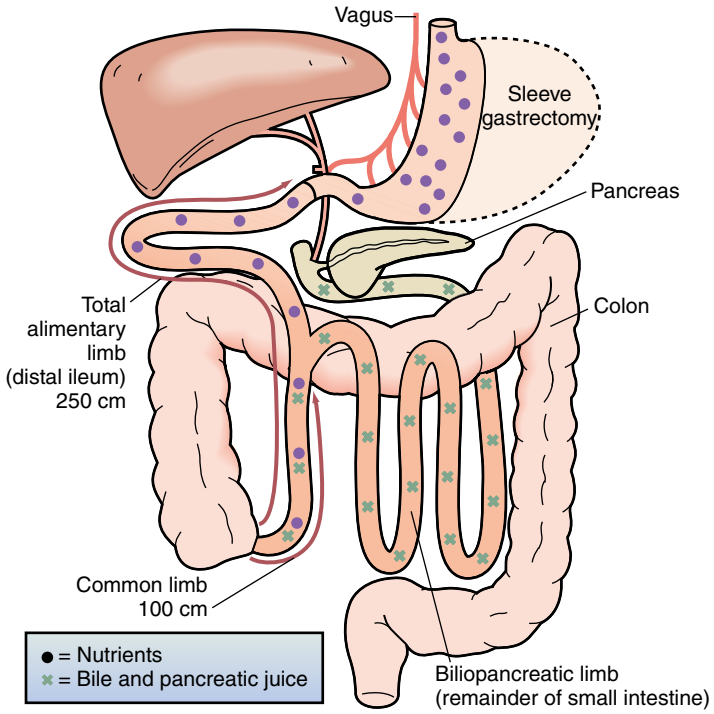


FIGURE 10-27 Configuration of the duodenal switch, which leaves a larger portion of the stomach intact, including the pyloric valve. This helps in alleviating dumping syndrome.

RESEARCH HIGHLIGHT

Antibiotic Therapy versus Appendectomy as Primary Treatment of Acute Appendicitis

Standard treatment for acute appendicitis is appendectomy to avoid perforation. However, appendectomy is associated with postoperative risks, such as small bowel obstruction. Because of such risks, there has been increased interest in antibiotic therapy as primary treatment. This study investigated the feasibility of antibiotic therapy as a first-line treatment for acute appendicitis by assigning patients (N = 369) to antibiotic treatment (n = 202) or surgery (n = 167).

Treatment efficacy was 90.8% for the antibiotic therapy group and 89.2% for the surgery group. Appendicitis recurred in 13.9% of the antibiotic group after a median of 1 year with one third of recurrences within 10 days after discharge. Eleven of the antibiotic group required an appendectomy because of clinical progression within 24 to 36 hours. Although minor complications were similar between groups, major complications were threefold higher in surgery patients.

The researchers concluded that antibiotic treatment appears to be a safe first-line therapy in patients with acute appendicitis.

Modified from Hansson J et al: Randomized clinical trial of antibiotic therapy versus appendectomy as primary treatment of acute appendicitis in unselected patients, *Br J Surg* 96:473-481, 2009.

ligature is required, 2-0 synthetic absorbable suture on an atraumatic GI needle is preferred.

8. The appendix is elevated as a purse-string suture of 2-0 synthetic absorbable suture is placed in the cecal wall at the appendiceal base.
9. The base of the appendix is crushed with a straight hemostat, a 3-0 synthetic absorbable suture tie placed over the crushed area, and a hemostat placed above the ligature.
10. A basin is provided for the specimen and instruments that contact the GI mucosa (bowel technique).
11. Protective gauze sponges are placed over the cecum around the base of the appendix.
12. The appendix is amputated with a scalpel. The stump is often swabbed with alcohol or povidone-iodine (Betadine) solution to reduce bacterial flora.
13. The appendiceal stump is usually inverted into the lumen of the cecum as the purse-string suture is tightened and tied by means of a fine straight hemostat and a small sponge on a holder. Soiled instruments are discarded into the basin.
14. If the appendix has ruptured, copious amounts of warm fluids are used to irrigate the peritoneal cavity. A drain may be inserted in the appendiceal bed to allow continuous drainage. Deeper layers are closed; the subcutaneous tissue and skin may be left open. The wound is then packed with moist fine-mesh gauze to heal by secondary intention. (This method may be used in any case in which bowel contamination or abscess formation is present. It allows clean healing and prevents pocketing of pus.)

Laparoscopic Appendectomy

The laparoscopic approach to appendectomy may be used for uncomplicated appendicitis. In the presence of perforation, conversion to an open procedure may be necessary.

Procedural Considerations. The procedure involves the placement of three trocars with standard laparoscopic instrumentation, equipment, and supplies available. The patient is positioned supine after induction of general anesthesia. An indwelling urinary catheter may be placed before the abdominal skin prep.

Operative Procedure

1. Pneumoperitoneum is obtained by a Veress needle or through the periumbilical trocar.
2. An 11-mm or 12-mm trocar is placed in the umbilicus for insertion of the laparoscope.
3. An 11-mm or 12-mm trocar is placed in the right upper quadrant (RUQ) to serve as the working port.
4. A 5-mm trocar placed in the midline suprapubic site serves as the traction trocar.
5. A laparoscopic Babcock forceps is inserted into the RUQ trocar to grasp the cecum and retract it toward the liver.
6. The appendix is grasped at its tip by a grasping forceps that has been inserted through the suprapubic trocar and is held in an upward position.
7. The Babcock forceps is removed, and a dissecting instrument is inserted through the RUQ trocar to create a mesenteric window in the mesoappendix.
8. Dissection is performed in proximity to the appendix, beginning directly under the base and progressing to a 1-cm to 2-cm length.
9. Depending on surgeon preference, the appendix may be transected in several different ways: (a) with an endoscopic linear stapling instrument, (b) with a ligating loop instrument, or (c) with a suturing instrument.
10. If an endoscopic linear stapling instrument is used, the lower jaw of the stapling device is passed through the mesenteric window previously created by way of the RUQ trocar.
11. The grasping forceps are used to rotate the tip of the appendix so that the stapling device can be snugged to the base of the appendix and closed.
12. The stapling instrument is fired and withdrawn, and the staple line is inspected.
13. The remainder of the mesoappendix is dissected, hemostasis achieved, and the appendix removed through the RUQ port.
14. If the appendix is too thick, a specimen pouch may be necessary for its extraction.
15. The abdomen is irrigated, irrigation fluid is aspirated with a suction and irrigation device, and the abdomen is deflated.
16. Trocar sites are closed and dressed or closed with skin-bonding sealer.

Resection of the Small Intestine

Resection of the small intestine involves excision of diseased intestine through an abdominal incision followed by reanastomosis. It is performed to remove tumors, a gangrenous portion of intestine caused by strangulation from bands of adhesions, intestinal obstruction, areas of ulceration and bleeding as in Crohn's disease, herniation of the intestine, or volvulus.

Procedural Considerations. Laparotomy and GI sets are required. Linear stapling instruments should be available. The patient is positioned supine after induction of general anesthesia. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter is inserted before the abdominal skin prep. The procedure may be performed laparoscopically.

Operative Procedure

1. The abdominal wall is incised through a midline incision and retracted.
2. The peritoneal cavity is explored and protected with moist, warm saline packs.
3. Intestinal clamps are placed above and below the diseased segment of small bowel and mesentery.
4. The involved area is removed with a linear stapling instrument such as a GIA, an electrosurgical blade, or a scalpel.
5. Continuity of the GI tract is established by an end-to-end, end-to-side, or side-to-side anastomosis.
6. The wound is closed and dressed.

An alternative approach to suture anastomosis is use of a mechanical stapling device to perform an end-to-end, end-to-side, or side-to-side anastomosis. An enterotomy is made close to the anastomosis site. The stapler is inserted, and the distal bowel secured between the anvil and the head of the stapler. The anvil is then inserted into the proximal loop of bowel and secured to the center rod. The gap is closed, and the stapler fired. The stapler is removed through the enterotomy. The integrity of the anastomosis is verified, and the enterotomy closed with sutures.

Ileostomy

Ileostomy is formation of a temporary or permanent opening into the ileum. This procedure is indicated in the presence of an extensive lesion to reduce large bowel activity, often called *bowel rest,* by creating a temporary fecal diversion to the outside of the body, or as permanent fecal diversion in total colectomy. The patient is site-marked before surgery and anesthesia by the WOCN (see Box 10-1).

Procedural Considerations. Laparotomy and GI sets along with linear stapling instruments are required. The patient is positioned supine after induction of general anesthesia. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter is inserted before the abdominal skin prep. An ostomy appliance for the stoma is available.

Operative Procedure

1. Through a midline incision, the peritoneal cavity is explored and the pathologic condition determined.
2. The ileum is mobilized with Metzenbaum scissors and hemostatic clamps.
3. The mesentery is clamped, divided, and ligated with 3-0 nonabsorbable sutures at the proposed site, usually about 15 cm from the ileocecal junction.
4. Two intestinal clamps are placed on the bowel, and the ileum is divided with a scalpel or linear stapling instrument (GIA) between the two clamps.
5. The distal end of the ileum is closed with 2-0 synthetic absorbable suture on a taper needle if a stapling device has not been used.
6. The proximal end is relocated to the skin through an opening on the right side and is held in place by clamps, making sure that the ileum is not overstretched or its blood supply compromised.

7. The mesentery of the ileum is sutured to the parietal wall to eliminate a potential internal hernia.
8. The abdomen is closed.
9. The stoma is sutured to the skin after the ileum is everted to form a protective cover over the exposed ileal serosa.
10. A disposable ostomy appliance is placed over the stoma to collect small bowel contents.

An alternative to conventional ileostomy for selected patients is the Kock pouch, or continent ileostomy. The internal pouch is created from a segment of small intestine with an outlet to the skin. When functioning properly, the stoma and pouch are continent and do not continually drain stool. A catheter is inserted into the stoma three or four times daily to evacuate the contents, eliminating the need for an external appliance.

Intestinal Transplantation

Small bowel transplantation may be indicated for patients with intestinal failure caused by short-gut syndrome as a result of extensive resections necessitated by Crohn's disease, necrotizing enterocolitis, mesenteric thrombosis, atresias, volvulus, trauma, dysmotility, or congenital enteropathy (Shortridge et al, 2004). Intestinal failure leads to malabsorption and malnutrition, preventing the bowel from meeting the body's nutrient and fluid requirements. Approximately 10 to 20 cm of small intestine with an ileocecal valve, or 40 cm without an ileocecal valve, is minimally required to maintain nutritional status. Patients with short-gut syndrome require TPN to sustain life. A critical indication for intestinal transplant arises when patients can no longer receive TPN because of clotting of major veins, frequent IV line sepsis, episodes of dehydration despite TPN and IV fluids, and TPN-induced liver failure (Markmann et al, 2008). Intestinal transplantation may also include the liver in the presence of impending progressive end-stage liver disease. The perioperative time frame, beginning with immunosuppression, surgery, transition from parenteral to enteral feedings, and the long recovery process, may be 6 months and poses many physical and emotional challenges to the patient and family. Despite these challenges, refinements in surgical technique and patient selection and advances in immunosuppression protocols have contributed to significant improvements in patient survival rates.

Procedural Considerations. The transplant surgeon does the final visual inspection and assessment of the donor organ. The allowable cold ischemic time of the donor intestine (allograft intestine) is approximately 12 hours. The patient is positioned supine and anesthetized with general endotracheal anesthesia. Arterial and multiple venous lines are inserted. An NG tube, urinary catheter, and physiologic monitoring are indicated.

Operative Procedure

1. The incision is made along previous incision lines, or a vertical midline approach is used.
2. The superior mesenteric artery of the donor organ is anastomosed to the recipient's infrarenal aorta.
3. Venous drainage of the donor organ is established by connecting the donor superior mesenteric vein to the recipient portal vein if the patient has no liver disease or signs of portal hypertension.
4. Reperfusion begins with release of venous flow when the clamps are opened.
5. Bleeding sites are identified and ligated or coagulated.
6. The arterial clamp is released.
7. Continuity of the intestine is restored after vascular supply is established.
8. Proximal anastomosis joins the donor jejunum to the recipient stomach, duodenum, or proximal jejunum.
9. The distal ileum is anastomosed side-to-side with the remaining colon.
10. A distal loop ileostomy is created for later endoscopic evaluation and intestinal biopsies.
11. The intact intestine is inspected, hemostasis verified, and the abdomen closed.

SURGERY OF THE COLON

Laparoscopic Colectomy

Resection of a segment of bowel and reanastomosis can be accomplished laparoscopically. Advantages of laparoscopic colectomy include reduction of morbidity associated with open techniques (e.g., postoperative ileus), less postoperative pain, faster return to normal activities, shorter length of stay, and improved cosmesis (Evidence for Practice). Laparoscopic colectomy is indicated for obstruction and benign tumors of the large bowel.

Procedural Considerations. Depending on the intended segment of bowel to be resected, the patient is initially positioned supine or in modified lithotomy for access to the rectum for end-to-end anastomosis. The surgeon may stand on the patient's left or between the patient's legs (modified lithotomy). SCDs are applied to minimize the risk of DVT. The patient is

EVIDENCE FOR PRACTICE

Laparoscopic versus Open Colectomy

Laparoscopic-assisted colectomy is a safe alternative to traditional open colectomy. Recent research comparing open laparotomy for colectomy with laparoscopic-assisted colectomy reveals better outcomes for the laparoscopic approach for both benign and malignant disease of the colon. The laparoscopic approach has also been shown to be equivalent to open colectomy in cancer-related survival for curable cancer. A large prospective, randomized, multi-institution trial compared laparoscopic-assisted to open colectomy for colon cancer. It involved 863 patients, 66 surgeons, and 48 institutions. The primary endpoint was time-to-tumor recurrence; the secondary endpoints were disease-free and overall survival, minimal complications, and increased quality of life. At the median follow-up of 4.5 years, there was no significant difference in oncologic outcome between the two groups. A higher 5-year survival rate for patients with the laparoscopic approach was shown in a retrospective cohort study of 11,038 patients compared with 231,381 patients who had the open approach for nonmetastatic colon cancer between 1998 and 2002. Laparoscopic-assisted colectomy is a technically demanding procedure with a significant learning curve for the surgeon; the advantages for the patient, however, make this approach the treatment of choice.

From Clinical Outcomes of Surgical Therapy Study Group (COST Trial): *NEJM* 350(20):2050-2059, 2004; Hageman D et al: Laparoscopic-assisted colon surgery, *AORN J* 88:403-416, 2008; Bilimoria KY et al: Use and outcomes of laparoscopic-assisted colectomy for cancer in the United States, *Arch Surg* 143(9):832-840, 2008.

secured with restraining straps to support and maintain position during steep position changes. A beanbag device may be used. An NG tube and urinary catheter are inserted before the abdominal skin prep. Laparotomy instrumentation, mechanical stapling devices, and endostapling devices are required. To assist the surgeon in accurately identifying the segment of bowel to be resected, a colonoscope may be used preoperatively or during the laparoscopic procedure to tattoo the lesion with india ink. Right hemicolectomy, described below, is performed to treat disease of the cecum, ascending colon, or hepatic flexure. Extended right hemicolectomy is done to treat tumors located in the transverse colon, particularly those located to the right of the midline (Sonoda and Milsom, 2007).

Operative Procedure (Right Hemicolectomy)

1. Pneumoperitoneum is established at 10 to 12 mm Hg, and the 10-mm umbilical trocar is placed after a supraumbilical cutdown. Alternatively, a 12-mm Hasson trocar may be inserted through the rectus muscle and into the abdominal cavity by way of a small incision in the left upper quadrant, 3 to 4 cm below the costal margin.
2. Additional ports (usually 5 mm) are placed in locations dependent on the anatomic segment of colon to be resected.
3. After the patient is moved into Trendelenburg's position, with right side tilted up, dissecting scissors and a grasper are inserted. The peritoneum along the cecum is incised as are the appendiceal and terminal ileal attachments. The bowel is then bluntly dissected from the retroperitoneum, the ureter identified, and the colon mobilized as necessary for resection of the diseased segment. A mesenteric window is created, and the mesenteric artery and vein and right colic vessels are identified and clipped.
4. A multifire endoscopic linear stapling device (GIA) is positioned over the segment of bowel and fired to both transect and staple the segment.
5. Unless an end-to-end anastomosis can be performed, as in a low sigmoid or rectal resection, a small incision is made over the area of the abdomen that will provide access to the segments for anastomosis.
6. The segment of bowel to be resected is grasped, transferred through the small incision, and transected, and anastomosis is performed in the surgeon's preferred manner (with staples or with sutures).
7. The anastomosed bowel is returned to the peritoneal cavity, and the cavity is irrigated and inspected for hemostasis and drained by suction. The cannulae are removed, port sites closed, and skin closed with subcuticular absorbable suture. Skin tapes (Steri-Strips) are applied.

Colostomy

Colostomy is mobilization of a loop of colon through a right rectus incision to expose the transverse colon. A left rectus incision can also be made to expose the descending sigmoid colon. The layers of the wound beneath or around the colostomy are subsequently closed. Colostomy is performed to treat obstruction in the sigmoid colon resulting from a malignant lesion or advanced inflammation or trauma that has caused distention or obstruction of the proximal portion of the colon. A temporary colostomy is often done to decompress the bowel or to divert bowel contents to promote healing (bowel rest) (Figure 10-28).

Procedural Considerations. Laparotomy and GI sets are required. Linear stapling instruments may be used. Stoma appliances are required. These items may include a colostomy rod, rubber tubing, or a loop ostomy bridge. The patient is site-marked by the WOCN before surgery. The patient is positioned supine after induction of general anesthesia. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter is inserted before the abdominal skin prep.

Operative Procedure

FIRST-STAGE LOOP COLOSTOMY

1. The abdomen is opened, and the wound edges are protected and retracted.
2. The peritoneal cavity is opened and walled off with moist laparotomy packs, and appropriate retractors are inserted.
3. A small opening is made in the mesentery near the bowel with curved hemostats and Metzenbaum scissors.
4. A piece of tubing or Penrose drain is passed around the colon, and the two ends are held with a hemostat to maintain gentle traction.
5. The loop of colon is moved through an incision made on the left side of the midline. The abdominal incision is closed.
6. A loop ostomy bridge is used to support and retain the loop of colon in position on the abdominal wall.
7. The loop of intestine is dressed with petrolatum gauze.

SECOND-STAGE LOOP COLOSTOMY. After 48 hours the loop of colon is completely opened with the blade tip of an electrosurgical pencil. By this time, if there is no tension, healing has advanced sufficiently to allow protection from feces contamination onto the wound. This procedure is simple and painless and is usually performed in the patient's room or in a treatment room. An ostomy appliance is applied.

TRANSVERSE COLOSTOMY

1. A short transverse or vertical incision is made to reach the transverse colon.
2. A loop of transverse colon, freed of omentum, is withdrawn (Figure 10-29).
3. A loop ostomy bridge is passed through an avascular area of the mesocolon, preventing the loop from returning to the peritoneal cavity.
4. A mushroom catheter, held in place with a purse-string suture, results in immediate decompression.

The bowel is opened 24 to 36 hours later, and the bridge is removed in about 7 to 10 days.

Closure of a Colostomy

Closure of a colostomy reestablishes internal intestinal continuity and repairs the abdominal wall.

Procedural Considerations. When the loop has been completely divided, a closed or open anastomosis may be performed. Laparotomy and GI sets are required. Linear stapling instruments may be used. The patient is positioned supine after induction of general anesthesia. The anesthesia provider inserts a nasogastric tube after intubation. An indwelling urinary catheter is inserted before the abdominal skin prep. Depending on location of the bowel to be reanastomosed, the patient may be placed in low lithotomy position to facilitate transanal access for a circular stapling device. An end-to-end anastomosis of the left colon or ileal pouch to the rectal stump can then be achieved.

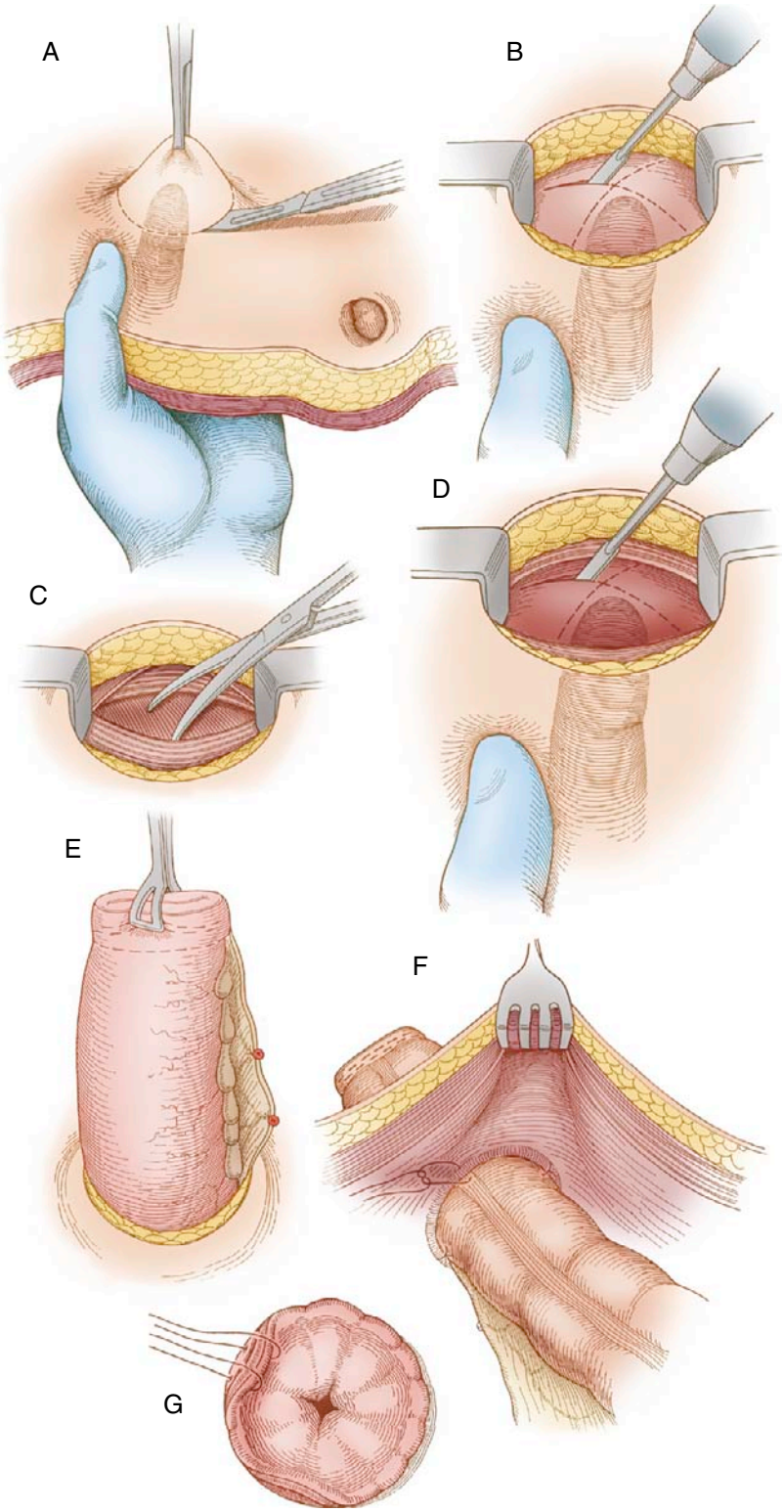


FIGURE 10-28 Construction of a colostomy through the anterior abdominal wall. **A**, A core of subcutaneous tissue is removed after making a circular skin incision with a #10 blade and using an electrosurgical pencil to dissect down to the anterior fascia. **B**, Muscle fibers are split. **C**, Tissues are dissected to the posterior layers, and, **D**, the peritoneum is opened. **E**, The colon is delivered through the abdominal wall so that it extends 2 to 3 cm beyond the skin surface. **F**, The bowel is tacked internally to the peritoneal defect. **G**, Four sutures are placed in each quadrant, incorporating the full-thickness cut end of the colon, the serosal surface approximately 1 to 2 cm below the open end of the colon, and up to the dermis. Additional sutures are used to mature the stoma, which refers to the procedure of everting the mucosa to create a stable opening through which feces can be evacuated.

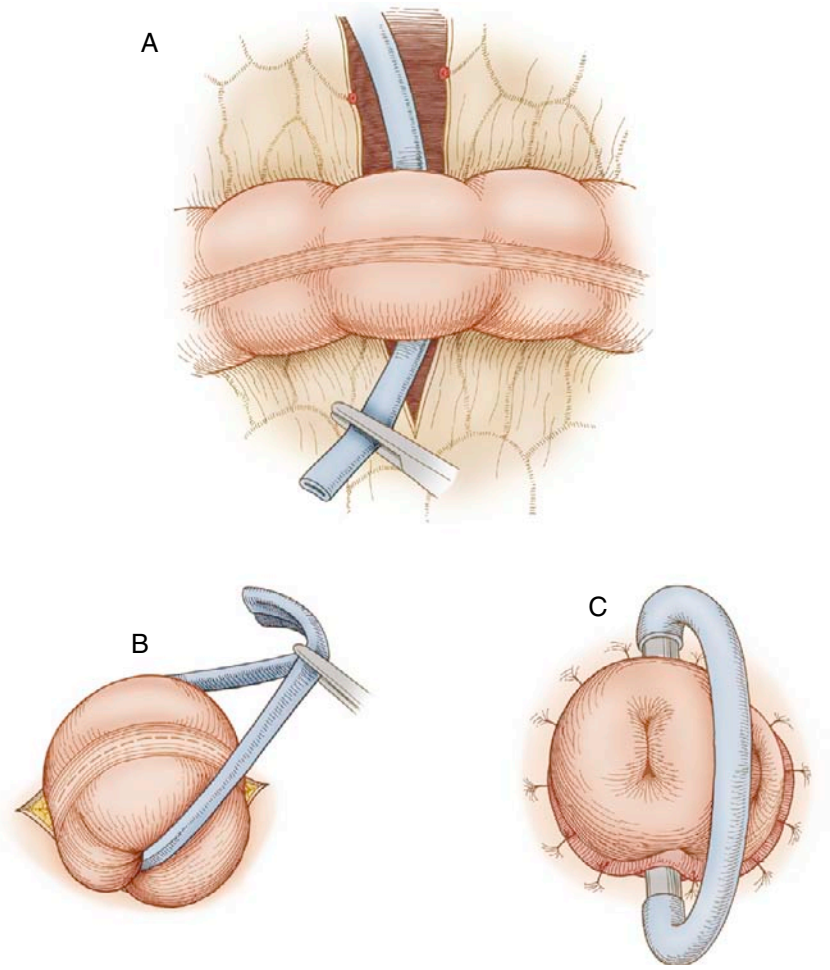


FIGURE 10-29 Transverse loop colostomy. **A**, The mesentery adjacent to the colon is taken down so that a Penrose drain may be passed beneath the colon. **B**, The colon is pulled through the transverse incision and opened longitudinally along the taeniae. **C**, An apparatus or rod is placed underneath the stoma; sutures are used to mature the colostomy. The rod can be removed after the seventh postoperative day.

Operative Procedure

1. A circumferential incision is made around the colostomy to free the skin margin.
2. Moist packs, a scalpel with #10 blade, Metzenbaum scissors, and Crile hemostats are used as layers of the abdominal wall are identified and dissected free.
3. An end-to-end anastomosis is completed in two layers—the inner with 3-0 synthetic absorbable suture and the outer with 3-0 nonabsorbable suture on an intestinal needle, using interrupted sutures. Alternatively, a surgical stapling device may be used.
4. The abdominal wound is closed in layers and a dressing applied.

The surgeon may elect to leave the subcutaneous tissue and skin open. In this instance the wound is packed and permitted to heal by secondary intention.

Right Hemicolectomy and Ileocolostomy

Right hemicolectomy and ileocolostomy involve resection of the right half of the colon—including a portion of the transverse colon, ascending colon, and cecum—and a segment of the terminal ileum and mesentery (Figure 10-30, *A*). An end-to-end, side-to-side, or end-to-side anastomosis is done between the transverse colon and ileum. A right hemicolectomy and ileocolostomy are performed to remove a malignant lesion of the right colon or, in some cases, to remove inflammatory lesions involving the ileum, cecum, or ascending colon.

Procedural Considerations. When a side-to-side anastomosis is carried out, the transected stumps of the ileum and transverse colon are closed before the anastomosis is done. A side-to-side anastomosis can also be performed by inserting the GIA stapler into both colon segments and firing the device. The stumps are then closed using a TA linear stapling device.

When an end-to-end anastomosis is performed, the layers of the transected stumps of the ileum and transverse colon are sutured together. Circular linear stapling devices, such as an EEA, may also be used for anastomosis.

Laparotomy and GI sets are required. The patient is positioned supine after induction of general anesthesia. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter is inserted before the abdominal skin prep.

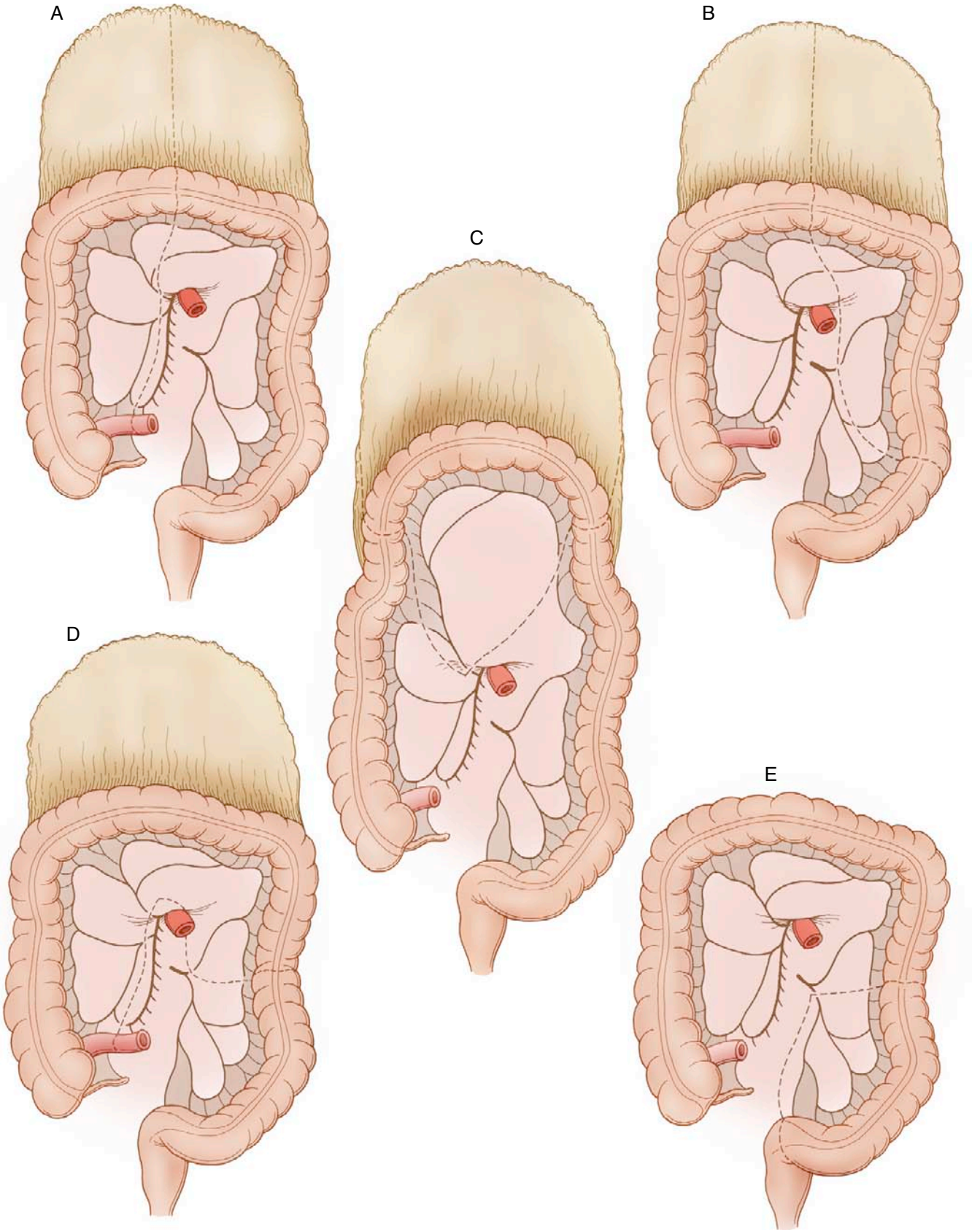


FIGURE 10-30 The resection lines for various types of colon resection. **A**, Right hemicolectomy and ileocolostomy. **B**, Left hemicolectomy. **C** and **D**, Transverse colectomy. **E**, Anterior resection of sigmoid colon and rectosigmoidostomy.

Operative Procedure

1. The abdomen is opened, and the peritoneal cavity retracted and packed with warm, moist sponges.
2. The mesentery of the transverse colon and terminal ileum is incised at the points where the resection is to be done.
3. Moist packs are placed to isolate viscera to be resected. Metzenbaum scissors, hemostats, and 3-0 nonabsorbable ligatures are used to clamp, cut, and ligate mesentery vessels.
4. The lateral peritoneal fold along the lateral side of the right colon is incised, and the right colon is mobilized medially. Metzenbaum scissors, hemostats, and sponges on holders are used.
5. The ureter and duodenum are identified.
6. The same procedure is carried out on the terminal ileum. The mesenteric vessels are clamped and ligated with 2-0 nonabsorbable ligatures.
7. The operative field is prepared for anastomosis (bowel technique).
8. Intestinal clamps are placed on the transverse colon and ileum.
9. Division is completed with a scalpel, and the specimen removed.
10. An end-to-end anastomosis is completed between the severed ends of the terminal ileum and transverse colon.
11. Instruments and supplies that have contacted bowel mucosa are discarded.
12. The mesentery and posterior peritoneum are closed with interrupted 3-0 nonabsorbable sutures.
13. The abdominal wound is closed and a dressing applied.

Transverse Colectomy

Transverse colectomy is excision of the transverse colon through an upper midline or transverse incision (Figure 10-30, *C* and *D*). Bowel integrity is reestablished by an end-to-end anastomosis. Transverse colectomy is performed to remove malignant lesions of the transverse colon. A more radical procedure may be required when the lesion has perforated the greater curvature of the stomach. If the entire lesion is resectable, a partial gastrectomy may also be performed.

Procedural Considerations. Laparotomy and GI sets are required. Linear stapling instruments and a self-retaining retractor system should be available. The patient is positioned supine after induction of general anesthesia. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter is inserted before the abdominal skin prep.

Operative Procedure

1. The abdomen is opened, and the peritoneal cavity explored to determine the pathologic area.
2. Moist packs are used to wall off surrounding structures to expose the hepatic and splenic flexures of the colon.
3. The colon is mobilized by incising the lateral peritoneum on either side and transecting the transverse mesocolon. Hemostats, Metzenbaum scissors, and 3-0 nonabsorbable ligatures are used.
4. The operative field is prepared for resection by placing towels or laparotomy sponges around the colon to isolate any contamination from the lumen of the bowel.
5. Two intestinal resection clamps are applied.
6. Transection is completed with a scalpel or mechanical linear stapling device.
7. An end-to-end or side-to-side anastomosis is completed.
8. Contaminated articles are isolated (bowel technique).
9. Approximation of mesentery and lateral peritoneum is completed with 3-0 nonabsorbable sutures.
10. The abdominal wound is closed. Retention sutures may be used.
11. The wound is dressed.

Anterior Resection of the Sigmoid Colon and Rectosigmoidostomy

Anterior resection of the sigmoid colon and rectosigmoidostomy involve removal of the lower sigmoid and rectosigmoid portions of the rectum (Figure 10-30, *E*). This is usually done through a laparotomy incision, and an end-to-end anastomosis is completed. This procedure treats lesions in the lower portion of the sigmoid and rectum that can be excised with a wide margin of safety and still retain sufficient tissues with adequate blood supply for a viable rectosigmoid end-to-end anastomosis.

Procedural Considerations. Laparotomy and GI sets are required. Linear stapling instruments as well as the end-to-end curved mechanical stapling instruments (EEA) are used. Long instruments for dissecting into the pelvis may be necessary. A rigid sigmoidoscope is used before patient preparation and after anastomosis. A self-retaining retractor set is required. After induction of general anesthesia, the patient is placed in a modified lithotomy position with legs extended in stirrups. An indwelling urinary catheter is inserted before the abdominal and perineal preps.

If there is an assisting surgeon, a table with a basic minor set and rectal instruments should be available to facilitate end-to-end stapling of the anastomosis. Cross-contamination from the table of instruments used on the patient's rectum to the table with the laparotomy instruments is prevented. A table with laparotomy closure instruments may be the surgeon's preference. In this case, only laparotomy instruments are required.

Identification of the ureters during extensive deep abdominal procedures is achieved by preoperative placement of ureteral catheters by a transurethral approach. If the tumor is believed to involve the ureters, a urologist will place ureteral stents cystoscopically before the abdominal prep begins.

Operative Procedure

1. The abdomen is entered through a laparotomy incision.
2. The peritoneal cavity is explored for metastasis and resectability of the lesion.
3. Before the colon is mobilized, the tumor-bearing segment is isolated by ligatures to the lymphovenous drainage, provided that these structures are accessible.
4. A loop of sigmoid colon is elevated as the small intestines are walled off with moist packs; retractors are placed.
5. The peritoneum on the left side of the colon is incised with a long scalpel, scissors, hemostats, and sponge forceps.
6. Traction sutures (2-0 nonabsorbable) may be used as the peritoneum is reflected.
7. Bleeding vessels are ligated with 2-0 or 3-0 nonabsorbable ligatures.
8. The pelvic peritoneum is exposed and dissected free to form the left side of the reconstructed pelvic floor. Long dissecting instruments are used.

9. Vessels are ligated with 30-inch nonabsorbable ligatures.
10. Extreme care is exercised throughout to protect the ureters from injury.
11. The sigmoid colon is turned leftward; incision and dissection of the peritoneum are then performed on the right side of the pelvis.
12. The two incisions are then curved and joined in front of the rectum.
13. The rectum is freed anteriorly and posteriorly from adjacent structures.
14. The sigmoid colon is clamped with intestinal clamps after mobilization of the proximal portion. A right-angled intestinal clamp or a reticulating linear stapling device may be used to clamp the distal portion of the rectosigmoid colon.
15. As the sigmoid colon is divided distally to the clamp, the transected rectal edges are grasped with Allis or Ochsner forceps and the rectal opening is exposed.
16. The diseased portion is removed, and the soiled instruments are discarded into a separate basin (bowel technique).
17. Continuity is established by an end-to-end anastomosis of the proximal colon and the rectum using a curved mechanical stapling instrument (EEA) (Figure 10-31).
18. "Donuts" of tissue are removed from the EEA stapling device, examined closely for thickness and continuity, and then sent as separate specimens to the pathology laboratory.
19. The assisting surgeon passes a rigid sigmoidoscope into the lumen of the bowel transanally.
20. Warm irrigating solution is poured into the peritoneal cavity, and the lumen of the bowel is insufflated.
21. The surgeon looks for air leaks from the anastomosis and oversews the site if indicated.
22. The pelvic floor is reperitonealized, and drains may be placed.
23. The abdominal wound is closed and a dressing applied.

Abdominoperineal Resection

Abdominoperineal resection (APR), also called *Miles' resection,* is the mobilization and division of a diseased segment of the lower bowel through a midline incision. The proximal end of bowel is exteriorized through a separate stab wound as a colostomy. The distal end is pushed into the hollow of the sacrum and removed through the perineal route (Figure 10-32). APR is performed to remove malignant lesions and to treat inflammatory diseases of the lower sigmoid colon, rectum, and anus that are too low for the use of EEA stapling devices.

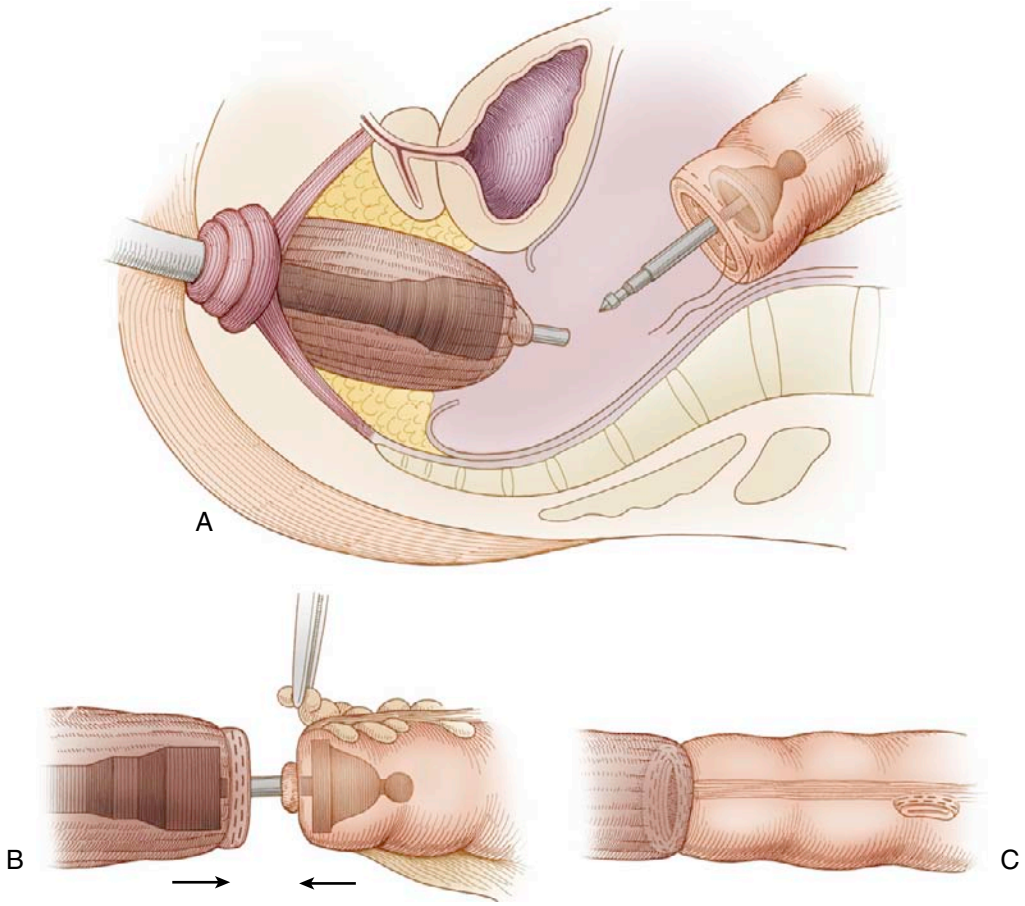


FIGURE 10-31 EEA stapling device, used to perform low anterior anastomosis. **A**, Stapler is introduced into anus, and the anvil is placed into the proximal colon loop. **B**, EEA is advanced to level of the anvil, and the EEA is closed and fired. **C**, Circular double-staggered row of staples joins bowel; simultaneously, circular blade in instrument cuts stoma. Instrument is gently removed. The resulting anastomosis is illustrated with bowel wall transparent to depict reconstruction.

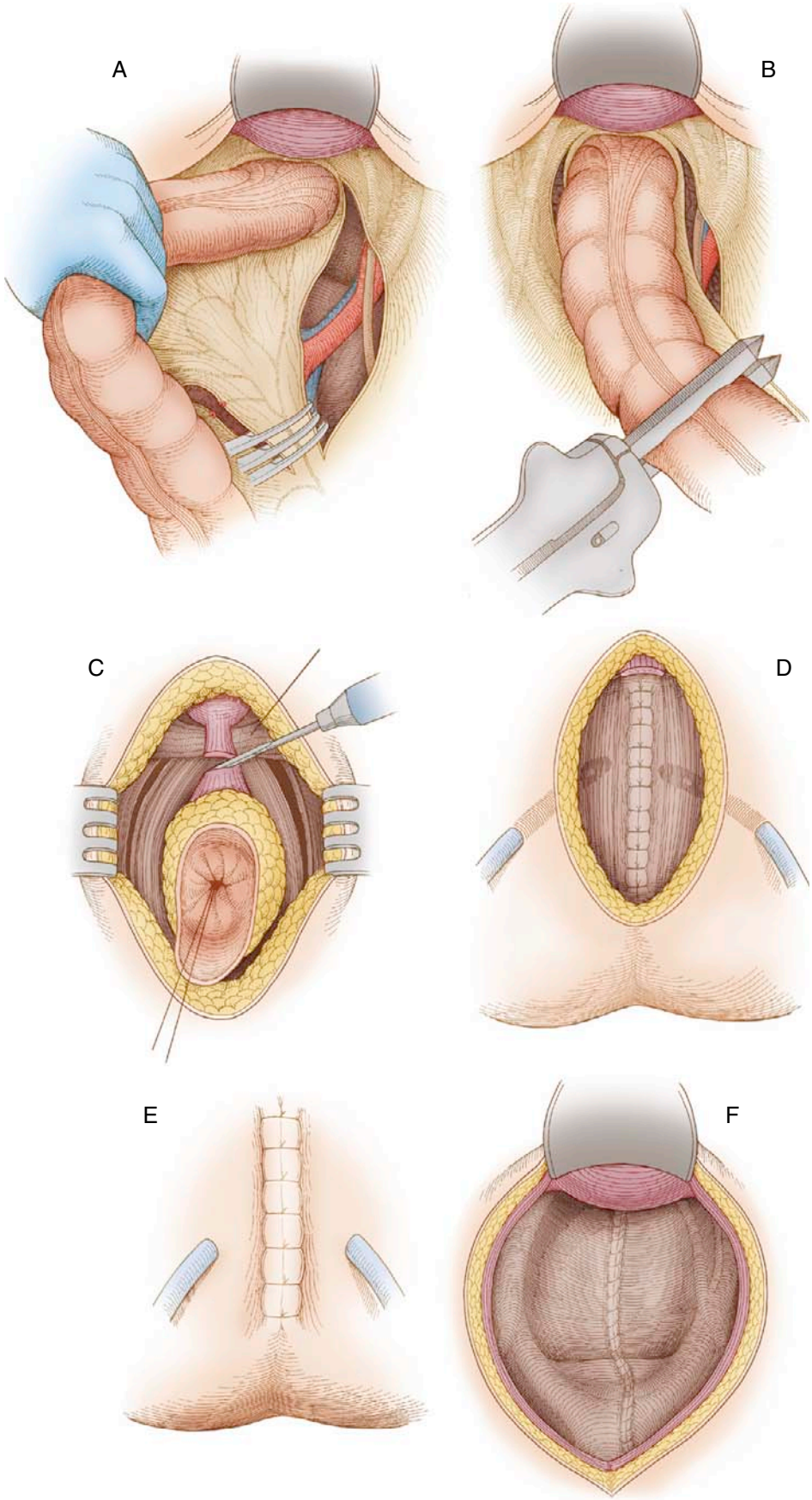


FIGURE 10-32 Abdominoperineal resection for cancer of the rectum. **A**, The sigmoid colon is deflected to the right to complete the rectosigmoid peritoneal detachment. **B**, The distal sigmoid is transected to allow for better access to mobilize the rectum from the sacrum. **C**, The rectal stump is excised from the perineal approach. **D**, Drains are placed and moved through stab wounds; the levator tissues are reapproximated with 2-0 synthetic absorbable sutures. **E**, The perineal skin is closed. **F**, The pelvic peritoneal floor is closed from the abdominal approach.

Procedural Considerations. The choice of patient position depends on the surgeon. Some surgeons prefer to start with the patient in supine position and move the patient into lithotomy for the perineal portion of the operation. Others initially position the patient in modified lithotomy. Thus surgery may be performed simultaneously by two teams, which may require two scrub persons with two different setups. An indwelling catheter is inserted into the urinary bladder after induction of anesthesia. The anesthesia provider inserts an NG tube after intubation. A GI instrument set and an ostomy appliance are required for the abdominal portion of the procedure. A perineal set is used for the rectal portion of the procedure. Identification of the ureters during extensive deep abdominal procedures may be achieved by the preoperative placement of ureteral stents using the transurethral approach.

Operative Procedure

1. A midline incision is made.
2. After thorough exploration of the abdominal cavity and inspection of the colon, the surgeon determines the extent of the lesion and probable surgical outcome. If a resection is indicated, the sigmoid colon is retracted to the right side.
3. The peritoneum on the left of the mesocolon is divided.
4. The incision into the peritoneum is made opposite the main branches of the inferior mesenteric vessels and extended into the pelvis and around, anterior to the rectum.
5. The pelvic peritoneum is mobilized by blunt dissection to form the left side of the new pelvic floor and permit visualization of the left ureter.
6. The peritoneum is incised on the right side until the incision connects with that made on the left.
7. The right ureter is identified and protected.
8. The blood supply of the portion of intestine to be removed is isolated and ligated. Care is taken not to damage the left colic artery, which will supply blood to the colostomy.
9. The mesentery is tied to permit greater exposure in the operative field.
10. The surgeon frees the rectum, usually as low as the sacrococcygeal junction. Care is taken to avoid injury to the presacral nerves, which could result in sexual and bladder dysfunction.
11. After the bowel is freed, the distal segment is transected with a linear stapling instrument (Figure 10-32, *B*).
12. The proximal margin of resection is examined and transected. The bowel and mesentery are removed from the abdominal cavity.
13. The surgeon prepares the permanent colostomy by extending the stump through the abdominal wall. The colostomy will be "matured" (sutured externally to the abdominal wall tissues so that the mucosa is everted into a raised and secured ostomy) after abdominal closure.
14. The combined excision and perineal dissection are initiated when the lesion is determined to be resectable.
15. To prevent contamination, the anus is often closed with a purse-string suture.
16. An incision is made around the anus in an elliptic manner outside the sphincter muscles with a generous margin of perianal skin.
17. The anus is grasped with an Allis or Ochsner forceps and tipped upward to enable its attachment to the coccyx to be severed more readily.
18. Electrodissection is used. The levator ani muscle is exposed; while the finger of the surgeon is held beneath it, it is divided as far from the rectum as possible.
19. All bleeding points are clamped and tied. The Foley catheter allows the surgeon to get as close to the bladder as possible without damaging it.
20. After the anococcygeal raphe is divided, the surgeon's hand is thrust up into the hollow sacrum to free the rectum by blunt dissection, grasp the upper end of the distal fragment, and deliver the stump through the perineum.
21. Drains may be placed into the pelvic cavity and exteriorized through stab wounds in the buttocks (Figure 10-32, *D*).
22. The surgeon is regowned and regloved before returning to the abdominal wound. When all bleeding is controlled, the incision is closed.

If two teams are not available for synchronous excision of the perineum, the perineal portion of the operation is performed after the abdominal resection is complete. In this case, the abdomen is closed and the remaining rectosigmoid stump is excised perineally.

Ileoanal Endorectal Pull-through

Ileoanal endorectal pull-through is removal of the entire colon and the proximal two thirds of the rectum. It includes a mucosectomy of the remaining distal rectum, creation of a pouch from the distal small bowel, and anastomosis of the pouch to the anus. The operation is performed to relieve ulcerative colitis and familial polyposis (e.g., diarrhea, pain, cramping, bleeding) and to prevent colon cancer in high-risk individuals. This procedure is an anal sphincter–saving operation that is done to avoid the need for ileostomy.

Procedural Considerations. The patient is usually positioned in modified lithotomy. Some surgeons prefer to perform the mucosectomy with the patient in jackknife position and then place the patient in modified lithotomy position for the remainder of the procedure. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter is inserted before the abdominal skin prep.

A GI instrument set, a perineal set, rectal instrumentation, and a self-retaining retractor system are used. Separate instrument tables are prepared for the rectal and abdominal approaches. Additional draping and gowning are needed because redraping and regowning occur after the mucosectomy and after the ileoanal anastomosis. An epinephrine solution should be available for injection into the submucosal tissue, proximal to the anus, to separate the mucosa from the muscularis layer. A proctoscope is available as it may be used at the conclusion of the procedure to check for leaks. Air is pumped into the scope, which is inserted into the anus. The surgeon at the abdominal site looks for air bubbles. If there are none, the anastomosis has no leaks. An ileostomy appliance is applied immediately postoperatively.

Operative Procedure

1. The anal canal is dilated and inspected through an anoscope.
2. Starting at the dentate line (the anorectal junction), epinephrine solution is injected circumferentially, separating the mucosa from the muscularis layer.
3. The mucosectomy is then performed by making a circular incision at the dentate line, cutting only through mucosa.

4. The mucosa is peeled off the muscularis tissue for a distance of 2 to 8 cm and resected.
5. When all bleeding is controlled, the patient is repositioned, if necessary, for the abdominal approach.
6. A midline incision is made, and the abdomen is explored.
7. The entire large intestine from the ileocecal junction through the upper two thirds of the rectum is freed and immobilized. All vessels are ligated.
8. The terminal ileum is separated from the cecum using a mechanical cutting and stapling device (GIA).
9. The mesocolon is ligated using suture ligatures or a ligating, dividing, and stapling (LDS) instrument.
10. The rectum is resected down to the level of the mucosectomy. The colon and resected portion of the rectum are removed en bloc.
11. The pouch is created. Most surgeons use either the J pouch or the S pouch.
12. The J pouch (Figure 10-33) is created at the terminal ileum by folding two adjacent loops of small bowel, approximately 10 to 15 cm each, parallel with each other and anastomosing them using a GIA. An opening is made at the bottom of the pouch, and the pouch is pulled through the rectal stump. The bottom of the pouch is anastomosed to the anus with interrupted absorbable sutures.

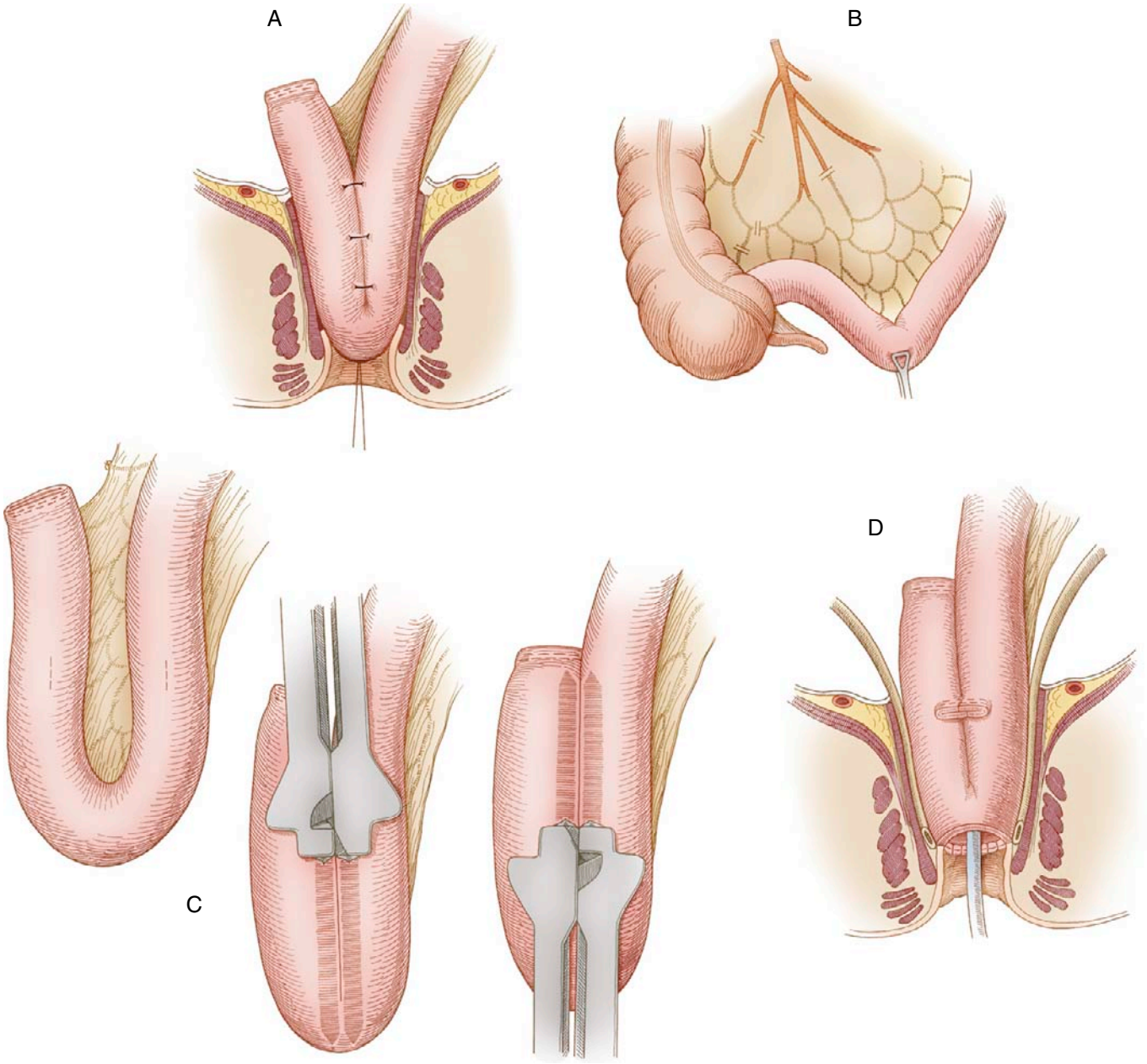


FIGURE 10-33 J pouch for ileoanal endorectal pull-through. **A**, The J pouch is created at terminal ileum by folding two adjacent loops of small bowel, approximately 10 to 15 cm each, parallel to each other. **B**, Mesenteric vascular arcades may need to be divided to provide adequate length for anal anastomosis. **C**, The two loops are anastomosed using a mechanical cutting and stapling device (GIA). **D**, Opening is made at bottom of pouch, and pouch is pulled through rectal stump. Bottom of pouch is anastomosed to anus.

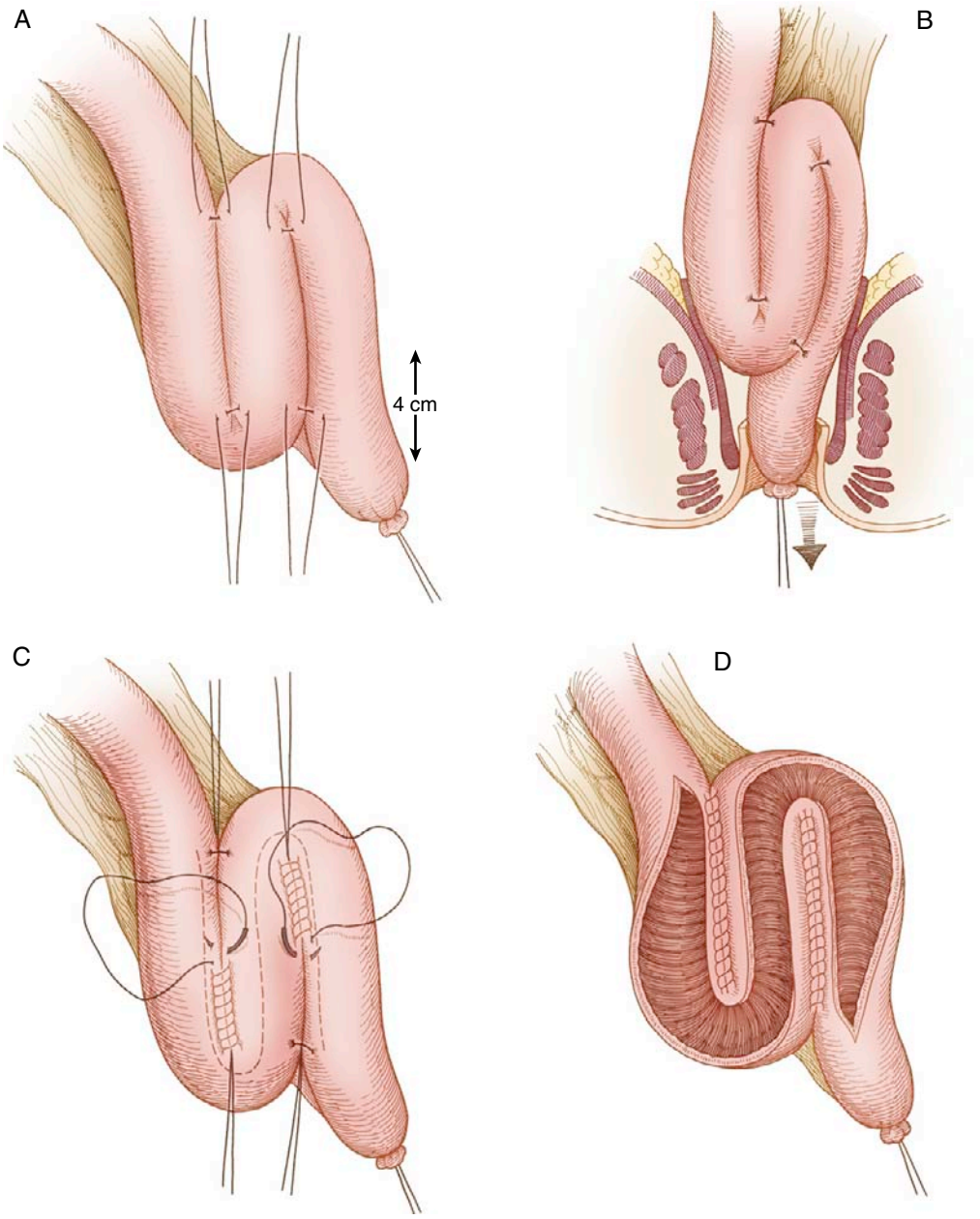


FIGURE 10-34 S pouch for ileoanal endorectal pull-through. **A**, Pouch is created by aligning distal ileum in S configuration with each limb (three in total) approximately 12 cm in length. **B**, The length is measured before anastomosis begins. **C**, Three limbs are incised and anastomosed to create pouch. **D**, Incision is made as illustrated.

13. A Y pouch (Figure 10-34) is created by aligning the distal ileum in an S configuration with each of the three limbs approximately 10 cm in length. The most distal 2 cm of the ileum is not incorporated into the pouch but is preserved for the anastomosis to the anus. The three limbs are manually incised and anastomosed to create a pouch. Mucosal tissue is approximated with absorbable suture; nonabsorbable suture is used for the serosal layer. The preserved distal end of the ileum and the pouch are pulled through the rectal stump and anastomosed to the anus. This completes the anal portion of the procedure.

14. The scrub team changes gowns and gloves, redrapes, and completes the abdominal procedure by creating a loop ileostomy through the abdominal wall, on a previously designated site.

SURGERY OF THE RECTUM

Hemorrhoidectomy

Hemorrhoidectomy is excision and ligation of dilated veins in the anal region to relieve discomfort and to control bleeding. Hemorrhoidectomy is an ambulatory surgery procedure undertaken with the application of sclerotherapy, heater probe coagulation, monopolar or bipolar coagulation, laser, infrared energy coagulation, or

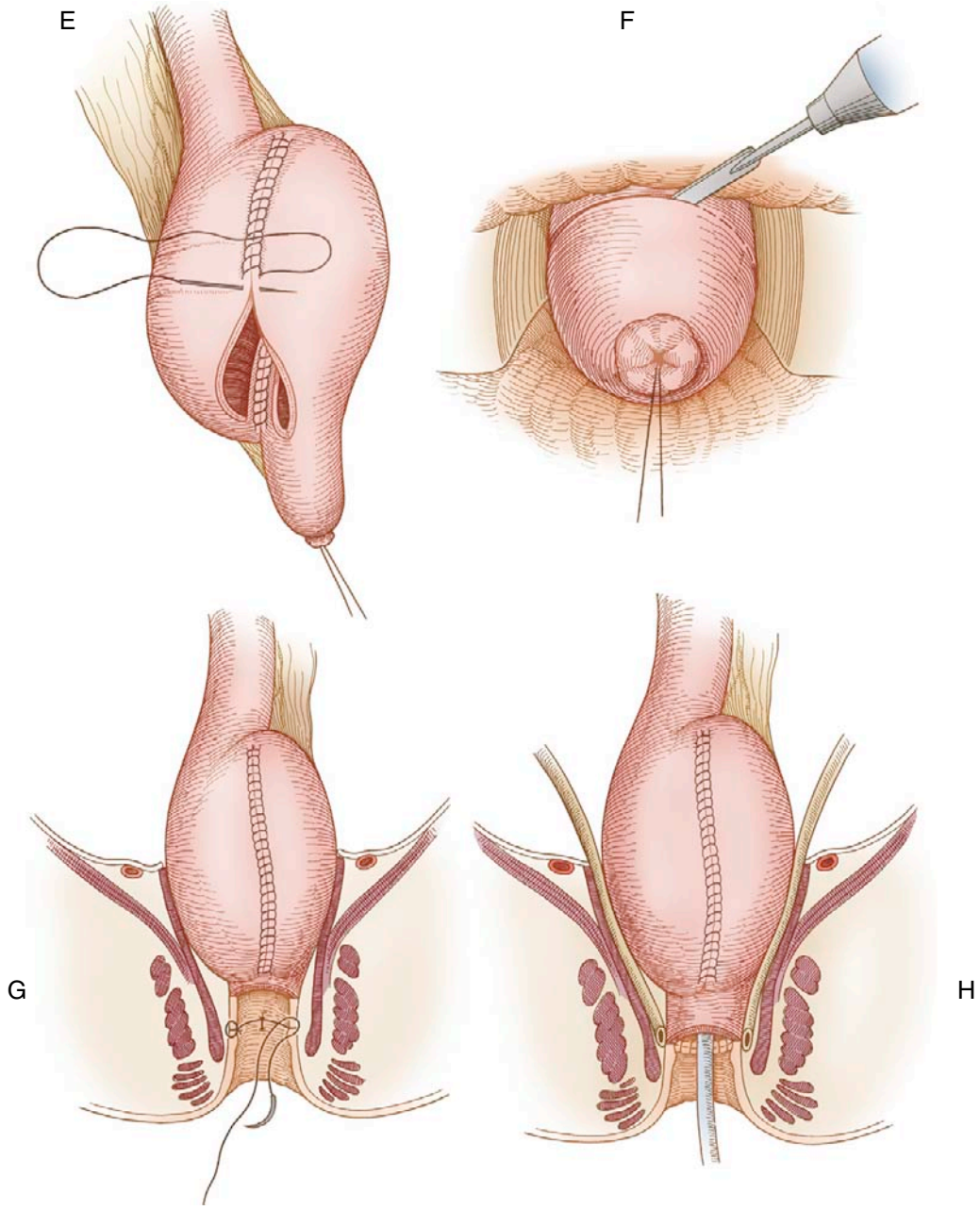


FIGURE 10-34, cont'd **E**, The pouch is closed using suture for the formation of the reservoir. **F**, Distal ends of ileum and pouch are pulled through the rectal stump, and the lower outflow tract is trimmed. **G**, With 3-0 absorbable sutures, the outflow tract is anastomosed to the anus at the dentate line. **H**, Drain in place in the lumen of the newly created ileoanal-rectal canal.

Doppler-guided hemorrhoidal artery ligation (Acheson and Scholefield, 2008). Rubber band ligation is done through an anoscope without sedation in an office or endoscopy setting. Larger symptomatic external and internal hemorrhoids that do not respond to conservative medical treatment are managed with surgery. This patient is at risk for hemorrhoid prolapse, strangulation, thrombosis, and possible ulceration and fistula formation. Surgical treatment aims to coagulate, seal, and excise the hemorrhoid, leaving sufficient anal mucosa surface to minimize pain and prevent stenosis or stricture. Various coagulation, vaporization, and tissue-welding technologies offer successful outcomes. Radiofrequency tissue/fusion energy (LigaSure, Valleylab, Inc.) is a unique form of electrocoagulation that provides hemostasis and sealing by fusing collagen in vessel walls. A specific stapling device may also be used (stapled hemorrhoidectomy; stapled anopexy).

Procedural Considerations. Preoperative anal dilation aids in exposing the vessels and contributes to the patient's comfort in the immediate postoperative period. Many surgeons prefer to precede the operation with a sigmoidoscopy. Spinal, caudal, epidural, or local anesthesia may be used. The patient is usually placed in lithotomy or jackknife position. Postoperative complications include hemorrhage, pain, constipation, fecal impaction, infection, and urinary retention.

Operative Procedure

1. The anal canal is dilated and inspected through an anoscope.
2. Four Allis forceps are applied several centimeters from the anal margin to expose the anus.
3. The base of the hemorrhoid and tissue are grasped with Allis forceps and held.
4. A 2-0 synthetic absorbable intestinal suture is placed and tied at the proximal end of the hemorrhoid, and a Buie Pile forceps is applied across the base and above the proposed incision line.
5. Excision is completed with a scalpel. Coagulation and excision may also be done with monopolar or bipolar electrosurgery, laser vaporization, infrared energy, radiofrequency fusion/ligation, cryotherapy, or even heater probe coagulation. Care is directed toward preserving the rectal sphincter.
6. Loosely placed continuous sutures are placed over the Buie Pile forceps. The suture is tightened as the forceps are removed, and the suture ends are then tied.
7. Traction may be maintained as hemostatic forceps are applied and dissection is completed segmentally.
8. 2-0 synthetic absorbable suture ligatures are used as each hemostat is removed.
9. Remaining hemorrhoids are excised in a similar manner.
10. Petrolatum gauze packing may be placed in the anal canal.

Excision of Pilonidal Cyst and Sinus

Excision of a pilonidal cyst and sinus is removal of the cyst with sinus tracts from the intergluteal fold on the posterior surface of the lower sacrum (Figure 10-35). A pilonidal cyst and sinus, which may be congenital in origin, rarely become

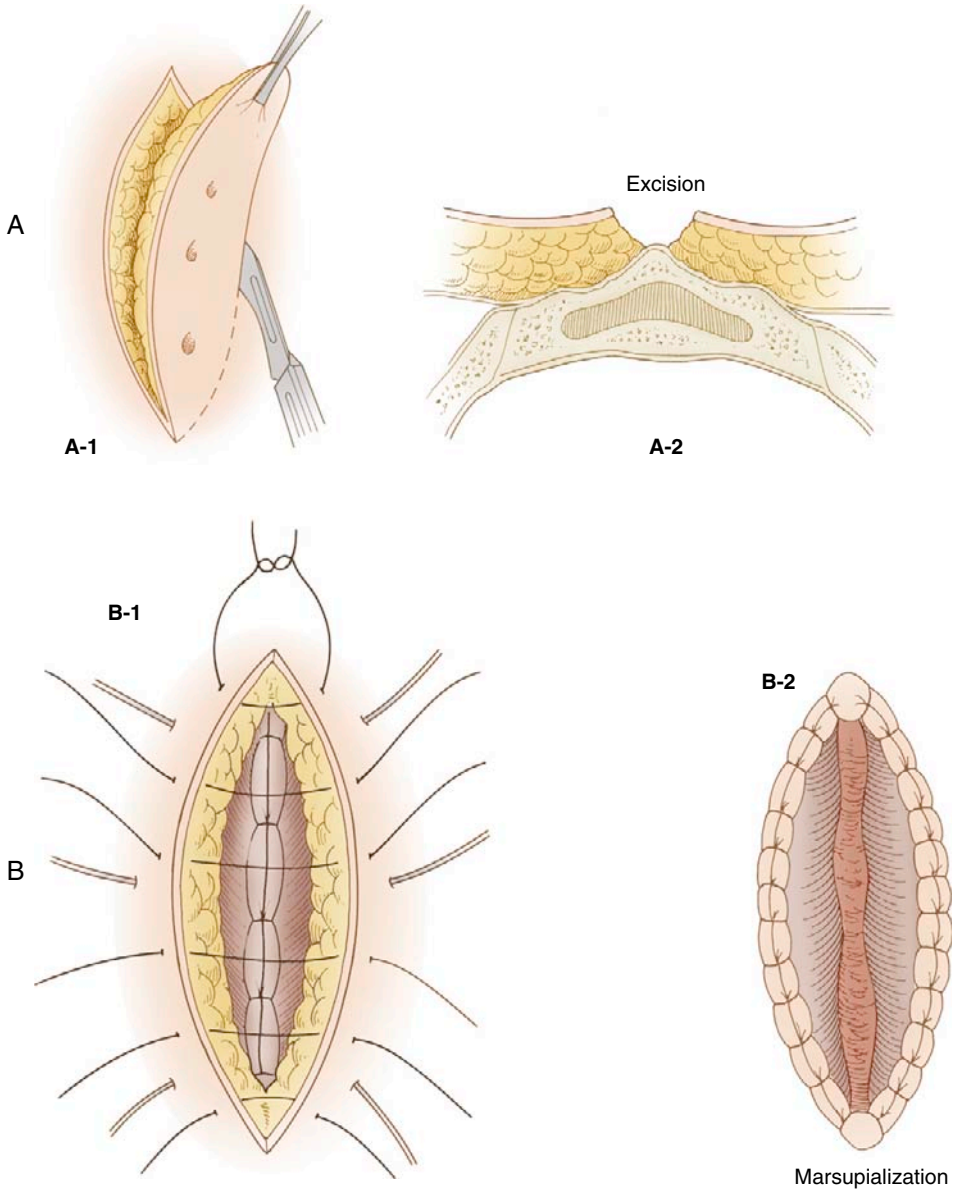


FIGURE 10-35 Pilonidal cyst. The pilonidal sinus tract is identified with injection of methylene blue into the tract. **A**, Wide elliptic incision (*A-1*) is made to include all the subcutaneous tracts and tissue that are part of the fascia overlying the sacrum and coccyx (*A-2*). **B**, Closure of the wound can be primary (*B-1*) or secondary (*B-2*).

symptomatic until the individual reaches adulthood, most commonly in young men. Inflammatory reaction varies from a mild, irritating, draining sinus tract to a painful, acute abscess with secondary recurrences. Treatment consists of drainage in the acute stage and total surgical excision during remission.

Excision of the cyst and sinus tracts must be complete to prevent recurrence. The defect resulting from recurrences may become too large for primary closure. In this case the wound is left open to heal by granulation.

Procedural Considerations. A minor set and rectal instruments are required, as well as methylene blue, a 10- or 20-ml syringe, and a blunt-tipped needle. The patient is placed in jackknife position with the buttocks taped open laterally and secured to the sides of the OR bed.

Operative Procedure

1. The sinus tracts are identified with probes and an incision made over the probe.
2. The tract is marked by injecting methylene blue with a blunt needle.
3. An elliptic incision is made down to the fascia.
4. A curette is used to remove granulation tissue.
5. Excision of cyst and sinus tracts is completed. Bleeding is controlled.
6. If the wound is to be left open, it is packed and a pressure dressing applied.
7. If the wound is closed, 2-0 nonabsorbable sutures are used for stay sutures on the deeper tissue and fine nonabsorbable suture is used on skin.

REFERENCES

Acheson AG, Scholefield JH: Management of haemorrhoids, *BMJ* 336: 380–383, 2008.

Adams RE et al: Long-term mortality after gastric bypass surgery, *N Engl J Med* 357:753–761, 2007.

Anaya DA, Dellinger EP et al: Surgical infection and choice of antibiotics. In Townsend CM et al, editors: *Sabiston textbook of surgery*, ed 18, Philadelphia, 2008, Saunders.

Association of periOperative Registered Nurses: Recommended practice for prevention of hypothermia. In *Perioperative standards and recommended practices,* Denver, 2009a, The Association.

Association of periOperative Registered Nurses: Recommended practice for environment of care. In *Perioperative standards and recommended practices,* Denver, 2009b, The Association.

Association of periOperative Registered Nurses: Recommended practice for sponge, sharp and instrument counts. In *Perioperative standards and recommended practices,* Denver, 2009c, The Association.

Association of periOperative Registered Nurses: Bariatric surgery guideline. In *Perioperative standards and recommended practices,* Denver, 2009d, The Association.

Barclay L: Natural orifice transluminal endoscopic surgery may allow incisionless operations, Medscape Medical News, 2008, available at www.medscape.com/viewarticle/578108. Accessed June 12, 2009.

Barclay L et al: Guidelines issued for the management of GERD, Medscape Medical News, 2008, available at cme.medscape.com/viewarticle/582673. Accessed October 9, 2009.

Beauchamp-Johnson BM: Scale down bariatric surgery risks, *OR Nurse* 48–54, January/February 2007.

Birn CS: Endoscopic ultrasound reveals GI tract secrets, *Nurs Spectr* 17:5–17, 2005.

Bisanz A et al: Characterizing postoperative paralytic ileus as evidence for future research and clinical practice, *Gastroenterol Nurs* 31(5):336–344, 2008.

Blackwood HS: Help your patient downsize with bariatric surgery, *Med Surg Insider*, Fall 2005.

Canobbio MM: *Mosby's handbook of patient teaching*, ed 3, St Louis, 2006, Mosby.

Carmel JE, Goldberg MJ: Preoperative and postoperative management. In Colwell JC et al: *Fecal and urinary diversions: management principles*, St Louis, 2004, Mosby.

Carpenito-Moyet LJ: *Nursing diagnosis: application to practice*, ed 12, Philadelphia, 2007, Lippincott Williams & Wilkins.

Carter S: The surgical team and outcomes management: focus on postoperative ileus, *J Perianesth Nurs* 21(2A):S2–S6, 2006.

Chambers KL: Obesity: an American epidemic, *Surg Technol* 41(5):213–220, 2009.

Cleveland Clinic: Cleveland Clinic First to Perform Successful Live Kidney Donation Through Single Belly Button Incision, 2008, available at http://healthorbit.ca/NewsDetail.asp?opt=1&nltid=140150708. Accessed June 12, 2009.

Curcillo PG: Drexel University College of Medicine Department of Surgery, Oral absract from SAGES Emerging Technology 2007.

Denholm B: Tucking patient's arms and general positioning, *AORN J* 89(4):755–757, 2009.

Edmondson D, Schiech L: Esophageal cancer—a tough pill to swallow, *Nursing* 38(4):44–50, 2008.

Ewing DR et al: Robots in the operating room—the history, *Seminars in laparoscopic surgery* 11(2):63–72, 2004.

Fowler D: Single Port Laparoscopy or NOTES: A Form of Image Guided Therapy? CISST ERC Seminar, 2008, available at http://cisst.org/wiki/seminar_2008_06_25_NOTES. Accessed June 12, 2006.

Hageman D et al: Laparoscopic-assisted colon surgery, *AORN J* 88:403–416, 2008.

Hager C: Quality of life after roux-en-Y gastric bypass surgry, *AORN J* 85(4):768–778, 2007.

Kulaylat MN, Dayton MT: Surgical complications. In Townsend CM et al, editors: *Sabiston textbook of surgery*, ed 18, St Louis, 2008, Mosby.

Kwon RS et al: Gastrointestinal cancer imaging: deeper than the eye can see, *Gastroenterology* 128:1538–1553, 2005.

Lee JM et al: Enduring effects of thorascopic Heller myotomy for treating achalasia, *World J Surg* 28:55–58, 2004.

Lewis BS: Obscure gastrointestinal bleeding. In Ginsberg GG et al, editors: *Clinical gastrointestinal endoscopy*, Philadelphia, 2005, Saunders.

Lucile Packard Children's Hospital: News Release: Pediatric surgeon pushes envelope (and belly button) to remove diseased organs. July, 28, 2008, available at www.lpch.org/newsEvents/NewsReleases/2008/surgeonPushesEnvelope.html. Accessed July 28, 2008.

Marin K et al: Intraperitoneal chemotherapy: implications beyond ovarian cancer, *Clin J Oncol Nurs* 11(6):881–889, 2007.

Markmann JF et al: Transplantation of abdominal ogans. In Townsend CM et al, editors: *Sabiston textbook of surgery*, ed 18, St Louis, 2008, Mosby.

Pappas SG et al: Malignane peritoneal mesothelioma, In Townsend CM et al: editors: *Sabiston textbook of surgery*, ed 18, St Louis, 2008, Mosby.

Pasricha PJ: Endoluminal surgery. In Ginsberg GG et al: *Clinical gastrointestinal endoscopy*, St Louis, 2005, Saunders, pp 841–843, .

Porth CM, Gaspard KJ: *Essentials of pathophysiology: concepts of altered health states*, Philadelphia, 2004, Lippincott Williams & Wilkins.

Raman JD et al: Single incision laparoscopic surgery: initial urological experience and comparison with natural-orifice transluminal endoscopic surgery, BJU Online article, 2008, available at www.advancedsurgical.ie/BJU_Online_Article/Default.245.html. Accessed June 14, 2009.

Ransohoff DF: Colon cancer screening in 2005—status and challenges, *Gastroenterology* 128:1685–1695, 2005.

Regenbogen SE et al: Utility of the surgical Apgar score, *Arch Surg* 144(1):30–36, 2009.

Shortridge K et al: Intestinal transplantation, In Colwell JC et al: *Fecal and urinary diversions: management principles*, St Louis, 2004, Mosby.

Society of Gastroenterology Nurses and Associates: *Manual of gastrointestinal procedures*, ed 5, Philadelphia, 2004, Lippincott Williams & Wilkins.

Sonoda T, Milsom JW: Segmental colon resection. In Souba WW et al: *ACS surgery—principles and practice*, New York, 2007, WebMD.

Sunada K et al: Clinical outcomes of enteroscopy using the double balloon method for strictures of the small intestine, *World J Gastroenterol* 11(7):1087–1089, 2005.

The Surgical and Clinical Adhesions Research (SCAR)-3 study, *Colorectal Dis,* November 2005.

Wang KK: Endoscopic therapy for superficial esophageal carcinomas, In Ginsberg GG et al, editors: *Clinical gastrointestinal endoscopy*, St Louis, 2005, Saunders.

CHAPTER 11

Surgery of the Liver, Biliary Tract, Pancreas, and Spleen

JANICE A. NEIL

A pathologic condition in the liver, biliary tract, pancreas, or spleen often requires surgical intervention. These organs are highly vascular and control many metabolic and immune functions of the body. Surgical intervention may be indicated for infection, cystic anomalies, congenital anomalies, metabolic diseases, trauma (see Chapter 27), or malignancy. Many new cases of malignancy of the pancreas, gallbladder, or extrahepatic biliary tract are diagnosed each year and the prognosis for these is often poor (Steer, 2008; Chari and Shah, 2008). Pancreatic cancer remains the fourth leading cause of death in the United States (McPhee et al, 2007). In the past decade, surgeries of the liver and biliary tract have become more advanced as research and new technology permit more complete diagnoses of pathologic conditions. A resection of the liver for carcinoma has achieved a recognized role for cure or substantial palliation with safety and low morbidity.

Cholecystectomy is the most common, nonemergency abdominal operation performed. In the United States more than 750,000 cholecystectomies are performed each year. It is one of the most frequently performed inpatient procedures in the United States (Afdhal and Vollmer, 2008; Chari and Shah, 2008). Laparoscopic cholecystectomy has become the gold standard surgical intervention for the treatment of cholecystitis. Since the early 1990s, laparoscopic cholecystectomy, as compared with open-incision cholecystectomy, has resulted in reduced trauma to tissues as well as shorter postoperative recoveries, both distinct advantages. About 94% of cholecystectomies are elective surgeries while the remainder are emergencies (Afdhal and Vollmer, 2008). Laparoscopic cholecystectomies were the precursor to numerous abdominal procedures now performed or assisted with the laparoscope. Current innovations in cholecystectomy are focusing on removal of the gallbladder through a natural orifice (referred to as NOTES, or natural-orifice transluminal endoscopic surgery) (Ramos et al, 2008).

New diagnostic technology and the intraoperative use of ultrasonography, biliary endoscopy, and radiography have enabled surgeons to better treat diseases of the biliary tract. Solid organ transplantation (History box), such as for the liver, pancreas, and kidneys, has become common as a means to treat primary hepatic tumors, end-stage liver disease, and insulin-deficient diabetes. Liver transplant procedures have advanced to include entire organ transplants as well as living-related organ donations.

This chapter explores the most common open and minimally invasive procedures performed on the liver, biliary tract, pancreas, and spleen.

Surgical Anatomy

The liver is in the right upper quadrant of the abdominal cavity, beneath the dome of the diaphragm and directly above the stomach, duodenum, and hepatic flexure of the colon. The external covering, known as *Glisson's capsule,* is composed of dense connective tissue. The visceral peritoneum extends over the entire surface of the liver, except at the point of posterior attachment to the diaphragm. This connective tissue branches at the porta hepatis into a network of septa that extends into an intrahepatic network of support for the more than 1 million hepatic lobules. The porta hepatis is located on the inferior surface of the liver and provides entry and exit for the major vessels, ducts, and nerves. The hepatic artery maintains the arterial blood supply, while venous blood from the stomach, intestines, spleen, and pancreas travels to the liver by the portal vein and its branches (Figure 11-1). The hepatic venous system returns blood to the heart via the inferior vena cava.

Lobules are the functional units of the liver. Each lobule contains a portal triad that consists of a hepatic duct, a hepatic portal vein branch, and a branch of the hepatic artery, nerves, and lymphatics. A central vein is located in the center of each lobule and provides venous drainage into the hepatic veins.

Lobules also contain hepatic cords, hepatic sinusoids, and bile canaliculi. The hepatic cords consist of numerous columns of hepatocytes—the functional cells of the liver. The hepatic sinusoids are the blood channels that communicate among the columns of hepatocytes. The sinusoids have a thin epithelial lining composed primarily of Kupffer cells—phagocytic cells that engulf bacteria and toxins. The sinusoids drain into the central vein.

Bile is manufactured by the hepatocytes. The bile canaliculi are tiny bile capillary vessels that communicate among the columns of hepatocytes. The bile canaliculi collect and transport bile to the bile ducts in the portal triad of each lobule, from which bile then flows into the hepatic ducts at the porta hepatis. These ducts join immediately to form one common hepatic duct that merges with the cystic duct from the gallbladder to form the common bile duct (Figure 11-2). The common bile duct opens into the duodenum in an area called the *ampulla,* or *papilla of Vater,* located about 7.5 cm below the pyloric opening from the stomach.

Bile contains bile salts, which facilitate digestion and absorption, and various waste products. The liver is essential in the metabolism of carbohydrates, proteins, and fats. It metabolizes

HISTORY

Solid Organ Transplant

In the eighteenth century, researchers experimented with solid organ transplants on animals and humans. Transplant science evolved after many trials and failures. Important medical breakthroughs, such as surgical technique, tissue typing, immunology, immunosuppressant drugs, and organ preservation, have permitted more success in the viability of organs and longer survival rates for transplant recipients. The following is a summarized timeline of significant "firsts" and milestones in the evolution of solid organ transplant surgery, an often clinically effective and life-saving strategy for patients with end-stage organ failure.

Year	Breakthrough
1954	The first successful kidney transplant Dr. Joseph E. Murray, Brigham & Women's Hospital, Boston, Massachusetts
1963	The first lung transplant Dr. James Hardy, University of Mississippi, Oxford, Mississippi
1966	The first simultaneous pancreas/kidney transplant Dr. Richard Lillehei, William Kelly, University of Minnesota, Minneapolis, Minnesota
1967	The first successful liver transplant Dr. Thomas Starzl, University of Colorado Health Sciences Center, Denver, Colorado
1968	The first isolated pancreas transplant Dr. Richard Lillehei, University of Minnesota, Minneapolis, Minnesota
1968	The first successful heart transplant in the United States Dr. Norman Shumway, Stanford University Hospital, Stanford, California
1981	The first successful heart/lung transplant Dr. Bruce Reitz, Stanford University Hospital, Stanford, California
1983	The first successful lung transplant Dr. Joel Cooper, Toronto Lung Transplant Group, Toronto General Hospital, Toronto, Canada
1986	The first successful double-lung transplant Dr. Joel Cooper, Toronto Lung Transplant Group, Toronto General Hospital, Toronto, Canada
1989	The first living-related liver transplant Dr. Christoph Broelsch, University of Chicago Medical Center, Chicago, Illinois
1990	The first successful living-related lung transplant Dr. Vaughn A. Starnes, Stanford University Medical Center, Stanford, California
1992	The first baboon-to-human liver transplant The University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania
1992	The first pig-to-human liver transplant Cedars-Sinai Medical Center, Los Angeles, California
1993	The first successful living-related lung lobes transplant (one from each of the recipient's parents) University of Southern California, Los Angeles, California
2002	The first uterus transplant took place in Saudi Arabia. The transplanted organ remained viable for 99 days. The intent of the transplant is to make childbirth possible for women who have undergone hysterectomies; the transplant would be temporary—the uterus would be removed once the baby was born to prevent ongoing administration of antirejection drugs
2005	The first partial face transplant, Amiens, France
2008	First partial face transplant in United States, The Cleveland Clinic, Cleveland, Ohio
2009	First simultaneous face-and-hand transplant, Paris, France. The upper half of the face, including the scalp, forehead, nose, ears, and upper and lower eyelids, was transplanted

Boston doctors perform face transplant, available at www.cbsnews.com/stories/2009/04/10/health/main4934319.shtml?source=RSSattr=HOME_4934319. Accessed April 15, 2009; *History of transplantation timeline,* available at www.organtransplants.org/understanding/history. Accessed April 1, 2009; Linden PK: History of solid organ transplantation and organ donation, *Crit Care Clin* 25(1), 2009; *Milestones in transplantation data,* available at www.unos.org/data/default.asp?display=liver&displayType=internationalData. Accessed April 1, 2009; *Saudi surgeons perform first uterus transplant,* 2002, available at www.nytimes.com/2002/03/07/world/medical-first-a-transplant-of-a-uterus.html?sec=health - 42k. Accessed April 1, 2009.

nutrients into stores of glycogen, used for regulation of blood glucose levels and as energy sources for the brain and body functions.

The liver plays several important roles in the blood-clotting mechanism. It is the organ that synthesizes plasma proteins, excluding gamma globulins but including prothrombin and fibrinogen. Vitamin K, a co-factor to the synthesis of prothrombin, is absorbed by the metabolism of fats in the intestinal tract as a result of bile formation by the liver. Patients with liver disease may have altered blood-coagulation abilities.

The liver also synthesizes lipoproteins and cholesterol. Cholesterol is an essential component of the blood plasma. It serves as a precursor for bile salts, steroid hormones, plasma membranes, and other specialized molecules. A diet high in cholesterol reduces the amount that must be synthesized by the liver. When the diet is deficient in cholesterol, the liver increases synthesis to maintain levels necessary for production of vital chemical molecules.

The liver also serves in the metabolic alteration of foreign molecules or biotransformation of chemicals. The microsomal enzyme system (MES) plays a major role in the body's response to foreign chemicals, such as pollutants, drugs, and alcohol. Patients with liver disease may have an altered response to chemical substances. This consideration is important in the

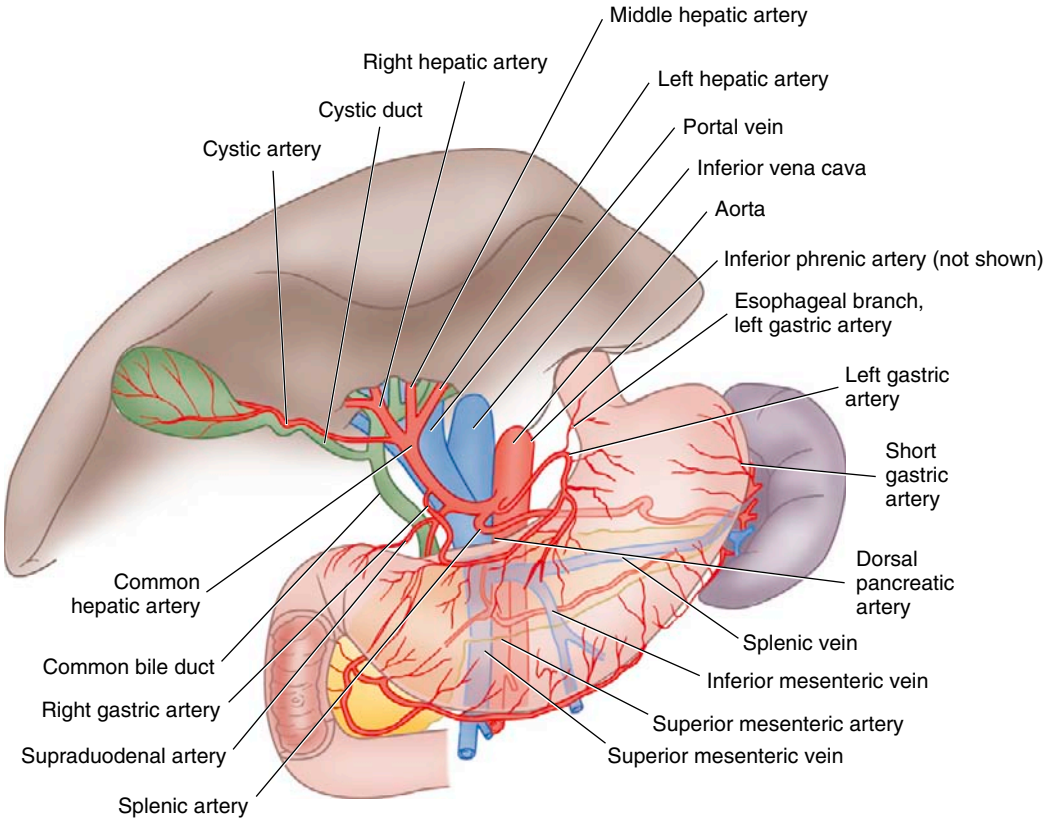


FIGURE 11-1 Intricate relationships of the arterial and venous blood supply of the liver, gallbladder, pancreas, spleen, and the biliary ductal system.

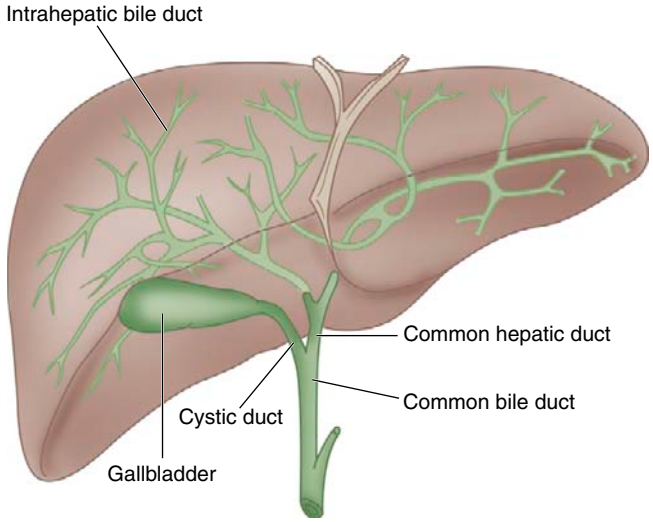


FIGURE 11-2 Biliary system can be divided into three anatomic areas: the intrahepatic bile duct, the extrahepatic bile duct (common hepatic and common bile ducts), and the gallbladder and cystic duct.

induction and management of general anesthesia for patients with liver disorders.

The gallbladder, which lies in a sulcus on the undersurface of the right lobe of the liver, terminates in the cystic duct (Figure 11-3). This ductal system provides a channel for the flow of bile to the gallbladder, where it becomes highly concentrated during storage. The liver produces about 600 to 1000 ml of bile each day. The gallbladder's average storage capacity is 40 to 70 ml. As foods, especially fats, are ingested, the duodenal cells release cholecystokinin. As the musculature of the gallbladder contracts, bile is forced into the cystic duct and through the common duct. As the sphincter of Oddi in the ampulla of Vater relaxes, bile is released, flowing into the duodenum to aid in digestion by emulsification of fats. The gallbladder receives its blood supply from the cystic artery, a branch of the hepatic artery. The triangle of Calot contains the cystic artery (and possibly the right hepatic artery); it is an anatomic landmark in surgical removal of the gallbladder. Its boundaries may be remembered as "the *3 Cs*": *C*ystic duct, *C*ommon hepatic duct, and *C*ystic artery (Chari and Shah, 2008). Innervation for the gallbladder and biliary tree is controlled by the autonomic nervous system. Parasympathetic innervation stimulates contraction, whereas sympathetic innervation inhibits contraction.

The pancreas (see Figure 11-3) is a fixed structure lying transversely behind the stomach in the upper abdomen. The head of the pancreas is fixed to the curve of the duodenum. Blood is supplied to the pancreas and the duodenum from the celiac axis and superior mesenteric artery (Figure 11-4). The body of the pancreas lies across the vertebrae and over the superior mesenteric artery and vein. The tail of the pancreas extends to the hilum of the spleen. In total, the pancreas extends about 25 cm. Pancreatic secretions containing digestive enzymes are collected in the pancreatic duct, or duct of Wirsung, which joins with the common bile duct to enter the

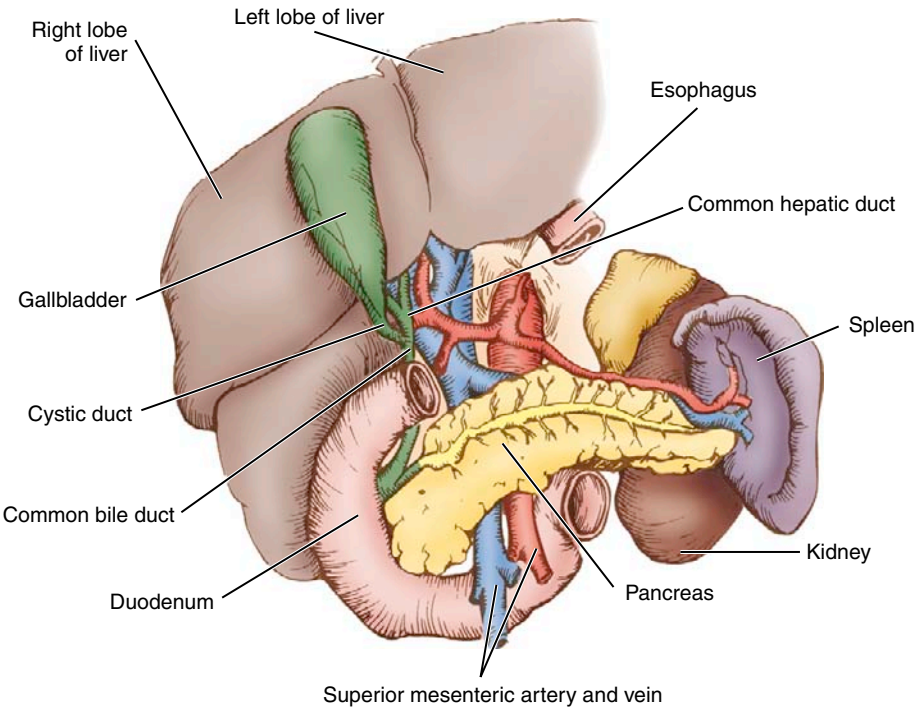


FIGURE 11-3 Gallbladder and surrounding anatomy.

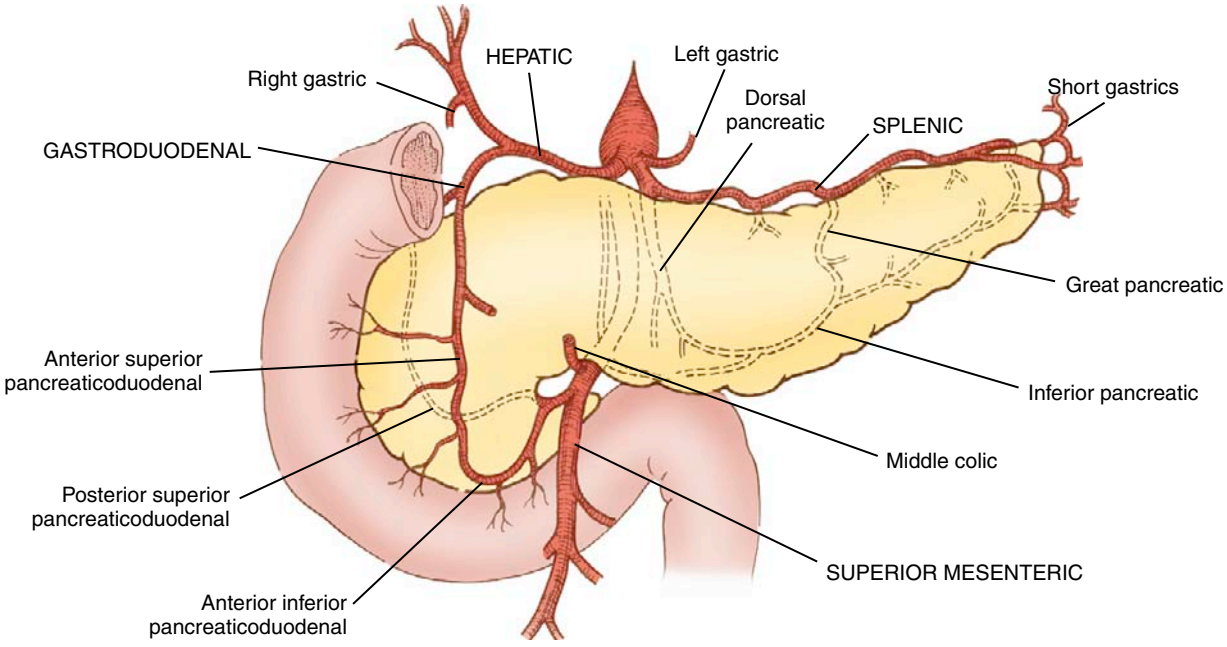


FIGURE 11-4 Arterial supply to the pancreas arises from the celiac axis (hepatic and splenic arteries) and the superior mesenteric artery. The blood supply to the head of the gland is by way of the pancreaticoduodenal (anterior and posterior) arcades, which arise from the gastroduodenal artery (superior) and superior mesenteric arteries (inferior).

duodenum about 7.5 cm below the pylorus. The dilated junction of the two ducts at the point of entry forms the ampulla of Vater.

The pancreas also contains groups of cells, called *islets,* or *islands, of Langerhans,* that secrete hormones into the blood capillaries instead of into the duct. These hormones are insulin and glucagon, and both are involved in carbohydrate metabolism.

The spleen (Figure 11-5) is in the upper left abdominal cavity, with full protection provided by the tenth, eleventh, and

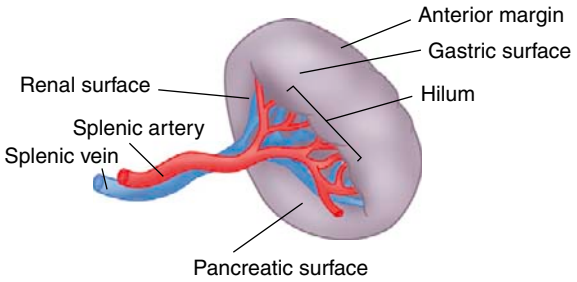


FIGURE 11-5 Spleen.

twelfth ribs; its lateral surface is directly beneath the dome of the diaphragm. The anterior medial surface is in proximity to the cardiac end of the stomach and the splenic flexure of the colon. The spleen is covered with peritoneum that forms supporting ligaments. The splenic artery, a branch of the celiac axis, furnishes the arterial blood supply. The splenic vein drains into the portal system.

The spleen has many functions. Among them are defense of the body by phagocytosis of microorganisms, formation of nongranular leukocytes and plasma cells, and phagocytosis of damaged red blood cells. It also acts as a blood reservoir.

Perioperative Nursing Considerations

Assessment

The patient with hepatobiliary disease may have extreme jaundice, urticaria, petechiae, lethargy, and irritability. Depending on the extent of the disease, bleeding and coagulation times may be increased and the platelet count decreased, contributing to intraoperative concerns with achieving hemostasis. A thorough nursing history is necessary for proper assessment of the health status of patients with dysfunctions of the hepatobiliary system, pancreas, or spleen. Assessment should include data about the patient's history of chronic disease, current medications, perceptions of his or her disease, comfort status, nutritional status, fluid and electrolyte balance, bowel and elimination patterns, energy level and independence, and exposure to toxins. Many industrial compounds are toxic to the liver (Table 11-1).

Establishing an objective database for a person with hepatobiliary or pancreatic dysfunction requires particular attention to characteristic signs of organ dysfunction. Increased abdominal girth and distention, palmar erythema, distended periumbilical veins, hemorrhagic areas, spider nevi, muscle wasting, and dry mucous membranes are some characteristic signs and symptoms. Vascular volume can be assessed by noting vital signs, including any orthostatic changes, skin turgor, temperature, appearance, and weight gain or loss. Physical examination of the patient's abdomen should include palpation and percussion to evaluate tenderness, ascites, and organ enlargement.

Common laboratory tests to assess liver function are those that evaluate fat metabolism, protein metabolism, blood coagulation properties, bilirubin metabolism, and antigens and antibodies of hepatitis (Table 11-2). Common tests of pancreatic function can be found in Table 11-3. Radiographic studies commonly used to evaluate function of the liver, pancreas, and spleen include abdominal examination, upper gastrointestinal (GI) series, ultrasound studies, computerized tomography (CT) scan, radioisotope scanning, nuclear magnetic resonance imaging (MRI), angiography, cholecystography, and cholangiography. State-of-the-art imaging includes contrast-enhanced MRI, MR cholangiopancreatography (MRCP), endoscopic ultrasound (EUS), and high-resolution, thin-section spiral CT for imaging pancreatic and biliary structures. In addition, fluorodeoxyglucose positron emission tomography (FDG-PET) is a whole-body technique that can detect metastases, recognition of which may change surgical management (Chari and Shah, 2008).

Endoscopy and biopsy are more invasive diagnostic procedures that may be used to evaluate the liver, pancreas, and spleen. Endoscopic retrograde cholangiopancreatography (ERCP) (Figure 11-6) allows direct visualization of the biliary tract, injection of radiographic dye into the ductal system, and biopsy when indicated. Percutaneous transhepatic cholangiography (PTC) uses percutaneous insertion of a long flexible needle into a bile duct of the liver. Contrast medium is injected and serial x-ray examination is performed. Arteriography of the liver, biliary tree, pancreas, and spleen requires femoral arteriotomy and placement of a catheter into the celiac branch of the abdominal aorta under fluoroscopic visualization. Contrast medium is then injected and serial x-ray examination allows the vessels to be visualized during the perfusion and drainage phases.

EVIDENCE FOR PRACTICE

Monitoring Mycophenolic Acid: A Method to Detect Rejection in Solid Organ Transplants

Although solid organ transplants are commonly performed, complications occur, the most common and significant being infection and acute graft rejection. In light of the significance of rejection, this review sought evidence for the utility of monitoring concentrations of mycophenolic acid (MPA) in patients who receive solid organ transplants to answer three questions: (1) if such monitoring resulted in a lower incidence of transplant rejections and adverse events versus no monitoring of MPA; (2) whether the incidence of rejection or adverse events differs according to dose, frequency, type of MPA, the form of MPA monitored, the method of MPA monitoring, or sample characteristics; and (3) whether such monitoring is cost-effective. A number of database searches were conducted. Each of the studies selected from the database search was abstracted according to select criteria, two of which were study design (i.e., randomized, controlled trial [RCT], observational study with comparison group, or case series) and patient receipt of allograft solid organ transplant. To be included in the search for evidence, any form of MPA had to be measured in the study at least once (plasma or serum, using any method of measurement). MPA measurement needed to be linked in the study to transplant rejection.

The results were inconclusive in providing evidence for clinical practice. While the state of knowledge about therapeutic drug monitoring of MPA in solid organ transplants remains in its infancy, clinicians are advised to make monitoring decisions on a patient-by-patient basis.

Modified from *Utility of monitoring mycophenolic acid in solid organ transplant patients,* Feb 2008, available at www.ahrq.gov/clinic/tp/mpaorgtp.htm. Accessed April 1, 2009.

TABLE 11-1

Common Hepatotoxic Agents and Type of Liver Damage

Toxic Agent	Source	Liver Damage
Aflatoxin B	Moldy foods, rice, corn, cassava, oil, grain dust (during bin clean out and animal feeding in enclosed buildings)	Jaundice, fatty liver, hepatocellular carcinoma, thromboses
Amanita phalloides	Poisonous mushrooms	Centrilobular and massive necrosis
Benzene	Chemical industry, to make plastics, resins, and nylon and synthetic fibers	Fatty liver, cirrhosis
Beryllium	From x-ray tube and fluorescent lamp manufacture; alloys are used in automobiles, computers, sports equipment (golf clubs and bicycle frames)	Necrosis and granulomas
Boron, cadmium, nickel, chromium, copper	From gold smelting, plating	Liver damage, rise in levels of liver enzymes
Carbon tetrachloride	Propellants for aerosol cans, as a pesticide, cleaning fluid, degreasing agent, fire extinguishers, spot removers (now banned)	Centrilobular necrosis
Kerosene	From fuel handling	Liver damage, rise in levels of liver enzymes
Lead	Environment	Steatosis, hepatitis
Pesticides	Polyvinyl chloride, farming industry	Steatosis, angiosarcoma (liver tumors)
Phosphorus	From poisons and firecrackers	Fatty liver, necrosis, fibrosis
Toluene, xylene	Occurs naturally in crude oil	Fatty liver, fibrosis
Vinyl chloride	Used to make polyvinyl chloride (plastics; also named PVC)	Angiosarcoma (liver tumors), fibrosis

Modified from Orfei L: *Toxic liver injury,* 2005, available at www.meddean.luc.edu/lumen/MedEd/orfpath/toxicinjury.htm. Accessed April 1, 2009; *Levels and distribution of aflatoxin B1 in grain dust,* 2002, available at www.cdc.gov/nasd/docs/d001301-d001400/d001376/d001376.html. Accessed April 1, 2009; *ToxFaqs for benzene,* 2004, available at www.atsdr.cdc.gov/tfacts3.html. Accessed April 1, 2009; *ToxFaqs for beryllium,* 2004, available at www.atsdr.cdc.gov/tfacts4.html. Accessed April 1, 2009; *ToxFaqs for carbon tetrachloride,* 2004, available at www.atsdr.cdc.gov/tfacts30.html; *ToxFaqs for toluene,* 2004, available at www.atsdr.cdc.gov/tfacts56.html; *ToxFaqs for vinyl chloride,* 2004, available at www.atsdr.cdc.gov/tfacts20.html. Accessed April 1, 2009.

Nursing Diagnosis

After review of the nursing assessment, the perioperative nurse formulates nursing diagnoses. Nursing diagnoses related to the care of patients undergoing surgery of the liver, biliary tract, pancreas, or spleen might include the following:

- Anxiety related to impending surgical procedure, perioperative events, and surgical outcome
- Risk for Imbalanced Fluid Volume
- Hypothermia related to exposure of body surface or abdominal cavity and effects of anesthesia on thermoregulation
- Risk for Infection related to organ systems involved (portions of the GI tract)
- Risk for Perioperative Positioning Injury
- Risk for Impaired Skin Integrity related to invasion of body structures, disruption of skin surface
- Acute Pain related to surgical procedure

Outcome Identification

Statements about desired outcomes reflect nursing diagnoses identified for a patient population. Nursing diagnoses are also individualized according to cultural, ethnic, religious, and spiritual values, as well as an individual patient's status. From these are derived the outcomes the perioperative nurse wishes to achieve. The best outcome statement has specific criteria by which the perioperative nurse intends to measure whether the outcome has been met. These criteria are more meaningful when they are established in partnership with the patient. Not all outcomes will be planned with the patient, but ones relating to nursing diagnoses such as anxiety and coping can and should reflect the patient's participation. Outcomes identified for the selected nursing diagnoses might be stated as follows:

- The patient will verbalize management of anxiety and ability to cope, demonstrate knowledge of his or her psychologic responses to the planned procedure, and show an understanding of the planned sequence of perioperative events.
- The patient will maintain fluid volume equilibrium throughout the operative procedure.
- The patient will evidence an intraoperative core body temperature within the normal range (35.5° to 37.2° C; 96° to 99° F).
- The patient will be free of clinical signs and symptoms of surgical site infection (SSI).
- The patient will maintain baseline neuromuscular function and intact skin at positional pressure sites.
- The patient will demonstrate understanding of the plan to heal the incision site.
- The patient will report that the pain management regimen relieves pain to a satisfactory level (Ackley and Ladwig, 2008).

Planning

Planning for the care of the patient requires knowledge of the anatomy and subsequent physiologic complications that may occur with surgical interruption of tissues. Planning is driven by intended outcomes. The experienced perioperative nurse reflects on those intended outcomes and, using theory, science,

TABLE 11-2

Liver Battery (Liver Function Studies)

Test Name	Normal Values
SERUM ENZYMES	
Alkaline phosphatase (ALP)	30-120 units/L. Elevated levels with biliary obstruction, cholestatic hepatitis, liver disease.
Aspartate aminotransferase (AST; previously SGOT)	0-35 units/L. Elevated levels with hepatocellular injury, necrosis.
Alanine aminotransferase (ALT; previously SGPT)	4-36 units/L. Elevated levels with liver damage, acute hepatitis; AST/ALT ratio usually is higher in liver necrosis and acute hepatitis and lower in cirrhosis, chronic hepatitis, cancer of liver.
Lactate dehydrogenase (LDH)	100-190 units/L (normal value may differ with method). Elevated levels in liver disease, untreated pernicious anemia, acute myocardial infarction, renal disease, muscle disease, malignant tumors.
5-Nucleotidase	0-1.6 units at 37° C. Elevated levels may indicate hepatobiliary disease.
Leucine aminopeptidase (LAP)	Males: 80-200 units/ml. Females: 75-185 units/ml. Elevated in liver necrosis and cancer, extrahepatic biliary obstruction (stones), viral hepatitis.
γ-Glutamyltransferase (GGT), γ-glutamictranspeptidase (GGTP)	Adults ≥45 yr: 8-38 units/L; <45 yr: 5-27 units/L. Newborns: 5× higher than in adults. Elevated levels in cirrhosis, acute and chronic liver necrosis, alcoholism, acute and chronic hepatitis, liver cancer. Enzyme produced by bile ducts. Reflects rare forms of liver disease. Medications commonly cause GGTP level to be elevated. Liver toxins such as alcohol can cause increases in GGTP level.
Alpha fetoprotein	<15 ng/ml. Elevated in cirrhosis, hepatitis. May indicate liver metastases from another cancer source.
Mitochondrial antibodies	Presence of these antibodies can indicate primary biliary cirrhosis, chronic active hepatitis, certain other autoimmune disorders.
BILIRUBIN METABOLISM	
Serum Bilirubin	
Indirect (unconjugated)	0.2-0.8 mg/dl. Elevated levels with hemolysis (lysis of red blood cells) and severe liver damage.
Direct and total (conjugated)	Total: 0.3-1.0 mg/dl. Direct: 0.1-0.3 mg/dl. Newborn: 1.0-12.0 mg/dl. Elevated levels seen with intrahepatic or extrahepatic obstruction.
Urine bilirubin	Negative: 0.02 mg/dl. Bilirubin in urine may be seen with hepatic disease or biliary obstruction; only conjugated bilirubin spills into urine because unconjugated bilirubin is bound to albumin in serum and thus cannot pass glomerular membrane.
Urine urobilinogen	Random: negative or <1.0 Ehrlich unit. 2 hr: 0.3-1.0 Ehrlich unit. 24 hr: 0.5-4.0 Ehrlich units. Increased levels seen with hemolytic processes, shunting of portal blood flow.
Fecal urobilinogen	50-300 mg/24 hr. Reduced levels cause clay-colored stools and are seen in biliary obstruction.
Ammonia	Adults: 10-80 mcg/dl. Elevated levels may be seen with liver dysfunction, hepatic failure, or heart failure.
SERUM PROTEINS	
Albumin	3.5-5.0 g/dl. Decreased levels seen in liver disease.
Globulin	Reduced levels seen with hepatocellular injury test of specific proteins: Serum globulin: 2.3-3.4 g/dl Immunoglobulin M (IgM) component: 75-300 mg/dl IgG component: 650-1850 mg/dl IgA component: 90-350 mg/dl
Total	Albumin + globulin: 6.4-8.3 g/dl. Decreased levels may be seen with hepatocellular injury.
Albumin/globulin (A/G) ratio	>1.0 (albumin ÷ globulin). Low ratio in liver disease.
Transferrin	215-365 mg/dl. Reduced levels may be seen with liver damage; increased levels may be seen with iron deficiency.
BLOOD-CLOTTING FUNCTIONS	
Prothrombin time (PT)	11-12.5 sec, or 90-100% of control. Increased levels may be seen with chronic liver disease (e.g., cirrhosis) or vitamin K deficiency.
Partial thromboplastin time (PTT)	Activated partial thromboplastin time (APTT): 30-40 sec. PTT: 60-70 sec. Increased levels may be seen with severe liver disease or heparin therapy.
International Normalized Ratio (INR)	Oral coagulant therapy: 1.5-3.5 INR. Test used to monitor therapy for patients receiving warfarin sodium (Coumadin) therapy. More consistent measure than PT.

Modified from *Liver disease: common liver function tests,* 2005, available at www.umm.edu/liver/tests.htm. Accessed April 1, 2009; Pagana KD, Pagana TJ: *Mosby's diagnostic and laboratory test reference,* St Louis, 2009, Mosby; *Serum globulin electrophoresis,* 2005, available at www.nlm.nih.gov/medlineplus/ency/article/003544.htm. Accessed April 1, 2009.

TABLE 11-3

Tests of Pancreatic Function

Test Name	Normal Values
Serum amylase	60-120 units/dl (Somogyi method). Elevated levels are seen with acute exacerbation of chronic pancreatitis, ampulla of Vater obstruction, pancreatic duct obstruction, pancreatic cancer, acute pancreatitis, and pancreatic trauma.
Serum lipase	0-160 units/L. Elevated levels are seen with pancreatitis, renal failure, and intestinal infarction or obstruction.
Urine amylase	0-5000 Somogyi units/24 hr; 6.5-48.1 units/hr (SI units). Elevated levels are the same as for serum amylase.
Secretin-pancreozymin test	Volume: 2-4 ml/kg body weight. Assessment of exocrine secretory ability of pancreas for carcinoma, ductal obstruction, or chronic pancreatitis. Low volume may indicate obstruction.

Modified from Pagana KD, Pagana TJ: *Mosby's diagnostic and laboratory test reference,* St Louis, 2009, Mosby.

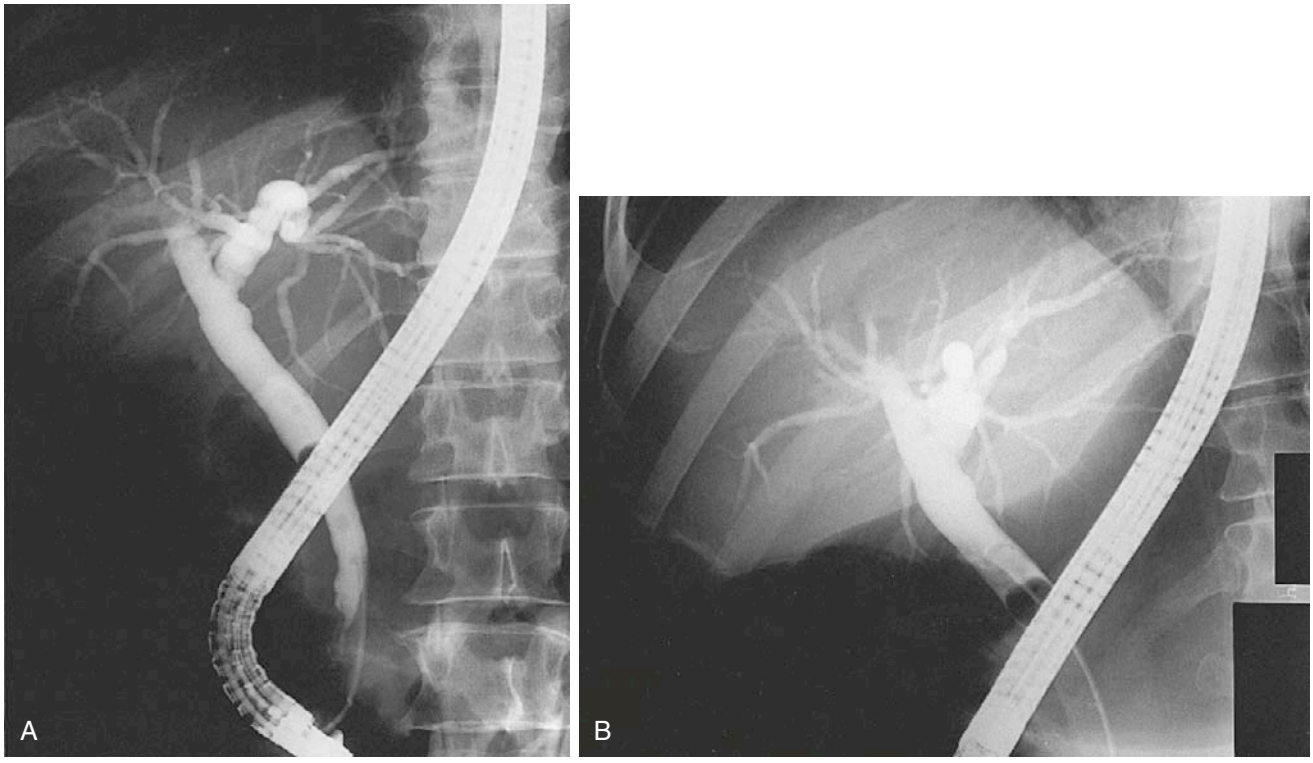


FIGURE 11-6 **A**, Endoscopic retrograde cholangiopancreatography demonstrates several calculi within the distal common bile duct. **B**, Stone removal with a Fogarty catheter.

and what has been learned through experience, identifies actions required for outcome achievement (Benner et al, 2009). Principles of safe surgical positioning, maintenance of asepsis, prevention of biologic and electrical hazards, and provision of proper instrumentation and equipment are a few constituents of the plan of care that are based on theory and science and augmented by nursing experience.

A review of the nursing assessment and a patient interview provide insights as to the specific needs of the patient. The patient's medical and surgical history, as well as age, size, and nutritional status, will assist the perioperative nurse in developing an effective plan of care. A Sample Plan of Care for a patient undergoing surgery of the liver, biliary tract, pancreas, or spleen is shown on p. 365.

Implementation

Patients having surgery of the liver, biliary tract, pancreas, or spleen are usually given a general anesthetic. The following pertinent factors should be considered in caring for these patients.

Universal Protocol. The Joint Commission (TJC) requires that the "wrong site, wrong procedure, wrong person" prevention protocol be carried out before each surgical procedure (TJC, 2009). This protocol involves the following principles:

- Wrong site, wrong procedure, wrong person surgery can and must be prevented.
- Active involvement and effective communication among all members of the surgical team are required.

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Anxiety related to impending surgical procedure, perioperative events, and surgical outcome

OUTCOME
The patient will verbalize management of anxiety and ability to cope, demonstrate knowledge of his or her psychologic responses to the planned procedure, and indicate an understanding of the planned sequence of perioperative events.

INTERVENTIONS
- Greet the patient positively; determine the name he or she prefers to be called.
- Introduce the patient to the OR team.
- Avoid hasty movements or gestures of indecision.
- Speak slowly and clearly when addressing the patient, and use terminology the patient can understand.
- Offer emotional reassurance by using touch, assisting the patient to a position of comfort on the OR bed, and offering warm blankets (thermal comfort).
- Classify the patient's level of anxiety (mild, moderate, severe) by asking the patient and observing signs of anxiety (e.g., clenching/unclenching hands, crying, tremors).
- Determine the patient's personally effective coping mechanisms, and facilitate use of these.
- Identify the patient's special concerns, values, and wishes concerning his or her care.
- Provide explanations of perioperative events; encourage questions.

NURSING DIAGNOSIS
Risk for Imbalanced Fluid Volume

OUTCOME
Patient will maintain fluid volume equilibrium throughout surgical procedure.

INTERVENTIONS
- Review orders for blood/blood products; have these available in easily accessible, refrigerated storage for timely access.
- Communicate availability of blood/blood products during the preop briefing or time-out.
- Measure, communicate, and record estimated or real fluid volume loss throughout surgical procedure.
- Anticipate and communicate to blood bank personnel the potential need for additional blood and blood products.
- Collaborate with anesthesia provider in fluid replacement therapies.
- Check laboratory values intraoperatively; monitor and note deviations in study results.

NURSING DIAGNOSIS
Hypothermia related to exposure of body surface or abdominal cavity and effects of anesthesia on thermoregulation

OUTCOME
The patient will maintain an intraoperative core body temperature of 35.5° to 37.2° C (96° to 99° F).

INTERVENTIONS
- Determine thermal comfort: ask the patient if he or she is cold.
- Adjust room temperature and humidity to accommodate preservation of body temperature.
- Provide warm blankets on transfer to OR bed.
- Expose only that part of the body necessary for the surgical prep; cover all other body surfaces to maintain body heat.
- Provide warm irrigation solutions, first ensuring solution temperature is below 40.5° C (105° F).
- Collaborate with anesthesia provider in warming intravenous (IV) fluids and blood/blood products before infusion.
- Use other active warming measures (such as forced-air warming system) for preventing hypothermia.
- Monitor body temperature to evaluate response to thermoregulation measures.

NURSING DIAGNOSIS
Risk for Infection related to organ systems involved (portions of the gastrointestinal tract)

OUTCOME
The patient will be free of clinical signs and symptoms of surgical site infection.

INTERVENTIONS
- Implement aseptic technique; communicate and correct breaks in asepsis.
- Ensure that preoperative antibiotics are administered as ordered; prophylactic antibiotics should be administered 1 hour before surgical incision is made. Follow guidelines for safe medication practices.
- Contain and confine contaminants appropriately.
- Ensure that all sterilization procedures have been properly observed.
- Ensure that the integrity of sterile supply packaging is intact before dispensing items to the sterile field.
- If ordered, verify that patient has performed preoperative showers.
- Perform intraoperative skin preparation with antimicrobial agent of choice (institutional protocol).
- Implement measures to prevent cross-contamination.
- Initiate traffic control and environmental measures that reduce risk for infection.
- Use aseptic technique in applying dressings to surgical sites.
- Correctly classify wound according to established wound classification system.
- Manage culture specimen collection according to institutional policy and safe practices for specimen management.

NURSING DIAGNOSIS
Risk for Perioperative Positioning Injury

OUTCOME
The patient will maintain baseline neuromuscular function and intact skin at positional pressure sites.

INTERVENTIONS
- Identify any physiologic alterations or mobility limitations that may affect procedure-specific positioning.
- Implement measures to prevent shearing forces during patient transfer to and from OR bed and during positional changes.
- Ensure that all positioning equipment is clean and functioning properly.
- Ensure patient is in optimal anatomic alignment after induction of anesthesia.
- Adequately pad all bony prominences and vulnerable neurovascular areas.
- Secure limbs to ensure position is maintained and to prevent limb from falling from positioning device (as appropriate to procedure-specific position).
- Ensure safe and proper placement of electrosurgical dispersive pad.
- Verify correct position during time-out.

Continued

SAMPLE PLAN OF CARE—cont'd

- Ensure that no weight or stress is placed on body parts and structures during the surgical intervention.
- Check protective padding and safety restraints after all positional changes.

NURSING DIAGNOSIS

Risk for Impaired Skin Integrity related to invasion of body structures, disruption of skin surface

OUTCOME

The patient will regain integrity of skin surface.

INTERVENTIONS (POSTOPERATIVE)

- Monitor incision site for color, redness, swelling, warmth, and pain.
- Avoid positioning patient on incision site.
- Individualize plan according to patient's skin condition, needs, and preferences.
- Monitor incision edges for intactness, bleeding, and drainage.
- Maintain a moist wound healing environment that is balanced with the need to absorb exudate.

NURSING DIAGNOSIS

Acute Pain related to surgical procedure

OUTCOME

The patient will report that the pain management regimen relieves pain to a satisfactory level, using a pain assessment scale.

INTERVENTIONS (POSTOPERATIVE)

- Review use of a pain scale with the patient and family before surgery.
- Identify cultural and value components related to pain.
- Provide patient and family with information on pain management.
- Determine whether the patient is experiencing pain at the time of the initial postoperative assessment.
- Assess and document intensity and location of pain.
- Assume pain is present and treat as ordered.
- Use a preventative approach to keep pain at or below an acceptable level.

- The patient (to the extent possible) should be involved in the process.
- Consistent implementation is necessary.
- The protocol is flexible to allow for implementation with adaptation to patient needs.
- Site marking should focus on operative and other invasive procedures involving right/left distinction (laterality) and multiple structures or multiple levels.
- The protocol is adaptable to all procedures that expose patients to the risk for harm.

Proper implementation of the Universal Protocol should use the following steps:

1. Preoperative verification
   - Relevant documents and studies should be available before the start of the procedure and must be consistent with each other, with the patient's expectations, and with the team's understanding of the intended patient, procedure, and site. As applicable, any implants, special equipment or positioning devices, and availability of ordered blood/blood products must be verified. Missing information or discrepancies must be addressed before starting the procedure. This begins an ongoing process of information gathering, verification, and open team communication.
   - The signed consent should have the correct site and specific procedure documented.
   - The surgical posting should match the procedure.
   - Before receiving sedation the patient (or the patient's representative) should know and be able to state in his or her own words the name of the procedure and the site of surgery.
2. Marking the operative site
   - This is intended to identify unambiguously the intended site of incision/insertion. For procedures with right/left, multiple structures, or multiple levels, the site must show a mark that is visible after the patient has been prepped and draped. Special marking pens are available for this process. Marking pens should only be used for a single patient and then discarded.
   - The surgeon (or another licensed independent practitioner who will be present during the procedure and is ultimately accountable for the procedure) marks the site with "yes" or his or her initials. Check marks or Xs are not appropriate.
3. "Time-out" immediately before starting the procedure (the final verification of the correct patient, procedure, and site).
   - The surgical position, and, if applicable, implants and other required special items may also be verified before the incision is made. At this time, it should also be verified that any flammable prep solutions have dried (see Chapter 2 for a full discussion of fire safety and prep solutions).
   - Active communication among all members of the surgical/procedure team must be consistently initiated by a designated member of the team (usually the registered nurse). This must be conducted in a "fail-safe" mode: that is, the procedure may not be started before any questions or concerns are resolved (this is also referred to as a *hard stop*).
   - Completion of the time-out must be documented on the patient record.

Positioning the Patient. For biliary surgery, the patient is placed in supine position. Arms are placed on padded armboards with the palms up and fingers extended. Armboards are maintained at less than a 90-degree angle to prevent brachial plexus stretch. If there are surgical reasons to tuck the arms at the side, the elbows are padded to protect the ulnar nerve, the palms face inward, and the wrist is maintained in a neutral position (Denholm, 2009). A drape secures the arms. It should be tucked snuggly, but not tightly, under the patient, not under the mattress. This prevents the arm from shifting downward intraoperatively and resting against the OR bed rail. A small positioning aid may be placed under the lower right side of the thorax to elevate the lower rib cage, providing better exposure and access to the viscera in the right upper quadrant of the abdomen. Alternatively, a lateral tilt of the OR bed may be used in combination with reverse Trendelenburg for procedures such as laparoscopic cholecystectomy.

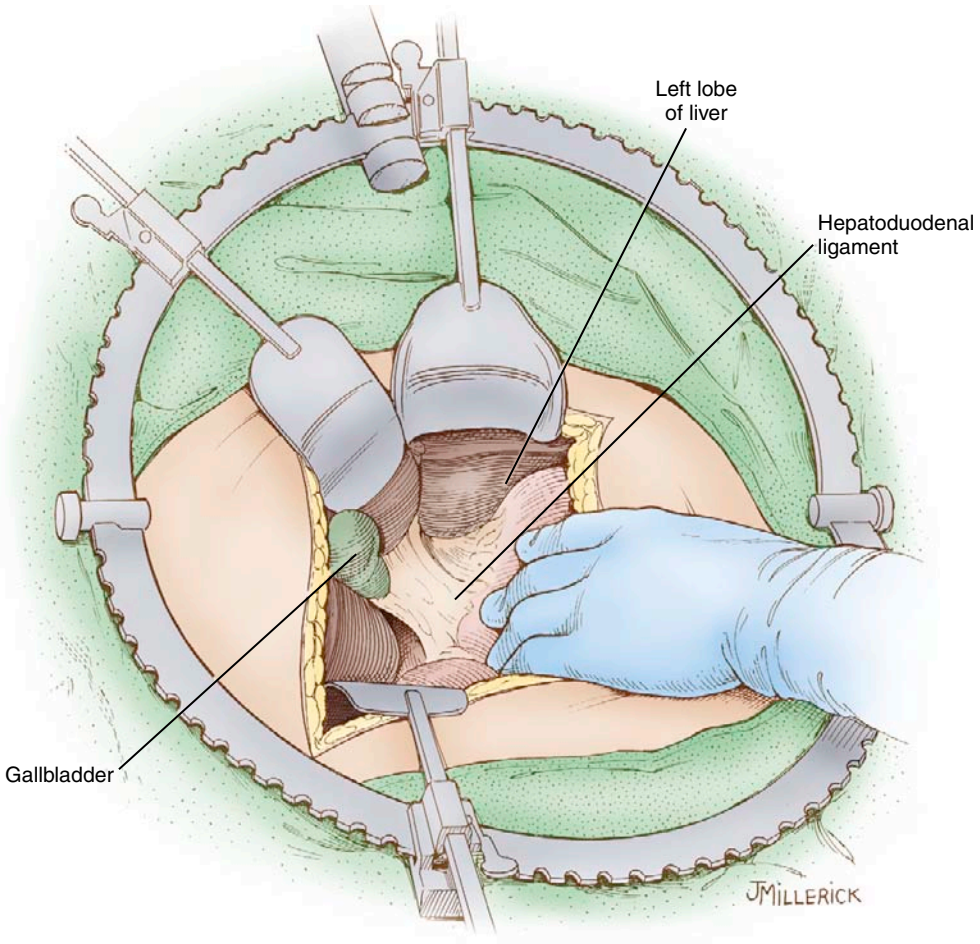


FIGURE 11-7 Bookwalter self-retaining retractor in place to provide optimal exposure to the abdominal viscera.

Positioning for laparoscopic procedures requires the perioperative nurse to exercise caution when applying safety straps. Given that the patient may be placed in a severe side tilt or reverse Trendelenburg position, safety or restraining straps must be placed securely, but not too tightly. Attention is given to proper alignment of the patient's body and extremities, and padded footboards are applied to prevent the patient from slipping. Areas of pressure in the selected surgical position (see Chapter 5) and bony prominences are padded well to prevent interruption of circulation and pressure injury to tissues and neurovascular structures. These precautions are especially important for diabetic, circulatory-impaired, immunocompromised, and elderly patients. Close monitoring of the patient is essential during positional changes, especially in laparoscopic procedures with decreased lighting in the room.

When anticipating an operative cholangiogram, the perioperative nurse must ensure that the OR bed has been equipped and positioned so that C-arm image intensification can be accomplished efficiently. Radiation-protection devices for the surgical team and patient should be available.

Thermoregulation. The risks of intraoperative hypothermia have been well documented (see Chapter 4). When laparotomy is performed, patients are at further risk for hypothermia. To prevent unplanned hypothermia, the perioperative nurse takes affirmative measures to maintain body temperature in the OR (Insler and Sessler, 2006). The environmental temperature and humidity are set to prevent body heat loss caused by evaporation and convection. A forced-air warming blanket placed over the patient's upper body, head, and neck assists in maintenance of body temperature. Minimizing body exposure to ambient air and the use of warm irrigating solutions also support thermoregulation. The temperature of irrigating fluids should be no higher than body temperature (37° C; 98.6° F) (AORN, 2009). A blood- and fluid-warming device may be used by the anesthesia provider to deliver intravenous (IV) fluids at a temperature higher than room air temperature (see Chapter 4). The anesthesia provider commonly monitors the patient's core temperature by use of an esophageal temperature probe when the duration and complexity of the surgical procedure place the patient at risk for hypothermia. Additional comfort measures include using warm blankets before and after surgery.

Application of Sequential Compression Device. Patients undergoing lengthy surgical procedures are at risk for venous dilation and blood pooling in the lower extremities. This may predispose the surgical patient to develop venous thromboembolism (VTE) in the postoperative period. Sequential

SURGICAL PHARMACOLOGY

Chemical Hemostatic Agents

Agent	Chemical Composition	Actions	Perioperative Precautions
Absorbable gelatin: powder or compressed forms (Gelfoam)	Purified porcine gelatin, beaten, dried, and heat sterilized	On areas of capillary bleeding, deposits fibrin, forming a clot. Absorbs 45× its own weight.	Dipped in warm saline or soaked in thrombin. Must be squeezed to remove air.
Absorbable collagen (Collastat, Superstat, Helistat, Lyostypt)	Bovine collagen origin	Collagen activates coagulation mechanism, aggregation of platelets.	Must be kept dry and applied with dry gloves. Do not use in infected areas or in pooled blood.
Microfibrillar collagen (Avitene, INSTAT)	Hydrochloric acid salt of purified bovine corium collagen	Promotes adhesion of platelets and prompt fibrin deposition.	Applied dry. Use firm pressure against bleeding surface.
Oxidized cellulose (Surgicel, Surgicel Nu-Knit)	Absorbable oxidation product of cellulose	On contact with blood, clot forms. Increases in size and forms gel. Absorbs 10× its own weight.	Applied dry. May be sutured in place.
Oxytocin	Synthetic pituitary hormone	Injected directly into uterine muscle during cesarean birth to cause contraction after delivery of baby and placenta. Prevents uterine hemorrhage.	Also may be given intravenously to induce labor.
Phenol and alcohol	Chemical compounds used to electrocoagulate tissue across lumen of appendix	Phenol coagulates proteins, and 95% alcohol neutralizes phenol.	Phenol is caustic and may cause severe burns.
Epinephrine (Adrenalin)	Adrenal hormone	Powerful vasoconstrictor—prolongs action of local anesthetics to decrease bleeding.	Gelatin sponges may be soaked in 1:1000 epinephrine; especially useful in ear and microsurgical procedures.
Tannic acid	Powder from astringent plant	Used on nose and throat mucous membranes to stop capillary bleeding.	Also used in dental procedures.
Silver nitrate	Crystals of silver nitrate compound mixed with silver chloride and molded onto applicator sticks	Astringent and antimicrobial. Seals areas of surgical incisions.	May also be used in treatment of burns.
Thrombin	Enzyme extracted from bovine blood	Accelerates coagulation of blood. Unites rapidly with fibrin to form clot.	May be used topically as a dry powder or as a solution in which gelatin sponges are dipped. May also be sprayed onto site. Topical use only. Loses potency after 3 hr.
Zeolite beads (QuikClot)	Derived from form of volcanic pumice	Beads cause hemostasis by absorbing water from blood.	Used for emergency hemostasis in uncontrollable bleeding or evisceration, especially in trauma. Causes an exothermic reaction. Must be removed, not biodegradable.

Modified from Phillips NF: *Berry and Kohn's operating room technique,* ed 11, St Louis, 2007, Mosby.

compression devices (SCDs) are frequently applied in the OR before commencing lengthy surgical procedures in order to prevent or minimize VTE risks.

Draping the Patient. After the abdominal prep, time must be allowed for the prep solution to dry and vapors to dissipate. This is an essential patient safety precaution when flammable prep solutions are used in conjunction with electrosurgery (or other ignition sources, such as a laser). Sterile towels are then arranged to accommodate the intended incision. A sterile drape sheet may be placed over the patient's lower torso and a laparotomy sheet is then placed to provide a wide sterile field and to cover all exposed body surfaces except the incision site.

Instrumentation. Instrumentation for open (i.e., performed via a laparotomy incision) surgeries of the liver, biliary tract, spleen, and pancreas includes a basic laparotomy set, biliary probes and forceps for dilating and exploring the ducts of the pancreas and biliary tract, vascular clamps, gastrointestinal (GI) clamps, and ligating clips and appliers of all sizes. Linear stapling instruments also should be available. A self-retaining system such as the Bookwalter retractor set (Figure 11-7)

RISK REDUCTION STRATEGIES

Latex Sensitivity and Allergy Guidelines

Natural rubber latex allergy can be a serious and life-threatening condition. Healthcare workers and others who have experienced repeated exposure to latex can develop latex sensitivity or allergy. The following is a list of guidelines that should be instituted in persons with suspected or known latex sensitivity or allergy:

- Identify the patient's risk factors and report them to the OR team. Those at high risk include persons with the following:
  - Myelomeningocele
  - Multiple surgeries, particularly if begun in early infancy
  - A positive serum latex antibody test
  - Occupational exposure to latex products, particularly powdered products
  - Allergy to bananas, kiwi, avocado, stone fruits, raw potato, tomato, papaya, chestnuts
  - History of hives or pruritus after incidental exposure (such as condom use, dental or other procedures)
- Schedule patients with known latex sensitivity as the first procedure of the day if facility is not latex-safe or latex-free.
- Notify the anesthesia department and OR 24 to 48 hours in advance.
- Notify healthcare providers in other perioperative areas of the patient's latex sensitivity status.
- Plan for a latex-safe environment of care:
  - Remove all latex products from the room unless no alternative exists.
  - Obtain a latex-free cart from the designated area.
  - Place a latex precaution card on the OR door.
  - Look for the signs and symptoms of latex reaction: contact rash, wheezing, bronchospasm, chest pain or tightness.

Modified from Association of periOperative Registered Nurses (AORN): *Perioperative standards and recommended practices,* Denver, 2009, The Association; Brown RH et al: The final steps in converting a health care organization to a latex-safe environment, *Jt Comm J Qual Patient Saf* 35(4):224-228, 2009; Phillips N: *Berry and Kohn's operating room technique,* ed 11, St Louis, 2007, Mosby.

provides excellent exposure of the abdominal viscera. In addition, a flexible choledochoscope, Cavitron ultrasound suction aspirator (CUSA), intraoperative ultrasound, laser, argon beam coagulator, harmonic scalpel, and electrosurgical unit (ESU) may be required to perform certain procedures on the hepatobiliary system. Safe practices when using devices that generate surgical smoke require the use of a smoke evacuation system and accessories in both open and laparoscopic procedures (AORN, 2009).

The basic equipment for minimally invasive surgical (MIS) procedures consists of two high-density monitors, an insufflation unit, ESU, light source, camera, and 0-degree and 30-degree telescopes in 10-mm and 5-mm sizes. A printer is optional. An ultrasonic dissecting unit is often used with MIS procedures. Trocars and sleeves are available in reusable, disposable, and resposable designs. Trocars and sleeves are commonly designed to accommodate 10-mm to 5-mm instruments and 12-mm to 5-mm accessories and instruments. MIS instruments include scissors and shears, dissecting forceps, atraumatic grasping forceps, hooks, Babcock clamps, retractors, needles, suturing devices, pouches, suction-irrigating devices, and mechanical stapling devices.

Thrombin, Gelfoam, Surgicel, Avitene, and other chemical hemostatic agents (Surgical Pharmacology) should be available in the OR suite. Radiographic dye, supplies, and radiation-protection devices will be required if intraoperative radiography or angiography is planned as part of the procedure.

Drainage Materials. Tubes and catheters are selected for the areas to be drained. If a defective drain is used, a free fragment may remain in the wound on removal of the tube. Thus the scrub person should note the condition of all drainage materials and should test them for patency before they are placed in the patient.

Soft rubber or latex tissue drains may be used after an open cholecystectomy or a choledochostomy. Verify that the patient has no latex allergy before using these devices and substitute nonlatex drains if necessary (Risk Reduction Strategies). The surgeon will prepare a latex rubber T-tube drain of suitable size after exploring the duct. The center of the crossbar is notched opposite the junction of the vertical limb so that its ends will bend more readily during removal. The ends are beveled and tailored to fit the duct.

Drains are usually exteriorized through separate stab wounds and anchored to skin edges to prevent their retraction. The perioperative nurse should document the types of drains and reservoirs inserted during the procedure. Depending on institutional protocol, these may be identified with an applied label. All drains and their locations should be included in the perioperative nurse's hand-off report to the nursing unit to which the patient is transferred postoperatively.

Aseptic Considerations. When the common duct is opened or an anastomosis is established between a duct and other parts of the alimentary tract, it may be the institution's policy or the surgeon's preference to isolate contaminated instruments and materials from the remainder of the operative field, as described for GI surgery (Chapter 10). The wound is classified according to a standard system: any procedure in which the alimentary tract is entered under controlled conditions and without unusual contamination is considered a *clean contaminated wound;* if there is gross spillage, however, the wound is classified as *contaminated.* Proper wound classification is considered an important predictor of postoperative SSI (Phillips, 2007; Meakins and Masterson, 2007).

Blood Products. During the preoperative verification process, the perioperative nurse should ascertain the type and amount of blood and blood products, both requested and available, as well as ensure the patient has a signed consent for transfusion. Constant, ongoing evaluation of blood loss is communicated to the anesthesia provider and surgical team during the procedure. When additional blood or blood products are required, the perioperative nurse communicates with blood bank personnel so that products are readily available and carries out the required steps to verify blood/blood products with the anesthesia provider before transfusion.

Autologous blood or donor-directed blood products may be used in elective procedures involving the liver, pancreas, spleen, and biliary tract. Cell-saver devices may be used when

AMBULATORY SURGERY CONSIDERATIONS

Same-Day Surgery versus Overnight Stay: Laparoscopic Gallbladder Surgery

Many patients have same-day surgery for elective laparoscopic cholecystectomy. A meta-analysis revealed that 80.5% of the patients were discharged the day of surgery with few untoward effects. The analysis demonstrated no significant differences in morbidity, prolongation of hospital stay, readmission rates, or pain with same-day procedures vs. overnight stays. Quality of life, patient satisfaction, and return to normal activity were also not significantly different in the group that went home the same day versus the group that was discharged the following day (or 24 hours after surgery).

As surgical stays for laparoscopic cholecystectomy become shorter, sometimes with a 4- to 8-hour observation before discharge, patient education and discharge planning become even more critical. Before the patient departs the ambulatory surgery center, the nurse verifies that the patient is hemodynamically stable, oriented, and alert; tolerates oral fluids; has voided; has dressings that are clean and dry; and has resolved or controlled postoperative nausea and vomiting (PONV). Important discharge preparation includes information about early and continuing ambulation to decrease VTE risk, diet, changes in bowel patterns (feces may pass more quickly after cholecystectomy), steps to take if diarrhea is persistent, when to call the surgeon or other healthcare provider (for routine follow-up as well as problems with bleeding, fever, abdominal distention, persistent pain, jaundice, persistent cough, or shortness of breath), and medication management strategies (these are especially important if a bile acid binder has been prescribed). After reviewing these and other important discharge planning information, have the patient and family, if applicable, "teach back" instructions in their own words and allow an opportunity to ask questions.

Adapted from Gurusamy K et al: Meta-analysis of randomized controlled trials on the safety and effectiveness of day-case laparoscopic cholecystectomy, *Br J Surg* 95(2):161-168, 2008; Society of American Gastrointestinal and Endoscopic Surgeons (SAGES): *Patient information for laparoscopic gallbladder removal (cholecystectomy) from SAGES,* available at www.sages.org/publication/id/PI11/. Accessed April 1, 2009; Thomas BR: Cholecystectomy: open surgery or laparoscopy, *Nursing* 39(2):36-39, 2009.

PATIENT AND FAMILY EDUCATION

General Discharge Instructions for the Patient Undergoing Surgery for Disorders of the Liver, Biliary Tract, Pancreas, or Spleen

- Keep incision area clean and dry.
- Swelling inside the GI tract may produce a feeling of tightness; this should dissipate in 6 to 8 weeks.
- Solid foods should be added to the diet gradually. Chew solid foods well, and avoid gulping or eating fast or swallowing large, bulky portions.
- Avoid carbonated beverages for 3 to 4 weeks to help prevent gas bloating.
- Plan small, frequent meals because the feeling of fullness comes quickly.
- Increase exercise gradually to return to normal activities of daily living. Exercise regularly.
- Make an appointment for follow-up care with the surgeon.

potential contamination of the blood from bile or bowel does not exist.

Evaluation

Evaluation of the patient after surgery includes examination of all skin surfaces and comparison with preoperative assessment data. Abdominal drains, chest drainage systems, urinary drainage systems, and peripheral infusion lines are assessed for patency. Fluid volume use and loss are documented and communicated appropriately. A report of the patient's history, preoperative assessment, intraoperative events, and postoperative evaluation is communicated to the postanesthesia care unit (PACU) or surgical intensive care unit (SICU) nurse during the hand-off report.

Evaluation of patient status can be phrased as outcome statements such as the following:

- The patient verbalized management of anxiety and ability to cope, expressed knowledge of his or her psychologic responses to the planned procedure, and indicated an understanding of the sequence of perioperative events.
- The patient maintained equilibrium in fluid volume; hematocrit remained in the expected range; vital signs were stable.
- The patient's intraoperative core body temperature remained consistently in the 35.5° to 37.2° C (96° to 99° F) range.
- The patient's surgical incision was dressed aseptically and was dry and intact. There will be no clinical signs or symptoms of infection.
- At the conclusion of the surgical procedure, skin surfaces were clean, intact, and free of reddened areas; adequate capillary filling was noted after blanching of tissues. The patient had palpable pulses in all distal extremities and showed no evidence of diminished neuromuscular function.
- The patient will be able to perform activities of recovery with acceptable levels of pain.

Patient and Family Education and Discharge Planning

The length of time and complexity of recovery vary greatly for patients undergoing surgical intervention for disorders of the liver, biliary tract, pancreas, or spleen. Laparoscopic cholecystectomy may be performed on an ambulatory surgery basis with extended recovery and observation of 6 to 8 hours (Ambulatory Surgery Considerations). In contrast, patients undergoing liver transplant or resection may require extensive recovery that includes a stay in the intensive care unit.

Patients undergoing laparotomy for surgical procedures on the liver, biliary tract, pancreas, or spleen may have varying degrees of postoperative edema, decreased GI peristalsis, and alterations in tissue oxygenation and lymphatic drainage, depending on the amount of manipulation, resection, and trauma to the normal anatomic structures of these viscera. General anesthesia is commonly administered. Smooth muscle relaxation is imperative for most major abdominal procedures. The patient usually experiences decreased peristalsis for 2 to 5 days after laparotomy. A nasogastric (NG) tube or gastrostomy tube is inserted during the procedure to evacuate large volumes of gastric juices. Diet is introduced

only after bowel sounds return. The patient may experience nausea and vomiting if food or oral fluid is introduced too early for the GI system to function with normal absorption and motility.

Coughing and deep breathing are important for the patient recovering from general anesthesia and abdominal surgery. Splinting of the abdominal muscles and use of an incentive spirometer assists the patient in postoperative coughing and deep breathing. Early ambulation assists the patient to regain overall muscle tone and prevents VTE in the lower extremities.

Pain management is very important in the patient's recovery and discharge planning. For most patients undergoing abdominal surgery, patient-controlled analgesia (PCA) or epidural analgesia may be used for better and more consistent control of pain and discomfort in the first 1 to 3 postoperative days. Narcotics may, however, add to the length of time for normal bowel peristalsis to return and their use is monitored closely after the third postoperative day.

General discharge instructions for the patient undergoing surgery for disorders of the liver, biliary tract, pancreas, or spleen might include the recommendations found in the Patient and Family Education box. In addition to such general instructions, surgical patients and their family or caregiver should receive surgery-specific special instructions. The nurse should review any medications the patient will be taking after discharge, and should explain the purposes, dosages, schedules, and routes of administration for each, as well as any side effects to be reported. Both verbal and written instructions are provided, with phone numbers of those to call if questions arise (Canobbio, 2006). Patients should "teach back," in their own words, all instructions and should be able to state the name of their surgical procedure. For most patients, a healthcare provider should be notified if any of the following develop:

- Persistent fever (body temperature of 38.3° C [101° F] or higher)
- Bleeding
- Increased abdominal swelling or pain
- Chills
- Persistent cough or shortness of breath
- Persistent pain, redness, swelling, or purulent drainage from incision sites

Follow-up care may also require providing referrals for home care (or other) services.

Surgical Interventions

SURGERY OF THE BILIARY TRACT

Cholecystectomy (Open Approach)

Cholecystectomy is removal of the gallbladder. It is performed for the treatment of diseases such as acute or chronic inflammation (cholecystitis) or stones (cholelithiasis) (Box 11-1). Most of these procedures are done laparoscopically. The few contraindications to the laparoscopic approach include suspected or diagnosed cancer of the gallbladder, third trimester of pregnancy, cirrhosis with portal hypertension, or poor pulmonary or cardiac reserve (Chari and Shah, 2008); these patients may not be able to tolerate the pneumoperitoneum required in laparoscopy. Further, if the surgeon is unable to identify all the anatomic structures during a laparoscopic approach, conversion to an open procedure becomes necessary.

Procedural Considerations. A basic laparotomy set and biliary instruments are used when cholecystectomy is performed through an open abdominal incision. The patient is positioned supine and receives a general anesthetic. After the patient is intubated, the anesthesia provider inserts an NG tube. Antibiotic prophylaxis may be administered. When an operative cholangiogram is anticipated, the perioperative nurse must ensure that the OR bed has been equipped and positioned so that C-arm image intensification can be efficiently accomplished. Radiation-protection devices for the surgical team and patient are used during image intensification.

Operative Procedure

1. The abdominal cavity is opened through a right subcostal or upper midline incision.
2. Hemostasis of capillary vessels is achieved with electrocoagulation. Larger vessels are clamped with hemostats and ligated with suture material.
3. Retractors and laparotomy packs are placed as the abdominal cavity is carefully examined.
4. The common duct is palpated for evidence of stones and pathologic conditions are determined.
5. Harrington, Deaver, or self-retaining retractors, such as an upper-hand or Gomez retractor, are placed to provide exposure. Long tissue forceps and suction are used to manipulate tissues. The surrounding organs are isolated from the gallbladder region by moistened laparotomy packs and deep retractors.
6. To facilitate gentle traction, Péan forceps are usually placed on the body of the gallbladder (Figure 11-8, *A*).
7. The peritoneal fold overlying the junction of the cystic and common duct is incised with a #7 knife handle and a #15 blade, long Metzenbaum scissors, and forceps. Suction is available, and bleeding vessels are clamped and ligated or electrocoagulated.
8. Adhesions are separated by blunt dissection with small, round, dry dissector sponges; sponges on holders; and blunt right-angled clamps.
9. Dissection is continued to expose the neck of the gallbladder, the cystic artery, and the cystic duct. Lateral traction on the gallbladder neck allows incision of the peritoneum overlying the triangle of Calot.
10. Dissection is continued to expose the cystic artery as it enters the wall of the gallbladder.
11. On complete exposure and visualization of the branches, the cystic artery is doubly ligated with silk or clamped with ligating clips and divided (Figure 11-8, *B*).
12. Occasionally a third ligature or clip may be used. If the cystic artery has more than one branch, each is ligated and divided separately.
13. Abnormalities of the arterial and ductal anatomy are common (Figure 11-9), and the surgeon and assistant work with meticulous care to identify these structures.

BOX 11-1

Overview of Cholelithiasis and Cholecystitis

The two most common diseases of the biliary tree are *cholelithiasis* (stone formation in the gallbladder) and *cholecystitis* (inflammation of the gallbladder). These conditions may occur alone but usually occur simultaneously. Gallstones are becoming more common in the United States, affecting an estimated 8% to 10% of adults. Cholecystectomy is one of the most common surgeries performed. Gallstones are usually found in individuals older than 40 years, with a high incidence in people of Pima and Chippewa descent, white women, and African Americans.

Clinical conditions that may predispose one to gallstones include diabetes, obesity, cirrhosis, ileal disease or resection, cancer of the gallbladder, and pancreatitis. Cholecystitis usually results from obstruction of the cystic duct from gallstones (acute calculous cholecystitis); in a few patients, however, it results from stasis, bacteria, or sepsis (acute acalculous cholecystitis).

PATHOPHYSIOLOGY

The pathophysiology of gallstones depends largely on the following factors: the type of stone, the stone's location within the ductal system, and the nature of its occurrence (i.e., acute or chronic). Gallstones are formed as a result of the imbalance of cholesterol, bile salts, and calcium. The metabolism of cholesterol is often altered so that the bile is supersaturated, leading to precipitation and formation of stones. Cholesterol stones are the most common type and occur most often in women. Mixed stones are a combination of pigment and cholesterol stones. The exact cause of gallstone formation is unclear. Contributing factors may include the following:

- *Supersaturation of bile with cholesterol.* Bile is composed mainly of water, with other components including cholesterol, bile salts, and pigments. Cholesterol alone is insoluble in water; it must be combined with other components (e.g., bile salts) to remain in solution. When bile salts are insufficient to maintain cholesterol in solution, cholesterol crystals form.
- *Bile stasis.* This occurs when the gallbladder has not contracted normally in response to a meal and the bile is stagnant and then becomes thick and concentrated. This occurs in patients receiving total parenteral nutrition (TPN) for a prolonged period. Approximately 50% of these patients develop "sludge" (a mucous gel composed of calcium bilirubinate and cholesterol crystals) in the gallbladder by week 6 of TPN therapy. Gallstones frequently occur during periods of fasting or dieting, during which there is a lack of stimulus for the gallbladder to contract.
- *Nucleation.* A nucleus (nidus) is formed of agents such as bacteria, bile, pigments, cellular debris, and calcium salts. Additional substances aggregate around this nucleus, forming a stone.
- *Genetics* may be a factor, as evidenced by increased prevalence in people of Pima and Chippewa descent.

Some stones may form and pass through the ducts without causing clinical manifestations (asymptomatic cholelithiasis). Symptomatic cholelithiasis occurs when stones intermittently become lodged in the cystic duct, causing biliary colic (episodic pain in the right upper quadrant or epigastric area). The pain usually occurs after meals, especially high-fat meals, as a result of increased intraluminal pressure when the gallbladder attempts to contract to release bile (a normal response to food entering the duodenum) against the obstructing stone.

Cholecystitis develops as stones become impacted within the cystic duct, causing unyielding obstruction, edema, distention, and inflammation of the gallbladder. In chronic cholecystitis, gallstones remain, causing recurrent obstructions and producing changes in the gallbladder wall from recurrent edema and inflammation. The muscular coat becomes fibrous, and the gallbladder functions less effectively.

COMPLICATIONS

Edema and distention of the gallbladder walls decrease blood supply, resulting in patchy areas of necrosis and gangrene. Perforation of these areas can then occur. Bile leakage through these perforations into the peritoneum results in peritonitis. Abscess formation may occur if secretions from the ruptured gallbladder are confined by the omentum or other adjacent organs (e.g., colon, stomach, duodenum, pancreas).

Stone migration from the gallbladder to the common bile duct (CBD) may cause cholangitis (acute CBD inflammation). The presence of gallstones in the CBD is called choledocholithiasis. CBD stones are a major source of morbidity in patients with symptomatic gallstone disease. Stone migration to the ampulla of Vater can cause pancreatitis.

From Lewis SL et al, editors: *Medical-surgical nursing: assessment and management of clinical problems,* ed 7, St Louis, 2007, Mosby.

14. The true junction of the cystic duct with the common bile duct is visualized.
15. The cystic duct is identified and carefully dissected down to its junction with the hepatic duct.
16. Any stones in the cystic duct are "milked" back into the gallbladder, and a tie is placed around the proximal part of the cystic duct.
17. If necessary, a cholangiogram is performed at this time (see following procedure: Intraoperative Cholangiogram). If a cholangiogram is not done, the cystic duct is doubly ligated and divided (Figure 11-8, *C*). A fine, absorbable transfixion suture may be used on the stump of the cystic duct near the common bile duct.
18. The gallbladder is then dissected from the liver bed and removed (Figure 11-8, *D*).
19. All bleeding is controlled; reperitonealization of the liver bed, if indicated, is accomplished with interrupted or continuous fine absorbable intestinal sutures.
20. A closed suction drain may be inserted near the cystic duct stump. The free end of the drain is exteriorized through a stab wound in the lateral abdominal wall.
21. The wound is closed in layers and a dressing applied.

Intraoperative Cholangiogram

An intraoperative cholangiogram is usually performed with both open and laparoscopic cholecystectomy to visualize the common bile duct and the hepatic ductal branches, and to assess the patency of the common bile duct.

Procedural Considerations. An intraoperative cholangiogram requires fluoroscopy to visualize the filling of the ducts. Before the patient's arrival in the OR, the perioperative nurse ensures that a radiolucent bed is available or prepares the OR bed with an image-intensification attachment. The perioperative nurse should ensure that the patient has not had previous allergic reactions to the x-ray medium before

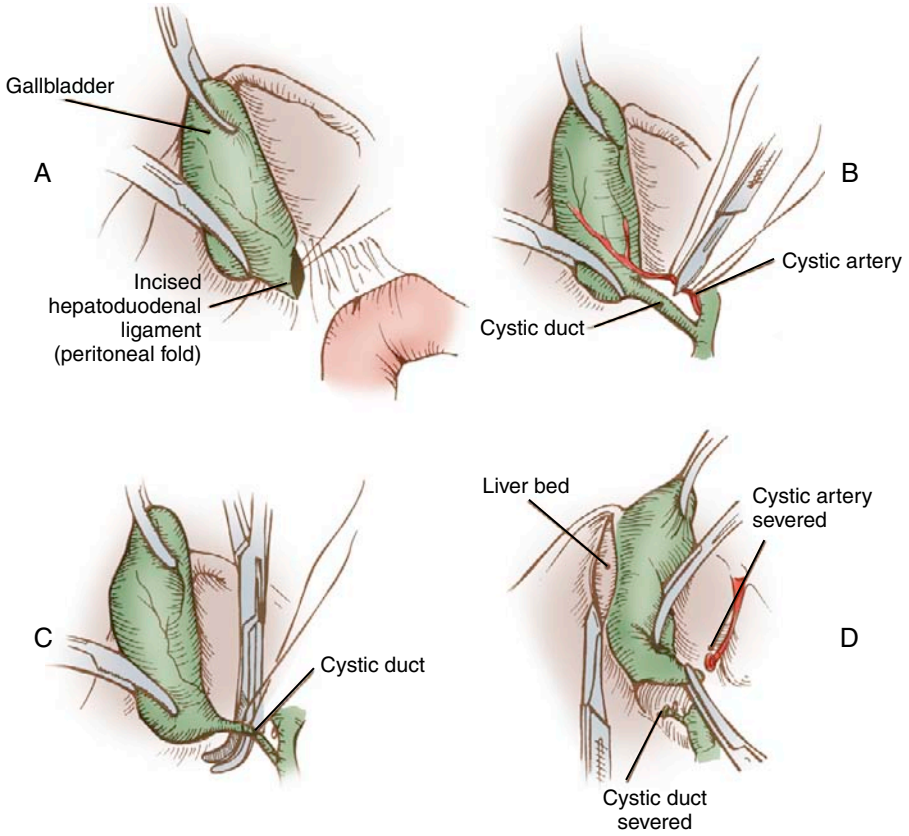


FIGURE 11-8 Cholecystectomy. **A**, With Péan forceps in place, gentle traction is maintained as peritoneum over the triangle of Calot is incised. **B**, Cystic artery is clearly visualized, doubly ligated, and divided. **C**, Cystic duct is carefully dissected and identified before forceps and ligatures are applied. **D**, Dissection of gallbladder from liver bed is completed.

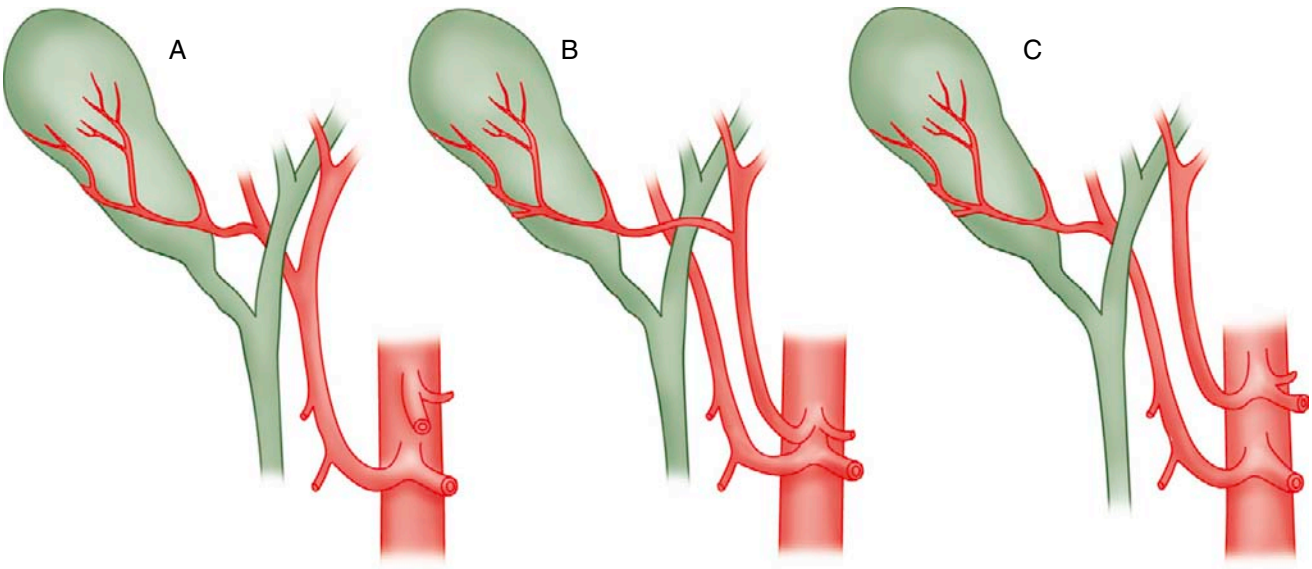


FIGURE 11-9 Arterial blood supply of the liver and biliary system is quite variable. **A**, The most common anatomic arrangement is a cystic artery arising from the right hepatic artery. **B**, A dual hepatic blood supply is found in 15% to 20% of patients, with the right hepatic artery arising from the superior mesenteric artery in a significant number of patients, as in **C**.

dispensing the pharmaceutic agent to the sterile field. Medication safety practices should be followed for labeling and dispensing all medications on and off the sterile field. Protection such as x-ray aprons or leaded shields is used for all members of the surgical team and the patient. As the patient's abdomen remains open while the x-ray equipment is positioned directly over the operative site, appropriate draping to maintain asepsis is necessary. Radiopaque sponges and any unnecessary instrumentation are removed from the abdominal site to avoid obscuring the view of the contrast medium filling the ducts.

The scrub person prepares a cholangiocatheter by attaching a stopcock with a 20-ml syringe of saline and a 20-ml syringe of contrast medium to the Luer-Lok ports. All air bubbles are removed because they might be misinterpreted as gall duct stones on the x-ray film.

Intraoperative Procedure

1. The cholangiocath is irrigated with saline before and during its insertion into the cystic and common bile ducts.
2. The cholangiocath is inserted into the duct using atraumatic grasping forceps. Irrigation during insertion facilitates dilation and reduces trauma to the ductal lumen.
3. The cholangiocath is anchored in the lumen of the common bile duct by the surgeon's preferred method. The more common methods are applying a ligaclip proximal to the insertion site; tying or suturing the catheter in place; or using a ring-jawed holding clamp, such as a Swenson clamp, that has been designed specifically for this purpose.
4. With placement of the cholangiocath confirmed and anchored, all radiopaque sponges, instruments, and obstructing equipment are removed from the field.
5. The surgical field is draped with a sterile drape sheet to maintain asepsis of the wound and field. The image-intensifier equipment (C-arm) is positioned, as the surgeon redirects the stopcock to allow for injection of the contrast medium. If stones are found, the surgeon removes them under fluoroscopic guidance.

Laparoscopic Cholecystectomy

Laparoscopic cholecystectomy is the surgical treatment of choice for patients with gallbladder disease who meet the appropriate criteria for safe laparoscopic intervention. Preoperative evaluation of patients having laparoscopic cholecystectomy differs little from that for patients scheduled for open cholecystectomy. For patients with a history of peptic ulcer disease, a flexible esophagogastroduodenoscopy (EGD) may be performed to rule out existing disease. For patients with suspected ductal stones, a preliminary ERCP or other diagnostic evaluation is often done. A laparoscopic procedure always has the potential to be converted to a laparotomy—a potential the patient should be informed about before the surgical procedure (Research Highlight). Laparotomy instrumentation and supplies should be available in the OR.

RESEARCH HIGHLIGHT

Identifying Risk Factors for Complications of Laparoscopic Cholecystectomy

Even though laparoscopic cholecystectomy (LC) is the treatment of choice for cholecystitis, perioperative nurses anticipate possible conversion to an open procedure and have the necessary equipment and supplies available for a "difficult cholecystectomy." In this study, researchers used a large, prospective database to attempt to accomplish two objectives: (1) identify perioperative risk factors that might be used to predict a difficult cholecystectomy and (2) determine the relationship of the risk factors to perioperative complications for LC. These complications were divided into two categories: (1) local intraoperative and postoperative complications (such as bleeding or bowel injury) and (2) systemic complications (such as myocardial infarction or pulmonary embolism).

There were 22,953 patients in the study database. Their mean age was 54.5 years, there were twice as many males as females, and the majority underwent LC for chronic cholecystitis. While the overall complication rate was 7%, the rate was higher for patients with acute cholecystitis. Using multivariate analysis, the researchers identified the following associated factors for increased local intraoperative complications:

- Male gender
- Duration of the procedure
- Increased body weight
- Surgeon experience

Postoperative local complications were associated with the following factors:

- Male gender
- Patient age
- Intraoperative complication
- ASA class III or IV
- Increased body weight
- Emergency surgery
- Duration of the procedure

Systemic postoperative complications were associated with the following factors:

- Conversion to an open procedure
- ASA class III or IV
- Emergency surgery
- Duration of the procedure

During the OR briefing, perioperative nurses, the anesthesia provider, and the surgeon can use this information to review and communicate possible risks based on assessment findings. Physical characteristics (gender, age, body weight), ASA class, and clinical reason for the procedure (acute or chronic cholecystitis) can be used to estimate the risk of complications. A well-prepared team can mitigate against extending the duration of the surgery by good planning; complication rates in this study were 4 times higher for procedures lasting more than 2 hours.

Adapted from Giger UF et al: Risk factors for perioperative complications in patients undergoing laparoscopic cholecystectomy: analysis of 22,953 consecutive cases from the Swiss Association of Laparoscopic and Thoracoscopic Surgery database, *J Am Coll Surg* 203:723-728, 2006.

Procedural Considerations. Patients are generally admitted to the ambulatory surgery center (ASC) on the morning of surgery and will commonly require less than a 24-hour stay or admission to an extended recovery unit (ERU). A general anesthetic is used, and antibiotic prophylaxis may be administered in the immediate preoperative period. The following instrumentation, supplies, and equipment are required for laparoscopic cholecystectomy: laparoscope, two 5-mm trocars and sheaths, two 10-mm or 11-mm trocars and sheaths (trocar size depends on surgeon preference and may vary), a #7 knife handle with a #11 blade, multiple clip appliers, blunt grasping forceps (an assortment of alligator, Babcock, and

spatula), and laparoscopic scissors. A laparoscopic video unit and secondary "slave" monitor, laparoscopic camera and control unit, light source, CO_2 source and insufflation unit, ESU, suction-irrigator (disposable), filtered insufflation tubing (disposable), and a pressure bag for IV saline 0.9% are commonly used. Instrumentation and supplies for laparoscopic common bile duct exploration should be available in the room. This may include a balloon-tipped Fogarty catheter, wire baskets, dilators, a T-tube, and a small, flexible choledochoscope. The patient is positioned supine with the usual comfort and safety measures observed. A Foley catheter (for bladder decompression) and an NG tube (for decompression of the stomach) will be inserted. Anesthesia is administered, the time-out completed, and the patient then placed in reverse Trendelenburg's position of 10 to 20 degrees.

Pneumoperitoneum may be accomplished using the closed or open technique. In the closed technique, a special hollow insufflation needle (Veress) with a retractable cutting sheath is inserted into the peritoneal cavity through a supraumbilical incision and used for insufflation. In the open technique, sometimes termed the *Hasson technique,* a small incision is made above or below the umbilicus into the peritoneal cavity. A blunt-tipped cannula (Hasson) with a gas-tight sleeve is inserted, and then insufflation takes place. This approach is used for patients who have had a prior abdominal incision near the umbilicus or for those who have the potential for intraperitoneal adhesions. The Hasson technique may also use sutures, placed on either side of the sleeve, to anchor and hold the sleeve in place.

CO_2 is the gas of choice for pneumoperitoneum. Gas flow is initiated at 1 to 2 L/min. Elevated CO_2 levels and respiratory acidosis may occur because CO_2 diffuses into the patient's bloodstream during laparoscopy. Intraabdominal pressure is normally between 8 and 10 mm Hg and is commonly used as an indicator for proper Veress needle placement by the surgeon. If the pressure gauge indicates a higher pressure, the needle may be in a closed space (such as fat), be buried in omentum, or be in the lumen of the intestine. The perioperative nurse should set the insufflation unit to a maximum pressure of 15 mm Hg. When intraabdominal pressure reaches 15 mm Hg, the flow will stop. Pressure higher than 15 mm Hg may result in bradycardia or a change in blood pressure, or may force a gas embolus into an exposed blood vessel during the operative procedure. Most insufflation units are equipped with an alarm mechanism to alert the operative team if the intraabdominal pressure is exceeded. Alarm systems on clinical equipment should be activated and sufficiently audible with respect to competing noise in the OR. The surgeon may frequently ask what the pressure reading is, as may the anesthesia provider.

Operative Procedure

1. A small skin incision is made in the folds of the umbilicus with a #11 blade on a #7 knife handle.
2. Pneumoperitoneum is created using either the open or the closed technique.
3. An 11-mm trocar is inserted through the supraumbilical incision; this becomes the umbilical port.
4. The laparoscope with attached video camera is inserted through the umbilical port and the peritoneal cavity is examined. The surgeon usually stands on the left side of the patient while the first assistant stands on the right. Video monitors are positioned at eye level at both the right and left sides of the operative field. The patient is then placed in a 30-degree reverse Trendelenburg's position and tilted slightly to the left.
5. Three additional trocars are inserted into the peritoneal cavity under direct visualization of the laparoscopic view (Figure 11-10).
6. Blunt grasping forceps are inserted through the medial 5-mm port to grasp the gallbladder.
7. The gallbladder is retracted laterally (Figure 11-11, *A*), exposing the triangle of Calot. The junction of the gallbladder and cystic duct is then identified. The endoscopic dissector, hook, and scissors are used to partially dissect the base of the gallbladder off the liver bed. Electrosurgery is also used. The electrosurgical instrument (active electrode) may have a channel through which suction can be applied to evacuate smoke plume. Some disposable instruments permit suction, electrocoagulation, and irrigation through the same instrument.
8. Hemoclips are placed proximally and distally on the cystic artery and the artery is divided. The use of a disposable, preloaded, multiple-clip applier assists in the placement of ligating clips in a more efficient manner than a singly loaded, reusable applier.
9. An intraoperative cholangiogram may be performed by placing a hemoclip proximally on the cystic duct, incising its anterior surface, and passing the cholangiogram catheter into the duct. Once the cholangiogram is completed, two clips are placed distally on the cystic duct and it is divided (Figure 11-11, *B*). A pretied loop ligature may be used if the duct is large.
10. Attention is then given to dissecting the gallbladder out of its fossa.
11. The surgical site is inspected for hemostasis and the gallbladder dissected off the liver.

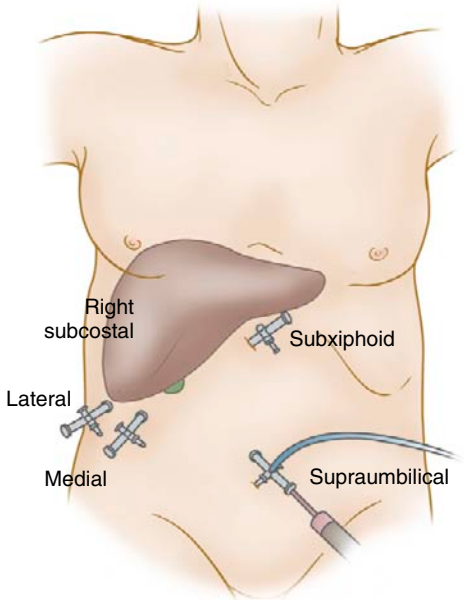


FIGURE 11-10 Trocar placement for laparoscopic cholecystectomy.

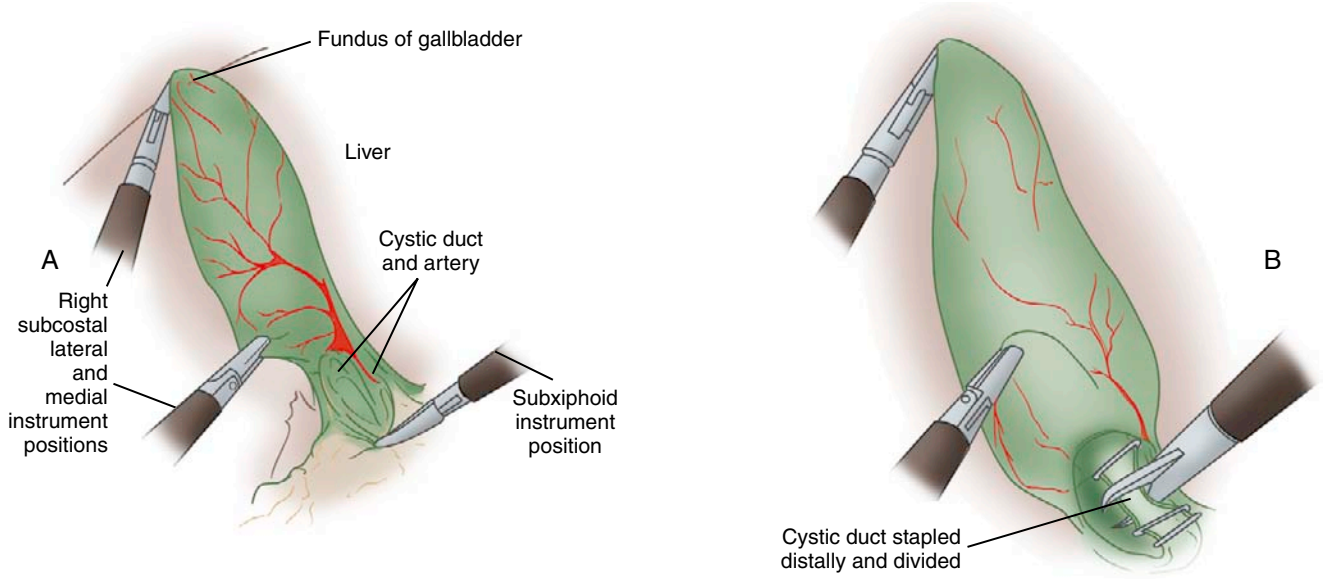


FIGURE 11-11 **A**, The gallbladder is retracted cephalad (using the grasper on the fundus) and laterally at the infundibulum. The peritoneum overlying the gallbladder infundibulum and neck and cystic duct is divided bluntly, exposing the cystic duct. **B**, Once the gallbladder–cystic duct junction has been clearly identified, clips are placed proximally and distally on the duct and it is sharply divided.

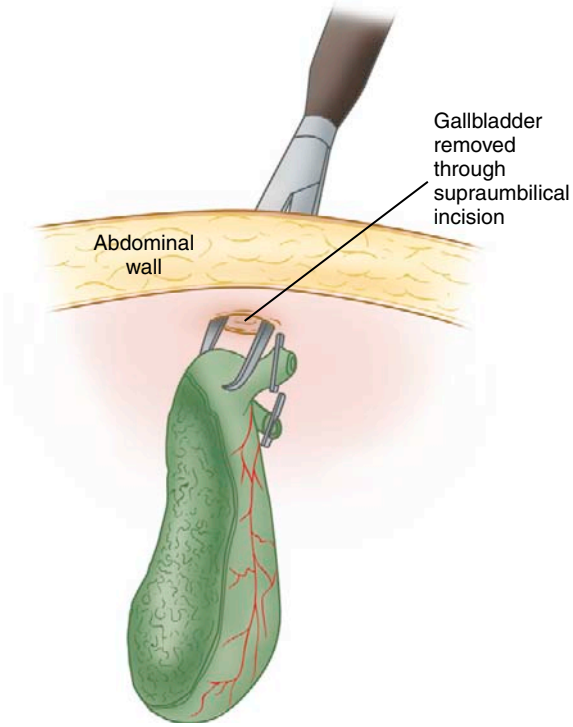


FIGURE 11-12 The gallbladder being removed through the supraumbilical incision.

12. The gallbladder is then removed through the umbilical port (Figure 11-12). An Endo-Bag or similar specimen-retrieval accessory may be used to secure the gallbladder for extraction.
13. The peritoneal cavity is decompressed. The port sites are closed and dressed with Steri-Strips.

Robotic-Assisted Laparoscopic Cholecystectomy

Procedural Considerations. Robotic surgery enables surgeons to perform more advanced and complex procedures. For this surgery, the surgeon controls two robotic arms with laparoscopic instruments and cameras while sitting at a console. Surgical assistants are positioned at the field. Many laparoscopic instruments have been developed to facilitate abdominal procedures. These include a bladeless trocar to minimize injury on entry and the ultrasonic shear to facilitate laparoscopic dissection with hemostasis. An endoscopic stapler and suture device may be used to facilitate intracorporeal anastomosis and knot-tying techniques (Nguyen et al, 2004). Laparoscopic cholecystectomy was one of the first procedures to demonstrate the utility of surgical robots in general surgery (Bodner et al, 2005a) (Research Highlight). For cholecystectomies, robotic operative times may be slightly longer because of equipment setup, but clinical outcomes are equivalent. The view of the ductal anatomy is subjectively superior with robotic surgery because of the magnified three-dimensional picture, which may reduce bile duct injuries (Hanley and Talamini, 2004).

The da Vinci Surgical System (Intuitive Surgical Inc., Sunnyvale, Calif) and the Zeus Robotic Surgical System (Computer Motion, Inc., Goleta, Calif) are two robotic systems used for minimally invasive laparoscopic surgery. The Automated Endoscopic System for Optimal Positioning (AESOP) can be "trained" to recognize the surgeon's voice (Jacobsen et al, 2004). A CT scan can also be imported into the console so that the surgeon can perform preoperative planning and surgical procedure rehearsal (Hanley and Talamini, 2004). It is even possible to perform telesurgery—the complete separation of the surgeon from the operative field. Transcontinental cholecystectomies have occurred successfully between Strasbourg, France, and New York City (Bodner et al, 2005a). For advantages and myths about robotic surgery see Box 11-2 and Table 11-4.

RESEARCH HIGHLIGHT

Robot-Assisted Laparoscopic Cholecystectomy

Laparoscopic cholecystectomy has been the gold standard since 1987. Robots were first used in surgery in the mid-1990s. With current robotic systems, the surgeon sits at an operative console with three-dimensional imaging and handheld controls. Movement of the controls follows the movement of the instrument's tip.

The Mayo Clinic in Scottsdale, Arizona, reviewed all robotically assisted laparoscopic cholecystectomies from October 2002 to July 2003. The Zeus Robotic Surgical System was used to dissect the cystic duct and artery, and the surgical assistant at the OR bed placed the clips on the cystic duct and artery. The robot was used to dissect the gallbladder from the liver. Cholangiocatheters were inserted into the cystic duct with the robotic instruments. Nineteen patients underwent the procedure. Sixteen were completed robotically. Conversions to laparoscopic techniques took place as a result of malfunctioning instruments; however, open procedures were not necessary. The mean setup time was 28.1 minutes (range 7 to 51 minutes). The mean hospital stay was 0.9 day (range: same-day release to 2 days postop). There were no complications or injuries related to use of the robot.

Often cholecystectomy is the initial robotically-assisted procedure to test surgical robots because the operation is technically straightforward and reproducible. Advantages of surgical robots are elimination of the surgeon's tremor, scaling of movements, increased degrees of freedom, three-dimensional visualization, and a comfortable working position for the surgeon, who sits at a console. The scaling of movements makes delicate dissection more exact, and the increased degrees of freedom make dissections simpler. Sitting at the console is ergonomically beneficial. The surgeon does not have to assume awkward positions or reach over assistants.

Telesurgery, the performance of surgery from a distant site using robotics, offers the potential of procedures being performed worldwide from remote sites.

Modified from Gomez G: Emerging technology in surgery: informatics, electronics, robotics. In Townsend CM et al, editors: *Sabiston textbook of surgery,* ed 18, Philadelphia, 2008, Saunders; Miller DW et al: Robot-assisted laparoscopic cholecystectomy: initial Mayo Clinic Scottsdale experience, *Mayo Clin Proc* 79(9):1132-1136, 2004.

BOX 11-2

Advantages of Robot-Assisted Surgery for the Patient and Surgeon

ADVANTAGES FOR THE PATIENT

Smaller incisions
Decreased postoperative pain
Shorter length of hospital stay
Reduced blood loss
Reduced tissue trauma and inflammatory response to surgery
Improved cosmetic result
Faster return to work

ADVANTAGES FOR THE SURGEON

Better visualization (higher magnification)
Hand tremor eliminated, allowing great precision
Three-dimensional video image of the operative field; view of ductal anatomy enhanced
Robotic "wrist" more flexible than human wrist, improving maneuverability around organs and vessels
Movements can be reduced, allowing complex technical tasks
Better ergonomic environment (sitting at a console), better levels of concentration

Modified from Gomez G: Emerging technology in surgery: informatics, electronics, robotics. In Townsend CM et al, editors: *Sabiston textbook of surgery,* ed 18, Philadelphia, 2008, Saunders; Purkayastha S et al: Robotic surgery: a review, *Hosp Med* 65(3):153-159, 2004.

Cholecystostomy (Open Procedure)

Cholecystostomy establishes an opening into the gallbladder to drain the organ and remove stones. The open approach is usually selected for patients with advanced medical problems who cannot tolerate general anesthesia or more extensive surgery. Ultrasound-guided percutaneous cholecystostomy has become an accepted procedure for patients who are not otherwise good candidates for surgery. In the rare situation where interventional radiology is not available, an open procedure may be done, as is described here.

Procedural Considerations. A large Toomey syringe (50 ml) or an Asepto syringe may be needed for irrigation purposes. If a local anesthetic is used, the anesthetic agent, syringes, and needles are assembled. Protocols for safe administration and labeling of all medications/solutions on and off the sterile field must be followed. Specified drainage tubes or catheters should be available. The patient is positioned supine. Although many surgeons prefer a right subcostal incision, when cholecystostomy procedures are performed as emergencies a quicker midline or transverse incision may be used. Instrumentation includes a basic laparotomy set plus a gallbladder set.

Operative Procedure

1. After incision into the abdominal cavity, the gallbladder is isolated by retraction of the surrounding viscera.
2. The fundus of the gallbladder is grasped with an Allis or Babcock forceps and, if needed, the proposed opening is encircled by means of an absorbable purse-string suture, leaving the ends long.
3. If the gallbladder is distended or tense, it may be isolated with moistened laparotomy packs to protect the abdominal cavity from contamination.
4. If decompression of the gallbladder is required, a large-bore needle (e.g., 18 gauge) may be inserted with suction attached. Gallbladder contents are aspirated and the site closed using surgical clips on a clip applier.
5. If a trocar is used within the purse-string suture, suction tubing is attached to the trocar sheath.
6. As the contents are aspirated, culture specimens may be taken. The contaminated trocar and sheath are removed and isolated in a discard basin.
7. The opening into the gallbladder can be enlarged with Metzenbaum scissors. Gallstones are removed with malleable scoops and stone forceps.
8. Irrigating the gallbladder with isotonic saline solution may be necessary to remove small stones, grit, or paste-like material. A syringe with a catheter or an Asepto syringe is sometimes used for irrigation.
9. Remaining contaminated instruments are placed in a discard basin.

TABLE 11-4

Myths about Robotic Surgery

Myth	Reality
Robots do all the work.	The surgeon manages the robot system from a console away from the operative field.
Robotic surgery is better than conventional surgery.	Current surgical outcomes are comparable.
Robotic arms function just like a surgeon's hands.	Robotic arms are better than human hands—steadier and more precise, with no tremor and smaller hand movements, and able to work in a very small space. However, hand dexterity is missing—a human hand can move 20 ways; robotic arm has good but not exactly replicable range of motion.
Robots make surgery simpler, faster, or less expensive.	System setup time can be lengthy. Some surgeries take longer to perform with a robotic system.
Robotic surgery has been a big disappointment.	Robotic surgery is constantly improving. This technology has significant implications for the future of surgery, with its near-perfect visualization and sophisticated camera system that provides a three-dimensional view of the heart.

Modified from 5 Myths about robotic surgery, *Cleveland Clin Heart Advis* 7(5):4-5, 2004; Robotics extend surgeon's reach, *Cleveland Clin Heart Advis* 11(3), 2008, available at www.heart-advisor.com/cgi-bin/texis/scripts/heartadvisor-search/search.html?query=robotic+heart+surgery. Accessed April 1, 2009.

10. A drainage tube is inserted into the gallbladder opening. The purse-string suture is tightened around the catheter, with care taken not to occlude it.
11. The free end of the catheter or tube is exteriorized through a stab wound and then anchored to the skin edges, as described for open cholecystectomy.
12. Drainage of the abdominal cavity is established with the exterior ends of each drain secured.
13. The wound is closed in layers, as described for laparotomy, and dressings applied at the incision and drain sites.

Open Common Bile Duct Exploration

With the advent of endoscopic, percutaneous, and laparoscopic techniques (Figure 11-13), open exploration of the common bile duct is rarely performed. When these newer methods are not available, when they are not possible because of prior surgery, or when an open procedure is otherwise necessary, open common bile duct exploration is performed.

Procedural Considerations. The patient is positioned supine after administration of a general anesthetic. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter may be inserted before the abdominal skin prep. Instrumentation includes a basic laparotomy set with the addition of gallbladder instruments. T-tubes of assorted sizes should be available. Intraoperative cholangiography will most likely be used to confirm that all stones have been removed; radiation-protection devices for the patient and surgical team are required. Culture tubes are needed. Soft rubber catheters for irrigation, balloon-tipped catheters such as the biliary Fogarty catheter, stone baskets, and the surgeon's preferred cholangiocath should be available, as well as both flexible and rigid choledochoscopes. A choledochoscope requires the following:

- Choledochoscope with accessories: biopsy forceps, stone-grasping forceps, and a sheath that can be used to direct other instruments into various portions of the biliary tract
- Video camera and viewing screen
- Light cord
- 0.9% normal saline (1000-ml bag)
- Sterile IV tubing
- Pressure bag
- Light source for the choledochoscope

Distending the common duct is necessary for better visualization and is accomplished by irrigating the duct with copious amounts of sterile saline. A pressure bag is placed around an IV bag of 0.9% saline, and pressure to 300 mm Hg is applied. Sterile tubing is then passed from the sterile field and attached to the saline bag. The scrub person attaches the distal end of the sterile IV tubing directly to the irrigating stopcock on the scope.

Operative Procedure

1. The abdomen is opened through a subcostal incision or midline incision.
2. If the gallbladder has not been previously removed, it is exposed and removed or retracted by means of laparotomy packs and retractors.
3. The common duct may be identified by means of an aspirating syringe and fine-gauge needle to make certain that the suspected duct is not a blood vessel. Culture specimens may be obtained.
4. The common duct region is isolated with moistened laparotomy packs and narrow-blade retractors. A discard basin for contaminated instruments is placed at the lower end of the operative field and suction is prepared for immediate use.
5. Two fine traction sutures are placed in the wall of the duct, below the entrance of the cystic duct. A longitudinal incision is made in the common duct, between the traction sutures, with a long #3 knife handle and #15 or #11 blade, and enlarged with Potts angled or Metzenbaum scissors.
6. Visible stones are removed with gallstone forceps, after which exploration of the duct is begun with small, malleable scoops, proximal and then distal to the opening. Isotonic solution in an Asepto syringe and a soft, small-lumen catheter or a balloon-tipped catheter are used to facilitate the removal of small stones and debris as well as to demonstrate patency of the common bile duct in its entirety to the duodenum.

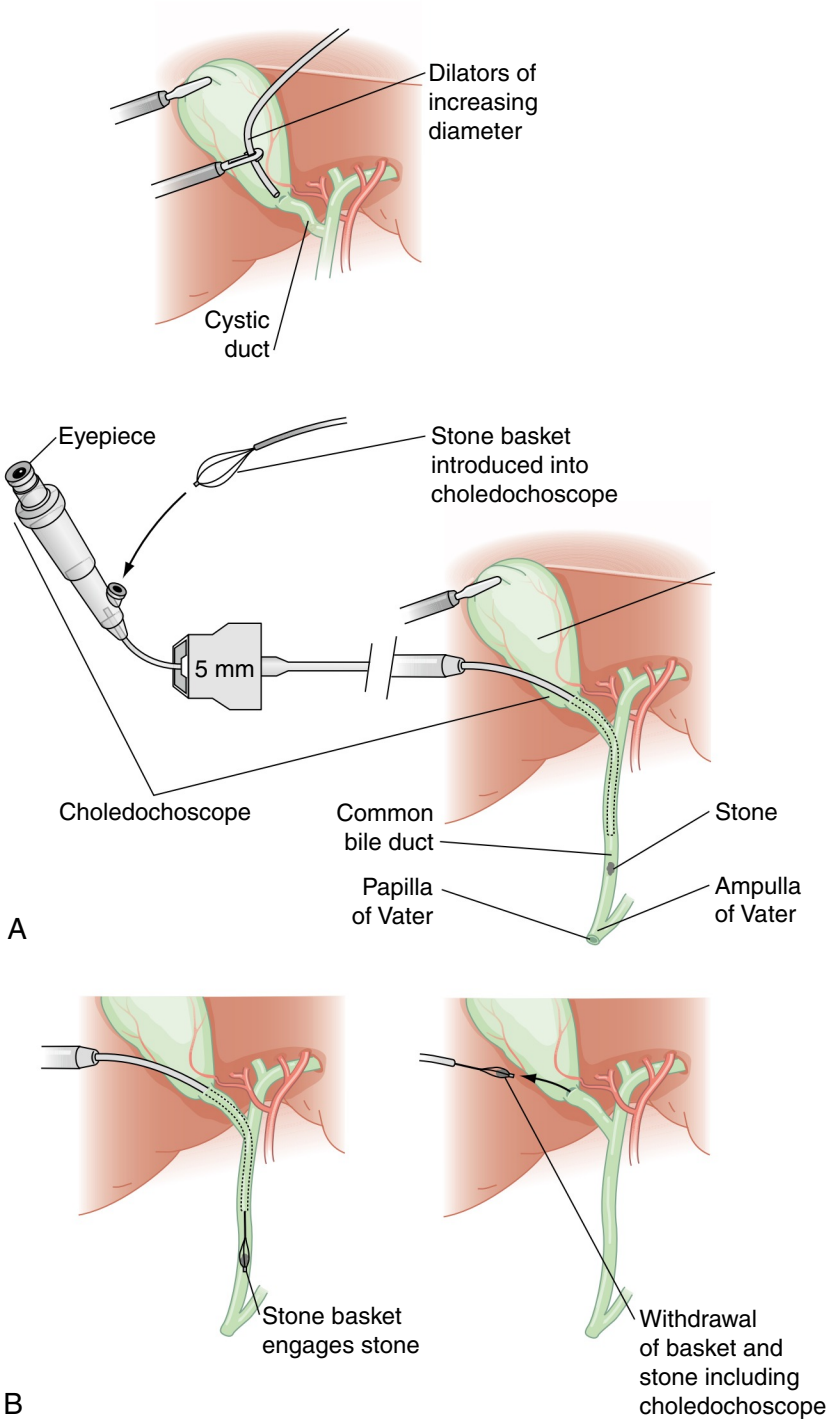


FIGURE 11-13 **A**, Laparoscopic common bile duct exploration. After dilation of the cystic duct, the flexible choledochoscope is inserted into the abdomen through the small trocar and maneuvered into the distal common bile duct. **B**, A stone basket is passed through the working channel of the choledochoscope and is used to snare a common duct stone. The stone basket and choledochoscope are then withdrawn together.

7. The choledochoscope may be used to identify additional stones. The scope is inserted into the common duct, which is then flushed with saline. After visualizing the duct to ensure that no stones remain, a T-tube is placed in the common bile duct and the choledochotomy is closed around the tube. A completion cholangiogram is performed to be certain all stones have been removed. The wound is closed, the T-tube anchored to the skin, and dressings applied. Sterile tubing is used to connect the T-tube to a small drainage container or bag.

Cholecystoduodenostomy and Cholecystojejunostomy

Cholecystoduodenostomy and cholecystojejunostomy create an anastomosis between the gallbladder and duodenum or the gallbladder and jejunum, respectively, to relieve an obstruction in the distal end of the common duct. An obstruction in the biliary system may be caused by a tumor of the ducts involving the head of the pancreas or the ampulla of Vater, an inflammatory lesion, a stricture of the common duct, or the presence of stones.

Procedural Considerations. Instrumentation includes a basic laparotomy set; gallbladder instruments with two curved Doyen intestinal forceps with guards, or similar atraumatic holding forceps; and a self-retaining retractor system. Fluoroscopy should be anticipated and radiation-protection devices for patient and surgical team should be available. The patient is positioned supine after administration of a general anesthetic. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter is inserted before abdominal skin preparation.

Operative Procedure

1. The abdomen is opened, the gallbladder exposed, the contents aspirated, and the pathologic condition confirmed.
2. The anastomosis site is prepared, posterior serosal silk sutures placed, and open anastomosis performed.
3. Anastomosis of the gallbladder to the duodenum or loop of the jejunum is usually performed as a two-layer anastomosis.
4. The serosa of the duodenum or loop of the jejunum is sutured to the full thickness of the fundus of the gallbladder.
5. A 1-cm to 1.5-cm opening is made into the small bowel and gallbladder in corresponding positions. GI technique (also referred to as bowel technique; see Chapter 10) is instituted.
6. Interrupted fine monofilament (5-0 or 4-0) sutures are then placed around the entire circumference.
7. Contaminated instruments are placed in the discard basin and the operative field is prepared for closure.
8. A drain may be inserted, the wound closed, and dressings applied.

Choledochoduodenostomy and Choledochojejunostomy

Choledochoduodenostomy is anastomosis between the common duct and the duodenum, and choledochojejunostomy is anastomosis between the duct and the jejunum. These procedures (referred to as choledochal drainage procedures) may be necessary in postcholecystectomy patients to circumvent an obstructive lesion and reestablish the flow of bile into the intestinal tract.

Procedural Considerations. Surgical approaches are similar to those for choledochostomy and cholecystojejunostomy. The patient is positioned supine after administration of a general anesthetic. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter is inserted before abdominal skin preparation.

Instrumentation and supplies necessary for this procedure include a basic laparotomy set with the addition of gallbladder instruments, a self-retaining retractor system, linear stapling devices, and T-tubes in varying sizes; a Silastic biliary stent should be available as should magnifying loupes. Fluoroscopy should be anticipated; radiation-protection devices will then be required for the patient and surgical team.

Operative Procedure

CHOLEDOCHODUODENOSTOMY

1. The abdomen is opened with a midline incision.
2. The common duct and duodenum are exposed.
3. The common duct is identified and dissected free, using forceps and Metzenbaum scissors.
4. The common duct and duodenum are approximated, side-to-side or with the end of the common duct to the side of the duodenum, and an anastomosis is established.
5. An intraluminal catheter is inserted.
6. The wound is closed and dressings applied.

CHOLEDOCHOJEJUNOSTOMY

1. The abdomen is opened with a midline incision.
2. The jejunum is mobilized, the common duct identified and opened, and the jejunum transected (Figure 11-14, *A*).
3. Anastomosis is established between the common duct and the transected jejunum.
4. A catheter is introduced, as described previously for cholecystoduodenostomy.
5. Jejunal continuity is reestablished by jejunojejunostomy (Figure 11-14, *B*).
6. As an alternative, anastomosis may be fashioned from the end of the severed duct to the side of a loop of jejunum, with a side-to-side jejunal anastomosis.
7. Contaminated instruments are removed from the operative field.
8. A drain may be inserted, the wound closed, and dressings applied.

Transduodenal Sphincteroplasty

Transduodenal sphincteroplasty achieves a choledochoduodenostomy between the distal end of the common duct and the side of the duodenum. The sphincters normally affecting the distal common and pancreatic ducts are rendered functionless because the stoma is noncontractile and therefore remains permanently open. An indication for transduodenal sphincteroplasty is sphincter of Oddi dysfunction—a poorly defined clinical syndrome that is characterized by pain characteristic of biliary colic and recurrent acute pancreatitis. There may be a structural or functional abnormality of the sphincter, with or without fibrosis and elevated sphincter pressures. Both endoscopic sphincterotomy and transduodenal sphincteroplasty with transampullary septectomy have been used with similar results. The procedure described has the advantage of including division of the transampullary septum, which promotes pancreatic duct drainage.

Procedural Considerations. Instrumentation is as described for choledochotomy, with the addition of a GI set, since the duodenum is entered. The patient is positioned supine after administration of a general anesthetic. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter is inserted before abdominal skin preparation. The abdomen is prepped from nipple line to pubis. Supplies for an operative cholangiogram are necessary

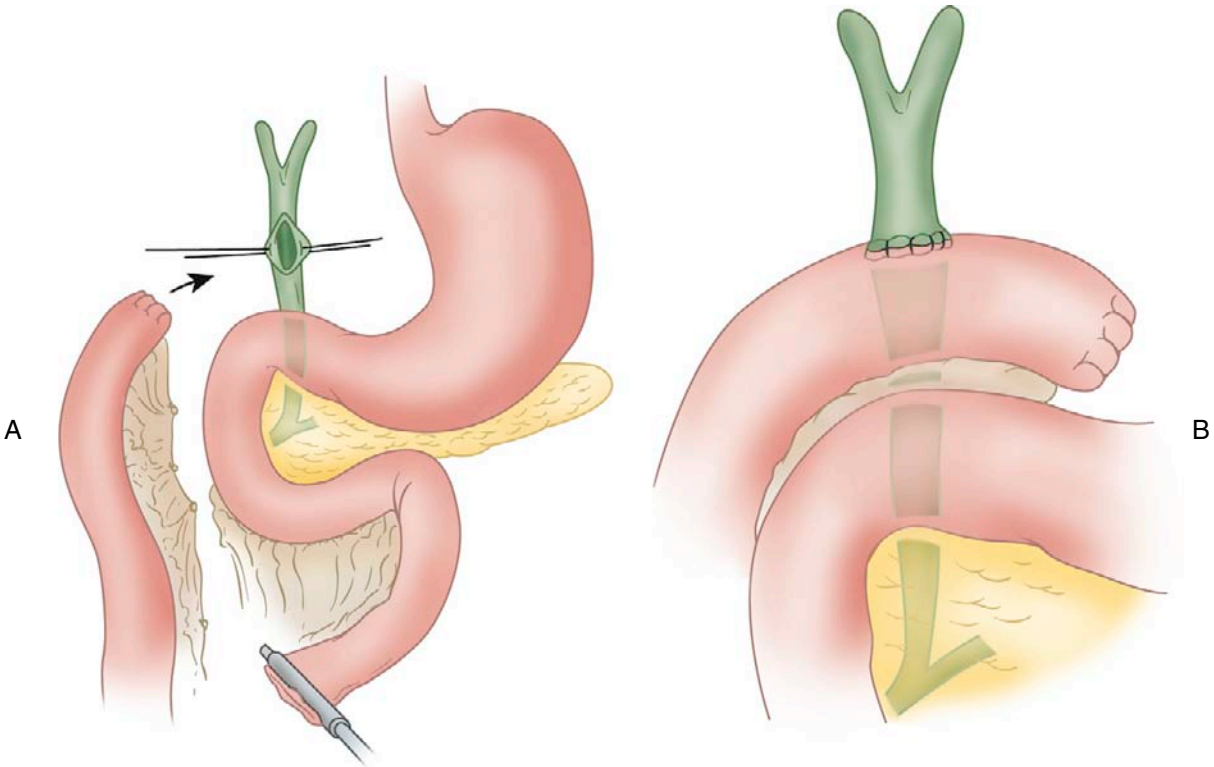


FIGURE 11-14 Choledochojejunostomy. **A**, The divided end of the jejunum is closed, and an end-to-side choledochojejunostomy is made in two layers to the jejunum. **B**, A jejunojejunostomy completes the operative procedure.

as are radiation-protection devices for the patient and surgical team.

Operative Procedure

1. A right subcostal or midline incision is made and the biliary tract exposed.
2. All structures are inspected and the normal configuration established before any structure is tied, clamped, or divided during biliary tract dissection.
3. Operative cholangiography is then performed by placing a cholangiocath through a small incision made with a #11 blade into the cystic duct.
4. If the gallbladder is present, cholecystectomy is performed.
5. The duodenum is mobilized by dividing the peritoneal reflection that covers the lateral portion of the second part of the duodenum and holds it in place.
6. The common duct is incised longitudinally between two stay sutures and explored.
7. Any residual stones are removed. Duodenotomy is performed with a longitudinal incision and the papilla of Vater located (Figure 11-15, *A*).
8. The sphincter of Oddi is divided at the 11 o'clock position with angled Potts scissors, and the ductal mucosa is sutured to the duodenal mucosa with a fine monofilament synthetic absorbable suture on a small needle (Figure 11-15, *B*).
9. The duodenum is then closed in two layers.
10. The common bile duct is joined to the apex of the mobilized duodenum in a two-layer anastomosis.
11. A T-tube may be inserted to splint the anastomosis (Figure 11-15, *C*).
12. The abdominal cavity is closed.

SURGERY OF THE PANCREAS

Drainage or Excision of Pancreatic Cysts (Open Method)

Pancreatic pseudocysts are localized collections of pancreatic secretions in a cystic structure. The preferred operative therapy in patients with uncomplicated pseudocysts is internal drainage by one of three options: cystojejunostomy (use of a defunctionalized Roux-en-Y jejunal limb) (Figure 11-16); cystogastrostomy (drainage into the stomach); or cystoduodenostomy (drainage into the duodenum) (Steer, 2008). Cystogastrostomy is a faster and technically simpler procedure used when the cyst adheres to the posterior wall of the stomach. Cystojejunostomy is the most versatile drainage procedure. Cystoduodenostomy is used in selected cases, depending on cyst location, but has limited utility.

Procedural Considerations. The patient is positioned supine after administration of a general anesthetic. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter is inserted before abdominal skin preparation. Instrumentation and supplies necessary for this procedure include a basic laparotomy set, gallbladder instruments, a GI set, and a self-retaining retractor system.

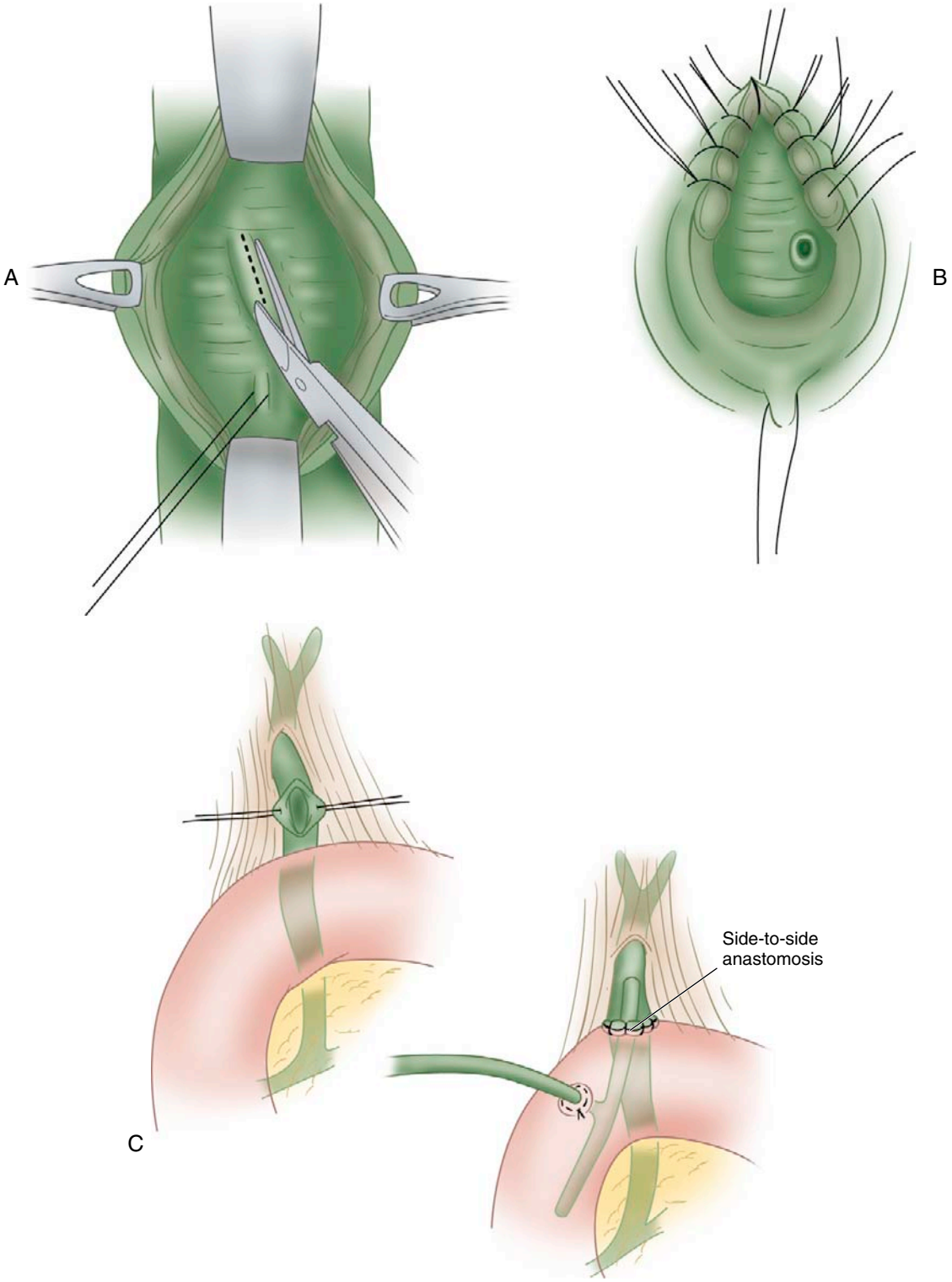


FIGURE 11-15 Transduodenal sphincteroplasty. **A**, The duodenum is opened longitudinally. **B**, The sphincter of Oddi is divided at 11 o'clock with angled Potts scissors, and the ductal mucosa is then sutured to the duodenal mucosa with 4-0 absorbable suture. The duodenum is then closed longitudinally in two layers. **C**, Choledochoduodenostomy. The common bile duct is joined to the apex of the mobilized duodenum in a two-layer anastomosis. A T-tube is placed to stent the anastomosis, with the external stem of the tube passed through the bile duct or through the wall of the duodenum.

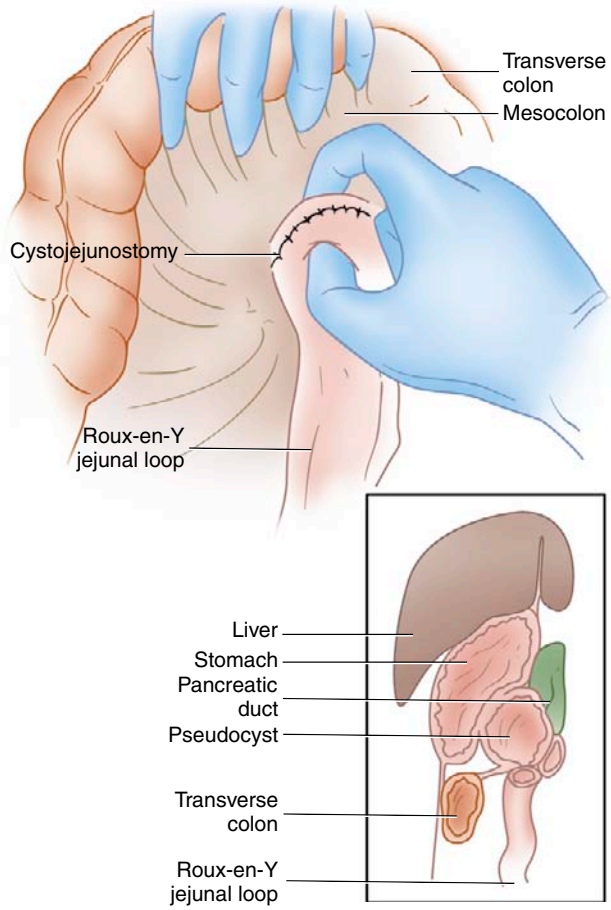


FIGURE 11-16 Internal drainage of a pancreatic pseudocyst by Roux-en-Y cystojejunostomy through the base of the transverse mesocolon.

Operative Procedure

1. A midline incision is made into the abdomen.
2. A self-retaining retractor system is used to expose the pancreatic area.
3. The pancreatic cyst is examined and the area isolated with moist packs.
4. Internal drainage may be accomplished by an incision into the anterior wall of the stomach, directly opposite the cyst if it adheres to the posterior wall, thereby providing drainage through the GI tract.
5. A fistula is established between the anterior wall of the cyst and the posterior wall of the stomach. Many surgeons prefer an anastomosis between the cyst and a Roux-en-Y loop of jejunum (see Figure 11-16) or into the duodenum directly, depending on the location of the cyst.
6. The anterior gastrostomy is closed, and wound closure completed.

Laparoscopic Pancreatic Cyst–Gastrostomy

Laparoscopic techniques may be used for internal drainage procedures for pancreatic pseudocysts. CT imaging is used to diagnose the pancreatic pseudocyst. An EUS may also provide additional information. The location, size, and thickness of the wall of the pseudocyst are all assessed to determine the most appropriate procedure for drainage, either a laparoscopic pancreatic cyst–gastrostomy or a Roux-en-Y pancreatic cystojejunostomy. Endoscopic drainage of pseudocysts may also be done in surgical centers where endoscopists are experienced in percutaneous drainage techniques (Steer, 2008).

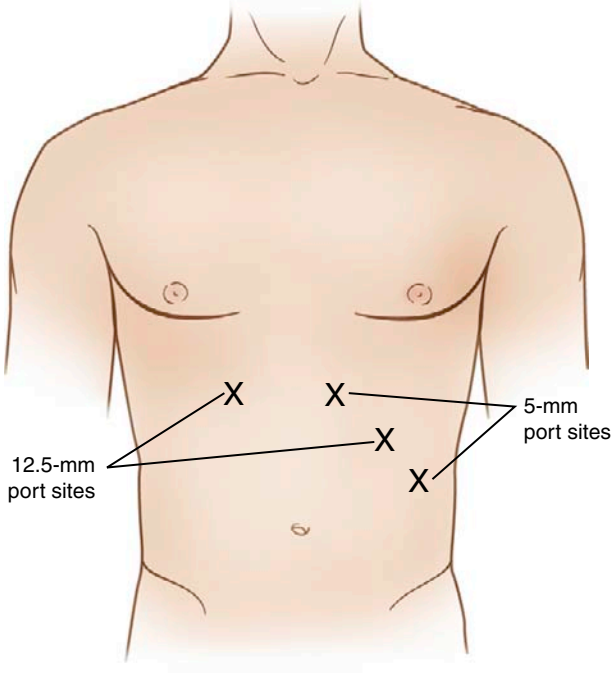


FIGURE 11-17 Port sites for trocar placement in laparoscopic pancreatic cyst–gastrostomy.

Procedural Considerations. General anesthesia is induced and an NG tube inserted. The patient is positioned supine. Equipment and instrumentation are a 30-degree telescope (10 mm or 5 mm); a video camera; two high-density video monitors; a high-flow insufflator with CO_2 tank; an electrosurgical unit; two 12.5-mm trocar ports; two 5-mm trocar ports; an endodissecting instrument (5 mm) or atraumatic grasping forceps (5 mm); endoshears/scissors (5 mm) with electrocoagulation connection; an endo-Babcock instrument; a mechanical stapling device; a 10-mm endoclip applier; a 10-mm endosuturing instrument (optional); 2-0 suture material, 7-inch length (optional); an electrocoagulation hook; a long 5-mm laparoscopic needle; and an endoretractor.

Operative Procedure

1. Pneumoperitoneum is created and the trocars inserted by way of port sites as illustrated in Figure 11-17.
2. The pancreatic pseudocyst is located by entering the lesser sac by way of the greater curvature. Hemostasis is achieved by using the endoclip applier. An endostapling device (GIA type) with vascular cartridges is used to dissect the greater curvature.
3. The surgeon assesses the site for entry into the stomach. An endoretractor may be used to retract the left hepatic lobe.
4. Using electrodissection an incision centered between the lesser and greater curvatures is made on the anterior wall of the stomach and then extended.
5. A long laparoscopic aspiration needle is inserted into the intraabdominal and gastric cavity. The camera is advanced to visualize the posterior wall of the stomach.

6. The needle is inserted into the cyst and its presence is confirmed by aspiration.
7. A small incision is made into the cyst and the pancreatic fluid aspirated.
8. The endostapling device is inserted into the gastric cavity. The smaller jaw of this instrument is inserted into the pseudocyst. The stapling device is closed. It is important that the anastomosis not be under tension. The stapling device is fired and the anastomosis checked for integrity. An endosuturing instrument is used to close any defects in the anastomotic line.
9. An NG tube is directed into the pseudocyst.
10. The two edges of the anterior wall gastrostomy are approximated using endograsping forceps (atraumatic) or an endodissecting instrument. The gastrostomy is then closed using an endostapling device (thoracic-abdominal [TA] type).
11. A drain is placed, the abdomen deflated, trocar ports removed, and trocar sites closed and dressed.

Robotic-Assisted Laparoscopic Pancreatic Procedures

Procedural Considerations. Pancreatic lesions can be resected with robotic-assisted laparoscopy. Pancreaticojejunostomy may be performed following an open pancreaticoduodenectomy (Hanley and Talamini, 2004). Computer-assisted robotic surgery may be used to resect, drain, and reconstruct the pancreatic duct. Precise tissue manipulation and three-dimensional imaging allow better surgical approaches for reconstruction of the pancreatic or common bile ducts than open techniques (Melvin, 2003).

Pancreaticoduodenectomy (Whipple Procedure)

Pancreatic cancer is treated using a multidisciplinary approach that may include surgeons, gastroenterologists, oncologists, radiologists, nurses, and nutritionists (Hines and Reber, 2006). Tumors arise from the exocrine glands (95%) and endocrine glands (5%) in the pancreas. Ductal adenocarcinoma constitutes 80% of all pancreatic tumors. Most tumors begin in the head of the exocrine gland, obstruct the bile duct, and extend to the duodenum, intestines, and spine. Metastasis occurs to regional lymph nodes, and common metastatic sites include the liver and lungs. As symptoms most often occur late in the disease, the prognosis is usually poor (Research Highlight). Pancreaticoduodenectomy (Whipple procedure) is the removal of the head of the pancreas, the entire duodenum, a portion of the jejunum, the distal third of the stomach, and the lower half of the common bile duct, with reestablishment of continuity of the biliary, pancreatic, and GI tract systems.

Procedural Considerations. A basic laparotomy set, a GI instrument set, a self-retaining retractor system (e.g., Bookwalter), linear stapling devices, and appropriate drains and catheters are required. The perioperative nurse should ensure that ordered blood and blood products are available. Pancreaticoduodenectomy may take 5 to 6 hours and require the transfusion of many units of blood or blood products. The patient is positioned supine after administration of a general anesthetic. Attention is paid to padding positional pressure points with gel pads or using a pressure-reducing OR bed mattress. SCDs are applied as well as a forced-air warming device and other active warming measures to prevent hypothermia. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter is inserted before abdominal preparation. The abdomen is prepped from nipple line to midthigh.

RESEARCH HIGHLIGHT

Pancreatic Cancer Research Matures

Cancer of the pancreas is found in industrialized countries in increasing numbers. Pancreatic cancer research has been slow to progress, making it the fourth leading cause of cancer deaths for men and women. Early detection techniques and effective treatment strategies have evolved slowly, but progress is being made in several areas.

It is now possible to describe the progression of lesions from precancer to full-blown disease. "Candidate genes for diagnosis, screening, and treatment, are being tested in trials. Several new risk factors have been identified. And a whole-genome scan of about 2,000 pancreatic cancer patients revealed new genetic targets and pathways affected by the disease" (Nelson, 2007, p 1432). There are currently more than 200 clinical trials testing combinations of chemotherapeutic agents. Lack of response to chemotherapy has been a problem, but new research shows an understanding of the genetic structure of precancerous pancreatic lesions. Drugs are being developed to inhibit the "hedgehog signaling pathway," a pathway that plays a role in cell differentiation, growth, and proliferation that is particularly active in many pancreatic cancers (Genentech, 2008). In addition, new screening techniques are being investigated in high-risk groups. Chronic alcohol abuse and smoking cause more than one third of all pancreatic cancers (Berger and Rau, 2007). However, other risk factors include persons with a family history of pancreatic cancer, inherited gene mutations, chronic pancreatitis, long-standing diabetes, and cirrhosis of the liver (Spader, 2009). Groups of high-risk individuals are being studied and screened in an attempt to identify pancreatic cancer in its early stages (Nelson, 2007).

Modified from Cell differentiation, growth and proliferation, *Genenetech BioOncology,* available at www.biooncology.com/bioonc/research/hedgehog/index.m?s_cid=0001&;s_src=googleppc&gclid=CPOp5evlwJcCFQNvHgod5X-qSg. Accessed April 1, 2009, Nelson NJ: Pancreatic cancer research matures, *J Natl Cancer Inst* 99(19):1432-1434, 2007; Berger HG, Rau BM: New advances in pancreatic surgery, *Curr Opin Gastroenterol* 23(5):522-534, 2007; Spader C: Pancreatic cancer takes center stage, *Nurs Spect* 18(7):14-16, 2009.

Operative Procedure

1. The abdomen is entered through either an upper transverse, a bilateral subcostal, or a long paramedian incision. Resectability is assessed, exploring for hepatic metastases, serosal implants of tumor, and lymph node metastases. If these are outside the zone of resection, the disease is unresectable.
2. Laparotomy packs and retractors are used to expose the operative site and protect vital structures.
3. The duodenum is mobilized using the Kocher maneuver (incision of peritoneal reflection lateral to the second portion of the duodenum) with Metzenbaum scissors and subsequent blunt dissection of loose areolar tissue.
4. Mobilization of the duodenum continues and bleeding vessels are ligated with silk.
5. The gastrocolic ligament and the gastrohepatic omentum are divided between curved forceps and are ligated or transfixed.

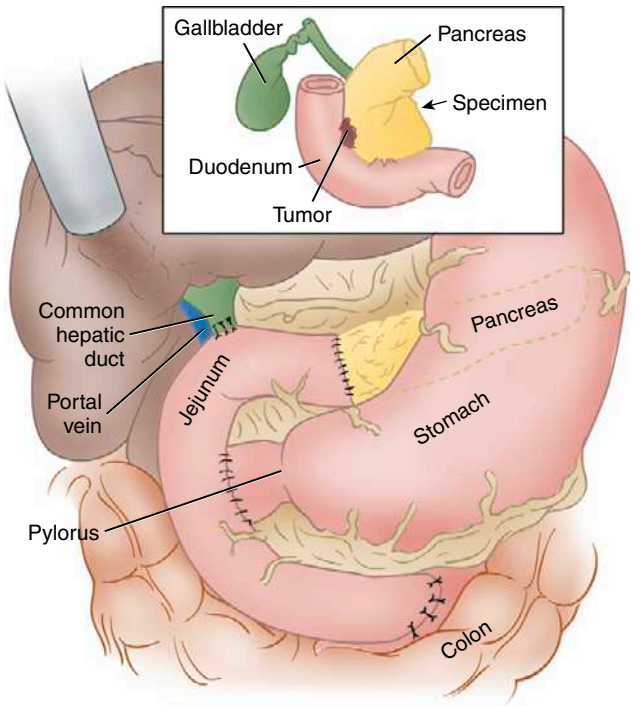


FIGURE 11-18 Illustration of a pylorus-preserving pancreaticoduodenectomy and the subsequent reconstruction. The inset at the top depicts the resected specimen. The jejunal limb is passed through and sutured to the transverse mesocolon.

6. The gastroduodenal and right gastric arteries are clamped, divided, and ligated.
7. The prepyloric area of the stomach is mobilized.
8. The operative field is prepared for open anastomosis by isolating the area with laparotomy sponges.
9. By placing two long Allen or Payr clamps near the midportion of the stomach, the transection is completed.
10. The duodenum is reflected, the common duct is divided, and the hepatic end is marked or tagged for later anastomosis.
11. The jejunum is clamped with two Allen forceps and the duodenojejunal flexure divided.
12. The pancreas is divided and the duct carefully identified.
13. Further mobilization of the duodenum and division of the inferior pancreaticoduodenal artery are done to permit complete removal of the specimen.
14. The most common reconstructive technique anastomoses the pancreas to the jejunum first, followed by the bile duct and the duodenum (Figure 11-18).
15. Drains may be placed, the abdomen closed, and an abdominal dressing applied.

Pancreatic Transplantation

Pancreatic transplantation is the implantation of a pancreas from a donor into a recipient for patients with type 1 (formerly known as juvenile-onset) diabetes. Options for pancreatic transplant include a pancreas transplant alone (PTA), an option chosen for patients with functioning kidneys; a simultaneous pancreas-kidney transplant (SPK), because severe diabetes is often associated with chronic renal failure; or a pancreas transplant after a kidney transplant (PAK), in which the pancreas is transplanted sometime after the kidney transplant. Pancreatic transplantation differs from other organ transplants in that it does not have immediate life-saving results. It is done in the hope of preventing debilitating side effects of diabetes, such as cardiovascular, retinal, and renal disease. For patients, a significant benefit is freedom from dependence on insulin. However, pancreatic transplant in patients with brittle diabetes remains a rare procedure because the trade-off of insulin dependence is lifelong immunosuppression (Gruessner et al, 2008). Transplant is most effective in persons with few or no secondary diabetic complications and it can reverse or stop the progression of these complications.

Procedural Considerations. The majority of pancreas transplants performed in the United States are SPK procedures (Figure 11-19). Instrumentation includes a transplant set as described for kidney transplantation in Chapter 14. In addition to the transplant set, vascular instruments and instruments for resection of the duodenal segment and management of the pancreatic duct are required. A linear stapling device may be used.

The patient is positioned supine after administration of a general anesthetic. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter is inserted before the abdominal skin prep and is attached to a urometer. Like other transplant procedures, these procedures are lengthy, lasting 5 to 7 hours. Positional pressure sites must be padded and a pressure-reducing mattress placed on the OR bed. Given the patient's diabetes, maintaining skin and tissue integrity is paramount. SCDs will likely be used. Careful monitoring of blood glucose level will occur throughout the procedure by the anesthesia provider. Blood and blood products will be ordered and their availability must be verified. Blood-warming devices, a forced-air warming device, warmed irrigating solution (<40.5° C [105° F]), and other measures are used to maintain normothermia. Communication among team members is essential in all transplant surgery. The patient is transferred to the SICU on completion of the procedure. Measures to address and reduce patient and family anxiety are usually part of all transplant programs. At-home rehabilitation is a gradual process and social services and other resources are part of the transplant team. The patient must take immunosuppressive drugs indefinitely. The verification process for organ transplant, established by the United Network for Organ Sharing (UNOS), must be followed to ensure that the organs of the donor and the recipient are compatible (Patient Safety).

Operative Procedure

1. The whole-organ pancreatic transplantation procedure is performed through an oblique incision opposite the side of the renal transplant in the lower abdominal quadrant. A midline incision may also be used for pancreatic transplant.
2. The external iliac artery and vein are skeletonized and lymphatics are tied off with 4-0 nonabsorbable ligatures.
3. The external iliac vein is clamped with noncrushing vascular clamps and a #11 blade used to make a venotomy.
4. The venotomy incision is extended with Potts scissors.
5. An end-to-side anastomosis of the donor portal vein to the recipient's external iliac vein is performed with four double-armed 5-0 polypropylene sutures.
6. The external iliac artery is then clamped and an aortic punch used to make an arteriotomy.

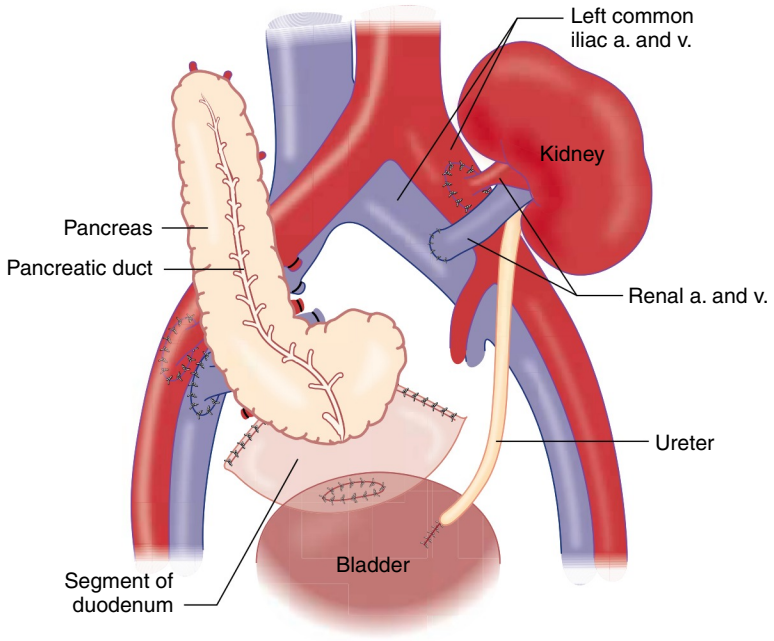


FIGURE 11-19 Transplantation of the pancreas with drainage of the bladder through a pancreaticoduodenocystostomy. A renal transplant is also shown with the common iliac vessels used for vascular anastomoses.

PATIENT SAFETY

Transplant of Donor Organs/Tissues: Example of Procedure for Establishing Identity and Matching Donor with Recipient

Before the transplant surgical procedure, a process of nine checkpoints is implemented to ensure identity and matching between the organs/tissues of the donor and the recipient.

Before the patient enters the OR the following must occur:

1. Once a transplant has been posted, Preliminary Transplant Crossmatch Reports are faxed from the human leukocyte antigen (HLA) lab to the OR where the transplant is to occur. The blood bank will fax ABO reports.
2. The OR charge nurse verifies the posted recipient's Preliminary Transplant Crossmatch Report and the ABO report.
3. The organ arrives at the OR.
4. The circulating nurse applies an addressograph label to the box with the organ.
5. The circulating nurse and another registered nurse together do the following:
   - **a.** Verify the tag on the organ with the Preliminary Transplant Crossmatch Report to ensure the following match:
     - **i.** Recorded ABO type of the recipient is the same or is compatible with the recorded ABO type of the donor.
     - **ii.** The UNOS (United Network for Organ Sharing) number on the organ is the same as the UNOS number on the Preliminary Transplant Crossmatch Report.
   - **b.** Identify the patient using the usual hospital policy.
   - **c.** Sign the Transplant Verification form.

In the OR the following must occur:

6. Preliminary anatomic checks are done by the surgeon. The transplant surgeon verifies that the UNOS number on the Preliminary Transplant Crossmatch Report is the same as the UNOS number on either the organ container or the paperwork provided and verifies the compatibility of the organ and the patient by ABO blood type. The transplant surgeon signs the Transplant Verification form.
7. Once the patient is taken into the OR, a time-out is taken with the OR team according to OR policy and procedure.
8. The Transplant Verification form and Preliminary Transplant Crossmatch Report are a permanent part of the patient's medical record.
9. The Transplant Verification form (deceased donor) is attached to the record.

Modified from *UNOS Policy 3.1.4.1: ABO verification prior to transplant,* 2005, available at www.unos.org/SharedContentDocuments/ABO_Verification_Processes_1_04.pdf. Accessed November 28, 2008.

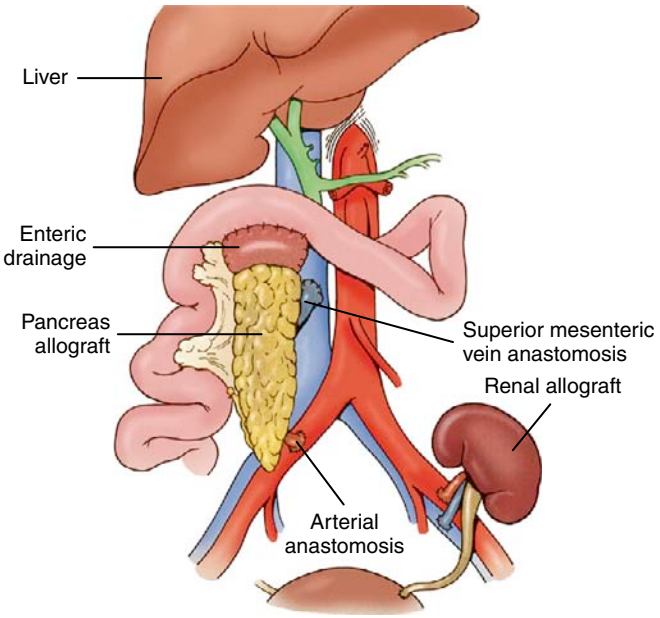


FIGURE 11-20 Pancreas and kidney transplants (PAK or SKP) with the donor pancreas vascularized to facilitate enteric exocrine drainage to a proximal portion of the jejunum (enteric drainage [ED] technique). The donor kidney is implanted in the left iliac fossa anastomosed to the femoral vessels and a ureteroneocystostomy is performed.

7. An end-to-side anastomosis of the recipient's external iliac artery with the donor aortic patch containing the origin of the superior mesenteric artery and the celiac axis is performed with four double-armed 6-0 polypropylene sutures.
8. Management of the pancreatic duct is then performed, according to the type of en bloc procedure performed.
9. Various enteric procedures for drainage of pancreatic duct secretions have been performed with whole-organ transplants en bloc with a segment of duodenum and the spleen. They include cutaneous jejunostomy, drainage into an ileal loop, and duodenojejunostomy with end-to-end or side-to-side anastomosis. Direct grafting of the pancreatic duct into the enteric or urinary system is also performed for management of exocrine secretions. Surgical procedures include pancreaticojejunostomy with an established Roux-en-Y loop of jejunum (Figure 11-20), pancreaticoductoureterostomy, and pancreaticocystostomy. The whole-organ pancreas transplant may also be performed as a pancreaticoduodenal transplantation or a pancreaticoduodenal-splenic transplantation.

SURGERY OF THE LIVER

Drainage of Abscess

Abscesses of the liver occur primarily by spread of bacteria or other organisms through the portal system (a direct route after trauma), the biliary tract, or the hepatic artery (in generalized septicemia); in addition, direct extension from a subdiaphragmatic or subhepatic abscess can lead to a liver abscess. In most instances, percutaneous drainage is effective and safe in the drainage of hepatic abscesses. However, open procedures may be required, often by way of the transperitoneal route. This approach permits inspection of the abdominal cavity for the underlying source of the abscess.

Procedural Considerations. A basic laparotomy set is used. Biliary instrumentation, drainage materials, and aerobic and anaerobic culture tubes are needed. Safe practices for handling specimens such as cultures are initiated. The patient is positioned supine after administration of a general anesthetic. The anesthesia provider inserts an NG tube after intubation. An indwelling urinary catheter may be inserted before the abdominal skin prep.

Operative Procedure

1. The incision preferred by many surgeons is the transperitoneal route; the surgical approach may be modified, however, according to the location of the abscess (e.g., in a high posterior abscess, the transpleural approach may be selected).
2. The abdomen is opened as described for laparotomy and abdominal inspection carried out.
3. The abscess is mobilized and evacuated, and cultures obtained.
4. Surgical drains are placed and the wound closed.

Hepatic Resection

Anatomically, the liver is divided into left and right lobes with the caudate lobe lying in the dorsal segment. Resection of the liver is undertaken for primary tumors, benign conditions (e.g., hepatolithiasis), and metastatic tumors. Hepatic resection is usually approached in one of three ways. The *anatomic* approach is based on the premise that malignant cells distribute along the portal venous segmental supply. In the *enucleation* approach, specific benign lesions with limited chance of local invasion are removed. The third approach, the *nonanatomic,* includes resections appropriate for a pathologic process in which a limited margin is acceptable, such as in tumor debulking.

Procedural Considerations. Instruments used are a laparotomy set, biliary instruments, vascular instruments, noncrushing liver clamps, a self-retaining retractor, and a surgical stapler. Supplies and equipment should be available for thermoregulation, electrosurgery, measurement of portal pressure, and replacement of blood loss. For major liver procedures, intraoperative ultrasound (to guide vessel isolation and minimize vascular occlusion), the argon beam coagulator, and the CUSA are used. Special blunt needles for suturing liver tissue are also necessary.

The patient is placed in supine position. Mild Trendelenburg's position may be requested by the surgeon. The anesthesia provider inserts an NG tube after induction of general anesthesia and intubation. An indwelling urinary catheter is inserted before abdominal skin preparation. The abdomen is prepped from nipple line to midthigh. Surgeons often use a right subcostal incision, with the ability to extend with a left subcostal if necessary. In some instances, a median sternotomy or right thoracotomy incision is required, and chest instruments are then necessary. Liver sutures, absorbable or nonabsorbable according to surgeon's preference, vessel loops, and umbilical tapes should be available on the sterile field.

Hemostatic material, such as Gelfoam, Surgicel, or Avitene, and absorbable collagen sheets should be readily available when the resection begins. The potential for bleeding exists both intraoperatively and postoperatively because of the high vascularity of the liver. If postoperative bleeding and subsequent hypovolemia occur, it may become necessary to call the Rapid Response Team (Rapid Response Team box).

RAPID RESPONSE TEAM

Treatment of nontraumatic shock can be delayed because of inadequate knowledge and/or skills of some clinicians. Some hospitals do not have system-wide resources to handle emergencies such as hypovolemic episodes, and the death rate can be high. Rapid response teams empower clinicians to identify and treat patients in shock using a multidisciplinary team approach. The team may consist of ICU nurses, respiratory therapists, emergency physicians, laboratory personnel, ECG and radiology technicians, pharmacists, and intensivists. These groups use evidence-based practice to promptly evaluate and treat deteriorating patients, which can lead to decreased inpatient cardiac arrests and postoperative morbidity and mortality.

Hypovolemia and sepsis are two typical reasons for team response. Early hemodynamic optimization improves survival in high-risk surgical patients and those with sepsis. Attitudes and behaviors of medical staff must be positive for this program to work effectively. Signs are posted that not only educate staff but also remind healthcare providers to use the team. Nurses are encouraged to call the team whenever something "doesn't feel right" about a patient or the patient is deteriorating rapidly.

In the case of hepatic, biliary, pancreatic, and splenic surgery, potential for bleeding exists postoperatively because of the high vascularity of these areas. When postoperative hypovolemia occurs and it becomes necessary to call the rapid response team, the nurse needs to provide a short, but comprehensive, report on the type of surgery performed. For liver transplant patients, it is paramount that early intervention occurs in patients with hypovolemia or hypotension as renal dysfunction can worsen and renal failure can result.

Modified from Sebat FS et al: Effect of a rapid response system for patients in shock on time to treatment and mortality during 5 years, *Crit Care Med* 35(11):2568-2575, 2007; Biancofiore G, Davis C: Renal dysfunction in the perioperative liver transplant period, *Curr Opin Organ Transplant* 13(3):291-297, 2008.

Surgeons use various methods to remove liver tissue. A CUSA allows the surgeon to dissect tissue using ultrasonic waves incorporated with fluid and suction. The ultrasonic waves cut through liver tissue, emulsifying it and diluting the tissue with fluid so that it can be suctioned. The electrosurgical pencil uses electrical current to cut through and desiccate liver tissue. Finger-fracture of the liver tissue is performed by digital pressure against the parenchyma to fracture the tissue.

Operative Procedure

1. Through a right subcostal incision, the abdominal cavity is opened and examined.
2. Pathologic condition is determined and resectability evaluated.
3. Moist laparotomy packs are inserted and a self-retaining retractor placed.
4. Intraoperative ultrasonography (US) is performed to assess all segments of the liver (Figure 11-21). Ultrasound-guided, digital intraparenchymal isolation of vessels is used during resection.
5. Lymph nodes in the porta hepatis and along the gastrohepatic ligament are then assessed by palpation to determine extrahepatic metastasis.
6. The intended resection line is scored with the blade tip of the electrosurgical pencil, and coagulation is set at the surgeon's selected setting (Figure 11-22).
7. The liver parenchyma is then delicately resected using the CUSA handpiece (Figure 11-23).
8. Once the portion of the liver is resected, the remaining liver resection margins are assessed for bleeding and bile leakage.
9. A laparotomy sponge may be placed against the transected surface for several minutes. The laparotomy sponge is gently rolled from the surface, which is then examined for bile leakage.
10. Areas may then be oversewn with 2-0 or 3-0 absorbable suture or an intended layer of eschar is applied using electrocoagulation or the argon beam coagulator.
11. Abdominal drains may be placed along the liver bed and exteriorized through the abdominal wall through separate stab wounds.
12. The abdominal wound is then closed and dressings applied.

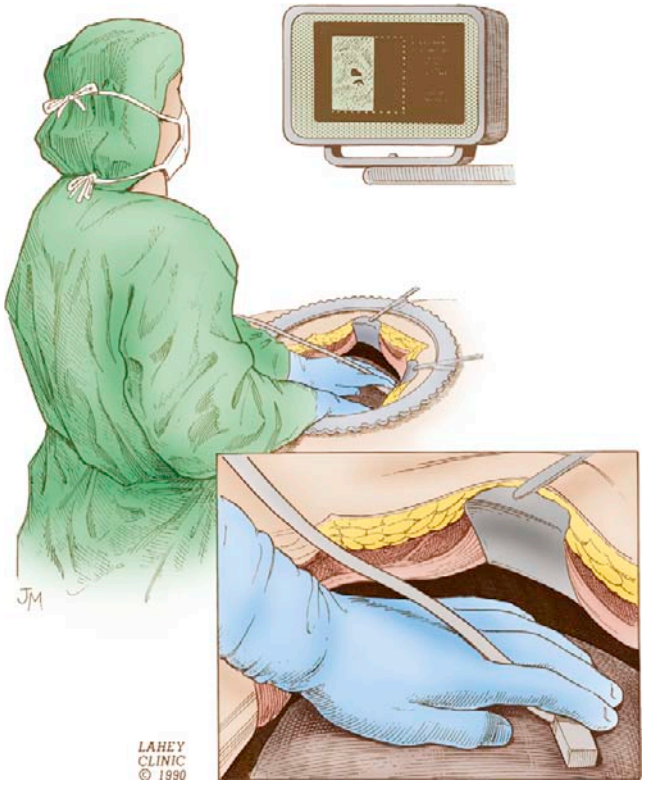


FIGURE 11-21 Use of intraoperative ultrasound using a 7-MHz T-probe to permit assessment of the liver.

Laparoscopic and Robotic-Assisted Laparoscopic Hepatic Surgery

Procedural Considerations. Laparoscopy for liver resection is a highly specialized field. It can present severe technical difficulties such as control of bleeding and risk of gas embolism (Belli et al, 2006; Borzellino et al, 2006). Other limitations relate to inadequate retraction, the inability to assess safe margins of resection with the loss of tactile sense, difficulty with safe parenchymal transection, and the potential for injury of adjacent structures (Poultsides et al, 2007). The use of stapling

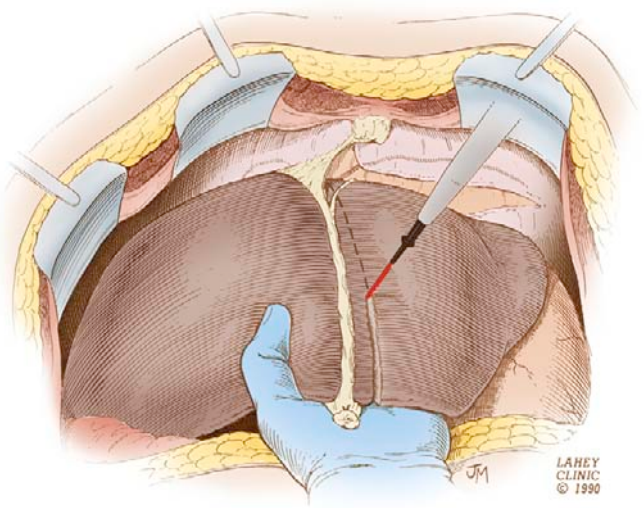


FIGURE 11-22 Use of electrosurgical pencil with blade tip to score the line of resection on the surface of the liver.

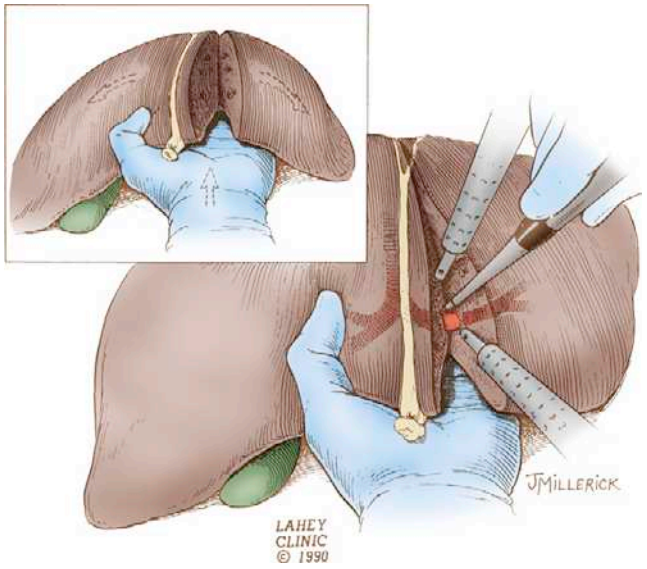


FIGURE 11-23 Use of the Cavitron ultrasonic surgical aspirator (CUSA) handpiece to dissect through the hepatic parenchyma.

devices has made the procedure faster and safer. Results for laparoscopic resections have been similar to those of open surgical technique in carefully selected cases (Borzellino et al, 2006). The benefits associated with robotic technology include less blood loss, faster recovery, less scarring, and reduced postoperative pain. The robot extends the surgeon's skills by providing a 360-degree range of motion not possible with traditional laparoscopic instruments. It also allows access to all the fine structures of the liver and better visualization of delicate blood vessels (First Robotic, 2005). Laparoscopic ultrasound navigation is often an important element in laparoscopic hepatic surgery as well (Kleemann et al, 2006). It enables determination of tumor location and the relationship to adjacent vascular and biliary structures (Santambrogio et al, 2007).

Radioimmunoguided Surgery

Radioimmunoguided surgery (RIGS) is a technique used intraoperatively to detect cancer that may not be readily detected by inspection or palpation. RIGS technique has been useful to determine safe margins of resection for metastatic colon cancer, as well as for extrahepatic disease and occult tumors in patients with rising serum carcinoembryonic antigen (CEA) levels.

About 2 to 3 weeks before surgery, patients receive an IV injection of radiolabeled monoclonal antibody, which binds reactive antigen on or near the surface of tumor cells. The antigen-antibody bond keeps minute amounts of radioactivity, or gamma emissions, localized in tumor tissue. An intraoperatively used, handheld gamma ray–detecting probe connected to a microcomputer emits an audible signal when the radioactive waves hit the crystal in the distal end of the probe. The Neoprobe instrument gives a digital reading as well as an audible pitch that rises or falls when placed on the gamma ray–emitting tissue. This advance in the intraoperative detection of adenocarcinoma and metastases can greatly assist in decision-making and resection of diseased tissue.

Procedural Considerations. Instrumentation includes a basic laparotomy set, biliary instruments, vascular instruments, and additional items such as a sterile marking pen, long clamps and a self-retaining retractor system (e.g., the Bookwalter retractor). Minimal suture (2-0 and 3-0 silk ties, 2-0 suture ligature) is added to the sterile field until the abdomen is explored and the extent of disease is assessed. The patient is positioned supine. The anesthesia provider inserts an NG tube after induction of general anesthesia and intubation. An indwelling urinary catheter is inserted before the abdominal prep. The abdomen is prepped from nipple line to midthigh. A midline abdominal incision provides access to the liver. Vertical abdominal incisions are sometimes used because they can be made and closed more rapidly and permit better exposure of all abdominal organs.

Operative Procedure

1. A midline abdominal incision is made from the xiphoid process to the pubis.
2. Intraoperative scanning of the liver and abdominal viscera is performed using the probe.
3. The digital readings as well as the anatomic structures being scanned are recorded.
4. Great care is taken to scan mesenteric, pelvic, and periaortic lymph nodes individually.
5. The liver is scanned and areas emitting strong-pitched tones are marked with a sterile marking pen. A very distinct change in pitch may be noted on liver tissue within a 2-cm to 3-cm radius of the tumor site.
6. Intraoperative ultrasonography and review of CT and MRI scans of the patient's liver are used to further confirm the liver lesions.
7. Margins for resection are drawn using an ESU tip on blend mode.
8. Resection of the lesion may be segmental, circumferential, or lobar.
9. After each resection, the margins of healthy liver tissue adjacent to the resection site are scanned and readings are recorded. This procedure continues until all tissue emitting high gamma ray waves has been resected.

10. Specimens are sent to the pathology laboratory for further pathologic and histologic analysis. The perioperative nurse supports accurate correlation of pathologic diagnosis with intraoperative RIGS findings by using safe specimen practices. Tissue specimens are verified, and specifically and meticulously identified.
11. The surgeon determines the best plan of treatment for the patient based on the information obtained from intraoperative assessment of the extent of the patient's disease. Resection of RIGS-positive tissue may result in an extensive retroperitoneal lymphadenectomy, liver resection, gastrohepatic ligament lymphadenectomy, or the resection of colon, uterus, or bladder.

Liver Transplantation

Liver transplantation is the implantation of a liver from a donor into a recipient. The total procedure involves retrieving or procuring the liver from a donor, transporting the donor liver to the recipient's hospital, performing a hepatectomy on the recipient, and then implanting the donor liver. Reanastomoses are then undertaken of the suprahepatic vena cava, infrahepatic vena cava, portal vein, and hepatic artery; biliary reconstruction with end-to-end anastomosis of donor and recipient common bile ducts; or Roux-en-Y anastomosis if the recipient's bile duct is absent as a result of biliary atresia.

Liver transplantation is indicated for patients with chronic hepatocellular disease, chronic cholestatic disease, metabolic liver disease, primary hepatic cancer, acute fulminant liver disease, and inborn errors of metabolism. When malignancies are the cause of end-stage liver disease, the right upper quadrant may be radiated intraoperatively—after hepatectomy and before transplantation. The patient undergoes extensive physiologic and psychologic assessment and evaluation by physicians and transplant coordinators before being placed on a national-network waiting list. The potential for postoperative complications (Table 11-5) requires ongoing evaluation.

Procedural Considerations. Successful transplantation requires the cooperative efforts of the organ-procurement agency and the staffs of the donor and recipient hospitals.

TABLE 11-5

Assessment and Prevention of Common Postoperative Complications Associated with Liver Transplants

Assessment	Prevention
ACUTE GRAFT REJECTION	
Occurs from fourth to tenth postoperative day.	Use prophylaxis with immunosuppressant agents, such as cyclosporine, FK-506, CellCept, Prograf, Imuran, sirolimus, and prednisone.
Manifested by tachycardia, fever, right upper quadrant (RUQ) or flank pain, diminished bile drainage or change in bile color, or increased jaundice.	Diagnose early to treat with more potent antirejection drugs, such as muromonab-CD3 (Orthoclone OKT3).
Laboratory changes include increased levels of serum bilirubin, transaminases, and alkaline phosphatase and prolonged prothrombin time.	Use antibiotic prophylaxis.
INFECTION	
Can occur at any time during recovery.	Diagnose early and treat with organism-specific antiinfective agents.
Manifested by fever or excessive, foul-smelling drainage (urine, wound, or bile); other indicators depend on location and type of infection.	Perform frequent cultures of tubes, lines, and drainage. Remove invasive line as early as possible. Use good hand hygiene.
HEPATIC COMPLICATIONS (BILE LEAKAGE, ABSCESS FORMATION, HEPATIC THROMBOSIS)	
Manifested by decreased bile drainage, increased RUQ abdominal pain with distention and guarding, nausea or vomiting, increased jaundice, and clay-colored stools.	Keep T-tube in dependent position and secure to patient; empty frequently, recording quality and quantity of drainage.
Laboratory changes include increased levels of serum bilirubin and transaminases.	Report manifestations to physician immediately. May necessitate surgical intervention.
ACUTE RENAL FAILURE	
Caused by hypotension, antibiotics, cyclosporine, acute liver failure, or hypothermia.	Monitor all drug levels with nephrotoxic side effects. Prevent hypotension.
Indicators of hypothermia include shivering, hyperventilation, increased cardiac output, vasoconstriction, and alkalemia.	Observe for early signs of renal failure and report them immediately to physician.
Early indicators of renal failure include changes in urinary output, increased blood urea nitrogen (BUN) and creatinine levels, and electrolyte imbalance.	

Modified from Ignatavicius DD, Workman ML: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, Philadelphia, 2010, Saunders.

Usually two members of the surgical team from the recipient's hospital travel to the donor's hospital to procure the donated liver. Often, multiple transplant teams may arrive at the donor hospital to procure various organs for transplantation. UNOS policies dictate a detailed system for checking and rechecking organs for transplantation to ensure that organs of the donor and recipient are compatible (see Patient Safety box, p. 386). These policies must be strictly followed before any transplant can take place. Safe practice further requires that hospital policies are consistent with applicable law and organ donation regulations and should address patient and family preferences for organ donation, as well as specify the roles and desired outcomes for every stage of the donation process (NQF, 2009).

PREPARING THE OR FOR THE DONOR. The donor OR is set up for a major laparotomy procedure. Basic instrumentation and equipment include a basic laparotomy set, cardiovascular instruments, power sternal saw, and nephrectomy instruments. A sterile, draped, medium-size instrument table is needed for preparation of the liver away from the main sterile field and instrument tables. The procurement team provides special Collins solution for flushing the organs, sterile plastic containers and ice chests for organs, and in situ flush tubing. The liver is generally placed in two Lahey bags immediately after procurement.

PREPARING THE OR FOR THE RECIPIENT. Each transplant surgeon has preferred instruments, supplies, and sutures. In general, the following are needed in the recipient's OR: a basic laparotomy set, a cardiovascular instrument set, an assortment of T-tubes, a slush unit or means of providing iced lactated Ringer's solution, two ESUs, a forced-air warming device, a temperature probe, IV volumetric pumps on stands, two blood warmers or water baths, an indwelling urinary catheter, an insertion tray, and a urometer. An argon beam coagulator may be used and should be available. A defibrillator is always located in the room with sterile external paddles available.

Large-bore cannulae for IV monitoring and fluid or blood replacement lines are placed in addition to an arterial line and a central venous line.

Two surgeon headlights and light sources will be necessary to augment visualization of the abdominal site. A venovenous bypass system may be used to support peripheral blood flow. Extra drape sheets, table covers, gowns, towels, gloves, sponges, and laparotomy pads; cold IV Ringer's solution; sterile IV administration set for flushing the new liver; umbilical tape; booties; and vessel loops should be available to support the many steps of the transplantation procedure.

A cart containing sutures and the numerous other small items should be arranged and placed in the room for each procedure. This eliminates the need for the circulating nurse to leave the patient and surgical team to obtain extra supplies.

The procedure for liver transplantation is a three-part process: retrieval of the donor organ, hepatectomy, and implantation of the donor liver. It is a lengthy procedure that takes many hours. The following aspects of implementing a plan of care deserve special attention.

Patient Positioning. The patient is placed supine with knees slightly flexed and padded. An indwelling urinary catheter is inserted after induction of anesthesia. Accurate body alignment is essential. A gel pad that is the length of the OR bed or a pressure-reducing OR bed mattress should be used, with attention to all potential pressure areas. Heel protectors are applied and SCDs are placed on the patient's legs. The safety strap is placed over the lower part of the thighs and secured. A forced-air warming device is applied over the upper body, neck, and head to assist in maintaining the patient's temperature. Fluid warmers are used to warm blood products and IV solutions.

Skin Preparation. The patient is prepped from the neck to midthigh, bedline to bedline. Prep solution should not pool at the bedline or wet the sheets on the OR bed. Fire safety precautions for prep solutions must be followed.

Blood Loss and Replacement. Blood loss may be extensive and replacement must be timely. The perioperative nurse should confirm that blood products are available at the beginning of the procedure. These include 10 units each of packed red blood cells (RBCs) and fresh frozen plasma (FFP) and 1 unit of pooled donor platelets. The perioperative nurse should be available to assist the anesthesia provider during the insertion of peripheral and arterial lines. An autologous cell-saver device may be used to assist in blood replacement by way of autotransfusion.

Intraoperative Laboratory Testing. It is possible that as many as 50 blood specimens will be drawn for analysis during the procedure. Safe specimen collection practices are implemented. These specimens must be recorded on the blood-loss record and calculated into replacement needs. Specimens are delivered to the laboratory immediately. A telephone in the OR is useful for receiving and reading back critical test results/reports directly from the laboratory. Safe practices for reporting of critical test results require the perioperative nurse to verify the test result by "reading-back" the result (NQF, 2009). Standard precautions in collection of specimens must be observed.

Length of Procedure. Procedures may last from 6 to 20 hours. Special attention must be paid to maintaining the integrity of the sterile environment, given the length of surgery and number of people entering and exiting the OR.

Communication with Family. Frequent reports to the family are important. Family members often are knowledgeable about liver function tests and laboratory values and want this information in addition to reports on the condition of their loved one. One person should be assigned in advance to make regular contacts with family and support persons. The UNOS team often works closely in communicating with the donor's and recipient's families.

Communication Among Teams. The perioperative nurse ensures that communication occurs among teams. Coordination among the procurement team, anesthesia team, and surgical teams is essential for a successful transplantation procedure. Perioperative nursing responsibilities also include monitoring and communicating blood-loss volume in suction canisters and on sponges, the availability of blood and blood products, laboratory results, time of organ arrival, ischemic time, and other events as they unfold in preparation for and during the transplant procedure.

Operative Procedure

1. Bilateral subcostal incisions are made with a midline incision extended toward the umbilicus. If necessary, the xiphoid is removed. The right side of the chest is entered if additional exposure is needed.
2. Initial dissection of the underlying tissues is achieved with electrosurgery and suture ligatures.

3. Isolation of all hilar structures and dissection to mobilize the lobes of the native liver are performed.
4. The retrohepatic vena cava is skeletonized, as are the hepatic artery, portal vein, common bile duct, and inferior vena cava.
5. The donor liver is examined.
6. Preparations may be made at this time for venovenous bypass using an extracorporeal assist device if the patient is unstable.
7. The infrahepatic vena cava and the suprahepatic vena cava are clamped, as are the portal vein, the hepatic artery, and the common bile duct.
8. Native hepatectomy is then performed.
9. The donor liver is placed in the right upper abdomen, and revascularization of the donor organ begins with end-to-end anastomoses in the vena cava and portal vein, with double-armed fine vascular suture.
10. At this point, the clamps on the portal vein, suprahepatic vena cava, and infrahepatic vena cava are released slowly, and blood flow through the vena cava and portal vein is restored.
11. The anastomosis sites are then checked for leaks.
12. If it was used, venovenous bypass is discontinued, and the cannulation sites are closed.
13. The postrevascularization phase focuses on achieving hemostasis. Complete hemostasis may require extensive time at this point. Bleeding may be exacerbated by a fibrinolytic episode associated with the reperfusion of the donor organ. The liver is monitored for a change in color from dusky to pink. An intraoperative Doppler may be used to confirm patency of the blood supply.
14. The anastomosis of the hepatic artery is then commenced, followed by bile duct reconstruction. This varies with the status of the recipient's biliary tract. If biliary atresia is the cause of the patient's end-stage liver disease, choledochoenterostomy into a Roux-en-Y loop of jejunum is performed (Figure 11-24).
15. The anastomoses are then checked for leaks.
16. Drains are placed behind and in front of the liver and exteriorized. The abdomen is then closed.

Donor Hepatectomy

Donor hepatectomy is performed for procurement of a healthy liver for transplant into a patient who has end-stage liver failure. This procedure occurs only after the donor patient has been determined to be brain dead and family consent for organ donation has been obtained. Donor hepatectomy can be performed at any hospital. Organ procurement agencies arrange contact with transplant centers when a viable organ donor has been identified.

Procedural Considerations. Once the liver transplant candidate has been identified, the procurement team from that transplant center travels to the institution where the organ donor is hospitalized. If multiple organs are being donated, surgeons from several transplant centers may arrive to procure the organs they will be transplanting to their respective centers.

The procedure for procurement of multiple organs will differ according to the transplant centers represented. Most commonly, the systemic cooling of the donor's body temperature is started before the procurement of the heart. Cannulation sites also vary according to which organs are procured.

Perioperative nurses at the donor hospital are responsible for supplying a basic laparotomy setup with instrumentation to open the sternum. Basic vascular clamps are also required to clamp the major vascular structures. Cold lactated Ringer's solution for parenteral infusion and cold Ringer's solution for irrigation are usually used in large amounts.

Operative Procedure

1. The donor patient is positioned supine on the OR bed. The skin area from neck to midthigh is prepped and draped.
2. A midline incision is made from the suprasternal notch to the pubis.
3. A subcostal incision is performed bilaterally on the abdomen for better exposure of the abdominal viscera.

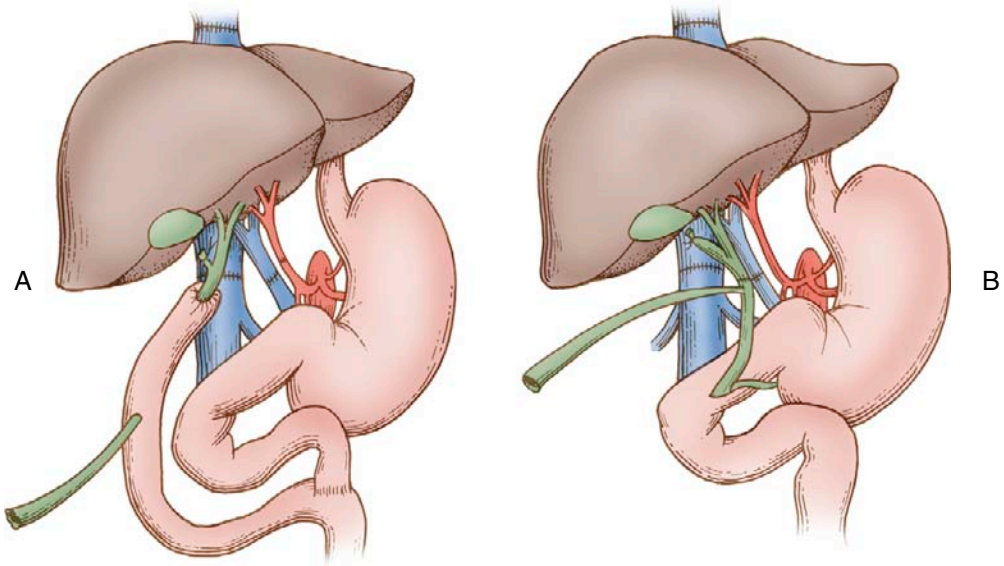


FIGURE 11-24 Completed orthotopic liver transplant with Roux-en-Y biliary reconstruction (**A**) and end-to-end anastomosis of the donor-to-recipient common bile ducts (**B**).

4. Retractors are placed to provide optimal exposure of the organs that will be procured.
5. The aorta and vena cava, superior and inferior to the liver and kidneys, are skeletonized by dissection and ligation of the lymphatics and smaller vasculatures.
6. The porta hepatis is dissected; the superior mesenteric artery and celiac trunk are then dissected and delicately exposed as close to the aorta as is convenient.
7. The superior mesenteric vein is dissected and prepared for cannulation. The donor is heparinized and systemically cooled.
8. If the heart is to be procured, removal takes place at this time.
9. Further cooling and flushing of the pancreas, liver, and kidneys are achieved by cannulation and infusion of cold lactated Ringer's solution through the inferior vena cava just superior to the bifurcation.
10. The liver, pancreas, spleen, and a segment of the duodenum harboring the pancreatic duct are procured en bloc by placing clamps on the suprahepatic and infrahepatic venae cavae.
11. The suprahepatic vena cava is transected with a surrounding cuff of diaphragm intact.
12. The infrahepatic vena cava is transected above the level of the renal veins.
13. The celiac axis is detached from the aorta as an aortic patch or taken with a full aortic circumference.
14. The duodenal segment is procured, using a linear stapling device at opposite ends of the segment.
15. The en bloc organs are taken to a back table for further dissection and ligation to separate the liver from the en bloc pancreas, spleen, and duodenal segment graft. Meanwhile, other members of the procurement team continue working to free the kidneys and ureters if they are to be taken.
16. The liver is placed in a basin of cold Ringer's solution, double-bagged in sterile Lahey bags, and placed in an ice chest for transport to the recipient's hospital.
17. The kidneys are placed in sterile cassettes and mechanically perfused.
18. The pancreatic en bloc graft is also placed in a basin of cold Ringer's solution, bagged, and transported in a thermal chest of ice.
19. The abdomen is closed with a single layer of size 1 or 0 nonabsorbable suture.
20. Drapes are removed, and the donor patient is cleaned and washed. Tubes and infusion lines are tied off or clamped. Sometimes family members of the donor patient request to view the body after organ donation. This factor may be important in helping them face their loss. Before family viewing, the donor's body is covered with a warm blanket. The perioperative nurse assists the family in their grieving process by providing a quiet and private environment in which to say good-bye to their family member. The nurse should stay with family members to support them.
21. The donor patient is then transported by stretcher to the morgue.

Living-Related Liver Transplantation

Just as kidney transplantation has evolved into living-related donor possibilities, so too has liver transplantation. The capacity of the liver to regenerate provided the scientific basis for development of the living-related donor transplantation procedure. Reduced-size and split-liver transplants have been performed successfully. Reduced-size liver transplantation has been performed for infants, children, or very small adults with results comparable to those obtained with whole-organ transplantation. Prospective living donors are thoroughly evaluated with a protocol that includes blood group compatibility, a comprehensive history and physical examination, laboratory studies, psychosocial evaluation, independent advocate opinion, anatomic compatibility, review of candidacy with the donor, and presentation to a selection committee (Patt and Thuluvath, 2003). As cloning, biogenetic engineering, and other technologic advances increase the possibilities for organ transplants, society will need to address ongoing debates of ethical dilemmas surrounding transplantation.

SURGERY OF THE SPLEEN

Splenectomy (Open Approach)

Splenectomy is removal of the spleen. It is performed for multiple reasons: trauma to the spleen; specific malignant conditions (Hodgkin's disease and non-Hodgkin's lymphomas; hairy cell, chronic lymphocytic, and chronic myelogenous leukemias); hemolytic jaundice or splenic anemia; idiopathic thrombocytopenia purpura (ITP); tumors, cysts, or splenomegaly; or accidental injury during vagotomy or other procedures involving mobilization of the splenic flexure of the colon. If accessory spleens are present, they are also removed because they are capable of perpetuating hypersplenic function. In most instances, patients evaluated for elective splenectomy are considered candidates for laparoscopic splenectomy. Contraindications to laparoscopic splenectomy include severe portal hypertension, uncorrectable coagulopathy, severe ascites, extreme splenomegaly, extensive adhesions, and most traumatic injuries to the spleen. For these patients, an open approach is indicated.

Procedural Considerations. Instrumentation is as described for a basic laparotomy, plus two large, right-angled pedicle clamps, long instruments, and hemostatic materials and devices. Abdominal suction apparatus is available and a cell-saver may be requested. The patient is positioned supine. After induction of general anesthesia and intubation, the anesthesia provider inserts an NG tube. An indwelling urinary catheter is inserted before the abdominal prep. The abdomen is prepped from nipple line to midthigh. The OR bed is moved to reverse Trendelenburg's position with a slight tilt to the right. A midline abdominal incision provides access to the spleen and allows maximal exposure of all abdominal organs. Occasionally, a subcostal approach is used for a patient without traumatic injury. Rarely, a thoracoabdominal approach is used.

Operative Procedure

1. The abdomen is opened through the selected incision.
2. Retractors are placed over moistened laparotomy packs and exploration is carried out.
3. The costal margin is retracted upward.
4. The splenorenal, splenocolic, and gastrosplenic ligaments are clamped and divided with long dressing forceps, long hemostats, sponges on holders, and long Metzenbaum or Nelson scissors.

5. Adhesions posterior to the spleen are freed.
6. The spleen is delivered into the wound.
7. The short gastric vessels are now easily identified, clamped, divided, and ligated.
8. The cavity formerly occupied by the spleen is packed with moist laparotomy pads, if necessary.
9. The splenic artery and vein are dissected free with fine dissecting scissors and forceps.
10. The artery is clamped and doubly ligated. The artery is ligated first to permit disengorgement of blood from the spleen and facilitate return of venous blood to the circulatory system.
11. The splenic vein is then clamped, divided, and ligated.
12. The specimen is removed, bleeding vessels controlled, and the wound closed in layers, as described for laparotomy. Dressings are applied.
13. Drainage is usually required only if extensive adhesions to the diaphragm were divided or if significant clotting abnormalities exist.

Laparoscopic Splenectomy

Laparoscopic splenectomy is standard procedure for surgical treatment of benign hematologic disorders (Beauchamp et al, 2008). Indications are the same as with open procedures, with the exception of the contraindications noted previously. Robotic assistance has improved visibility and motion control (Bodner et al, 2005b).

Procedural Considerations. After induction of general anesthesia, an NG tube and indwelling urinary catheter are inserted, and SCDs applied to the lower extremities. The patient is positioned in right lateral position, with the OR bed flexed and kidney rest raised to increase the distance between the lower rib and iliac crest. The anterior abdomen is brought close to the edge of the OR bed. A beanbag device may be used. Safety restraints must be placed, especially in anticipation of a possible slight backward patient tilt. Alternatively, supine or modified lithotomy position may be used. The surgeon stands on the patient's right side, as does the scrub person, and assistants stand to the left.

Instrumentation and equipment include a 30-degree telescope (10-mm or 5-mm); a camera (triple-chip or single-chip); a high-flow insufflator with CO_2 tank; a high-resolution monitor (second monitor optional for assistant); a printer (optional); a Surgineedle or Veress needle; four 12-mm trocars (trocar size depends on surgeon preference—some surgeons substitute one or two of the 12-mm trocars with 5-mm trocars or even 3-mm trocars); endoshears/scissors; ultrasonic endoshears; an endodissecting forceps or endograsper (atraumatic); an endoretractor; an endoclip applier; a linear stapling device (GIA type) with vascular cartridges; an endoretrieval pouch; and a suction-irrigation system. As with other laparoscopic procedures, instruments and supplies are available if it becomes necessary to convert to an open approach.

Operative Procedure

1. Pneumoperitoneum is created and the first trocar placed under direct visualization. Three to five 2- to 12-mm operating ports are used, with the camera port at the umbilicus.
2. The laparoscope is inserted through the port and the camera placed.
3. The stomach is retracted to expose the spleen and a search made for any accessory spleens.
4. Initial dissection is begun by mobilizing the splenic flexure of the colon.
5. The splenocolic ligament is divided using sharp dissection, mobilizing the inferior pole of the spleen. The spleen is now retracted cephalad, taking care not to rupture the splenic capsule during retraction.
6. The lateral peritoneal attachments of the spleen are then incised using either sharp dissection or ultrasonic endoshears.
7. The lesser sac is entered along the medial border of the spleen.
8. With the spleen elevated, the short gastric vessels and main vascular pedicle are visualized. The tail of the pancreas is also visualized and avoided.
9. The short gastric vessels are divided by means of an ultrasonic dissector, endoclips, or an endovascular stapling device.
10. After the short gastric vessels have been divided, the splenic pedicle is carefully dissected from both the medial and lateral aspects.
11. After the artery and vein are dissected, the vessels are divided by application of the endovascular stapler. Multiple vascular branches may be encountered and each is taken individually.
12. The spleen is now devascularized and ready for removal.
13. An Endo-Bag is introduced through one of the trocar sites, usually the left lateral site.
14. The bag is opened and the spleen placed into it. The drawstring is grasped and the bag closed, leaving only the superior pole attachments, which are now divided.
15. The open end of the bag is exteriorized from the abdomen through the supraumbilical port or epigastric trocar site. The spleen is then morcellated and removed in fragments.
16. The laparoscope is reinserted and the splenic bed is assessed for hemostasis.
17. If necessary, a drain is placed in the intraabdominal cavity, the abdomen deflated, and the trocars removed.
18. The trocar sites are then closed.

REFERENCES

Ackley BJ, Ladwig GB: *Nursing diagnosis handbook: an evidence-based guide to planning care*, ed 8, St Louis, 2008, Mosby.

Afdhal NH, Vollmer CM: Complications of laparoscopic cholecystectomy, available at www.uptodate.com/patients/content/topic.do?topicKey=~JduJa7QAGmGYd., 2008. Accessed Nov. 27, 2008.

Association of periOperative Registered Nurses (AORN): Recommended practices for a safe environment of care. In *Perioperative standards and recommended practices*, Denver, 2009, The Association.

Beauchamp RD et al: The spleen. In Townsend CM et al, editors: *Sabiston textbook of surgery*, ed 18, Philadelphia, 2008, Saunders.

Belli G et al: Laparoscopic left lateral hepatic lobectomy: a safer and faster technique, *J Hepatobiliary Pancreat Surg* 13(2):149–154, 2006.

Belli G et al: Laparoscopic versus open liver resection for hepatocellular carcinoma in patients with histologically proven cirrhosis: Short- and middle-term results, *Surg Endosc* 21(11):2004–2011, 2007.

Benner P et al: *Expertise in nursing practice: caring, clinical judgment, and ethics*, ed 2, New York, 2009, Springer Publishing Co.

Bodner J et al: Long-term follow-up after robotic cholecystectomy, *Am Surg* 71(4):281-288, 2005a.

Bodner J et al: A critical comparison of robotic versus conventional laparoscopic splenectomies, *World J Surg* 29(8):982-985, 2005b.

Borzellino G et al: Laparoscopic hepatic resection, *Surg Endosc* 20(5):787–790, 2006.

Canobbio MM: *Mosby's handbook of patient teaching*, ed 3, St Louis, 2006, Mosby.

Chari RS, Shah SA: Biliary system, In Townsend CM et al: editors: *Sabiston textbook of surgery*, ed 18, Philadelphia, 2008, Saunders.

Denholm B: Tucking patient's arms and general positioning, *AORN J* 89(4):755–757, 2009.

First Robotic Complex Liver Surgery, available at www.medicalnewstoday.com/articles/22589.php.2005. Accessed March 30, 2009.

Gruessner RW et al: Over 500 solitary pancreas transplants in nonuremic patients with brittle diabetes mellitus, *Transplantation* 85(1):42–47, 2008.

Hanley EJ, Talamini MA: Robotic abdominal surgery, *Am J Surg* 188(4A, Suppl):19S–26S, 2004.

Hines OJ, Reber HA: Pancreatic surgery, *Curr Opin Gastroenterol* 22(5): 520–526, 2006.

Insler SR, Sessler DI: Perioperative thermoregulation and temperature monitoring, *Anesthesiol Clin* 24(4):823–837, 2006.

Jacobsen G et al: Robotic surgery update, *Surg Endosc* 18(8):1186–1191, 2004.

Kleemann M et al: Laparoscopic ultrasound navigation in liver surgery: technical aspects and accuracy, *Surg Endosc* 20(5):726–729, 2006.

McPhee JT et al: Perioperative mortality for pancreatectomy: a national perspective, *Ann Surg* 246(2):246–253, 2007.

Meakins JL, Masterson BF: ACS Surgery: principles & practice, In Souba WW, editor: *American College of Surgeons*, ed. 6, New York, 2007, WebMD Professional Pub, p. 20.

Melvin WS: Minimally invasive pancreatic surgery, *Am J Surg* 186(3): 274–278, 2003.

National Quality Forum (NQF): *Safe Practices for Better Healthcare, 2009 Update: A Consensus Report*, Washington, DC, 2009, NQF.

Nguyen NT et al: Application of robotics in general surgery: initial experience, *Am Surg* 70(10):914–917, 2004.

Patt CH, Thuluvath PJ: Adult living donor transplantation. Medscape Gastroenterology, 2003, available at www.medscape.com/viewarticle/458740?src=search. Accessed October 8, 2008.

Phillips NF: *Berry & Kohn's operating room technique*, 11th ed, St Louis, 2007, Mosby.

Poultsides G et al: Hand-assisted laparoscopic management of liver tumors, *Surg Endosc* 21(8):1275–1279, 2007.

Ramos AC et al: NOTES transvaginal video-assisted cholecystectomy: First series, *Endoscopy* 40:572–575, 2008.

Santambrogio R et al: Impact of intraoperative ultrasonography in laparoscopic liver surgery, *Surg Endosc* 21(2):181–188, 2007.

Steer ML: Exocrine pancreas, In Townsend CM, editor: *Sabiston textbook of surgery*, ed 18, Philadelphia, 2008, Saunders.

Universal Protocol for Preventing Wrong Site, Wrong Procedure and Wrong Person Surgery. The Joint Commission (TJC), available at www.jointcommission.org/PatientSafety/UniversalProtocol/. Accessed March 30, 2009.

CHAPTER 12

Repair of Hernias

MAYA CLARK and JANE C. ROTHROCK

A hernia is an abnormal protrusion of a peritoneum-lined sac through the musculoaponeurotic covering of the abdomen. The word *hernia* is a Latin term that means "rupture" of a portion of a structure. Descriptions of hernia reduction date back to Hammurabi of Babylon and the Egyptian papyrus (History box). Weakness of the abdominal wall, congenital or acquired, results in the inability to contain the visceral contents of the abdominal cavity within their normal confines. This defect occurs frequently; hernia repair is the most common operation in general surgery (Menon, 2008). More than 700,000 surgical procedures are performed each year to repair congenital hernia defects; nearly 75% of all acquired hernias occur in the inguinal region. Of these, about 50% of hernias are indirect inguinal hernias and 24% are direct inguinal hernias. Incisional and ventral hernias account for approximately 10% of all hernias; as the frequency and magnitude of abdominal surgeries have increased in recent years, so has the incidence of incisional hernia. Femoral hernias account for 3%, and unusual hernias account for the remaining 5% to 10%.

Hernias occur most often in males. The most common hernia in both males and females is the indirect inguinal hernia. Femoral hernias occur much more frequently in females, and only 2% of females will develop inguinal hernias in their lifetime. Also, hernias occur more commonly on the right side than on the left. Herniorrhaphy is one of the most common operative procedures performed and is the preferred treatment when a defect is detected.

Hernias have a tremendous economic significance in the United States. The number of workdays lost is substantial. The trend toward ambulatory surgery for hernia repair is one of many attempts to provide cost-effective healthcare that also leads to patient satisfaction.

A hernia can occur in several places in the abdominal wall, with protrusion of a portion of the parietal peritoneum and often a part of the intestine. The weak places or intervals in the abdominal aponeurosis are (1) the inguinal canals, (2) the femoral rings, and (3) the umbilicus. Any number of conditions causing increased pressure within the abdomen can contribute to the formation of a hernia. Contributing factors to hernia formation include age, gender, previous surgery, obesity, nutritional status, and pulmonary and cardiac disease. Loss of tissue turgor occurs with aging and in chronic debilitating diseases. Current evidence suggests that adult male inguinal hernias are likely associated with impaired collagen metabolism and weakening of the fibroconnective tissue of the groin (Gilbert et al, 2009). Smoking has also been noted as a contributing factor to hernia formation (Read, 2004). A successful herniorrhaphy is measured by the percentage of recurrence, the number of complications, the total costs, and the ability to return to normal activities of daily living (Research Highlight).

Surgical Anatomy

A hernia is a sac lined by peritoneum that protrudes through a defect in the layers of the abdominal wall. Generally, a hernia mass is composed of covering tissues, a peritoneal sac, and any contained viscera. Hernias may be acquired or congenital.

Depending on their location, hernias are classified as direct inguinal, indirect inguinal, femoral, umbilical, incisional, or epigastric (Figure 12-1). Hernias in any of these groups are either reducible or nonreducible; that is, the contents of the hernia sac either can be returned to the normal intraabdominal position or are trapped in the extraabdominal sac (incarcerated). The conditions preventing the return of the hernia contents to the abdomen can result from (1) adhesions between the contents of the sac and the inner lining of the sac, (2) adhesions among the contents of the sac, or (3) narrowing of the neck of the sac. Patients with incarcerated hernias may have signs of intestinal obstruction, such as vomiting, abdominal pain, and distention. The greatest danger of an incarcerated hernia is that it may become strangulated. In a strangulated hernia, the blood supply of the trapped sac contents becomes compromised and eventually the sac contents necrose. When bowel is strangulated in such a hernia, resection of necrotic bowel, in addition to the repair of the hernia defect, becomes necessary. This is a surgical emergency.

Inguinal Hernias

The anterolateral abdominal wall consists of an arrangement of muscles, fascial layers, and muscular aponeuroses lined interiorly by peritoneum and exteriorly by skin (Figure 12-2). The abdominal wall in the groin area is composed of two groups of these structures: a superficial group (Scarpa's fascia, external and internal oblique muscles, and their aponeuroses) and a deep group (internal oblique muscle, transversalis fascia, and peritoneum).

Essential to an understanding of inguinal hernia repair is an appreciation of the central role of the transversalis fascia as the major supporting structure of the posterior inguinal floor. The inguinal canal, which contains the spermatic cord and associated structures in males and the round ligament in females, is approximately 4 cm long and takes an oblique course parallel to the groin crease. The inguinal canal is covered by the aponeurosis of the external abdominal oblique muscle, which forms a roof (Figure 12-3). A thickened lower border of the

HISTORY

History of Hernia Repairs

Groin hernias were originally documented 3500 years ago, with surgical intervention starting approximately 1500 years after that. Before the intervention of surgical repair of the hernia, external supports called *trusses* were used to contain hernias that protruded from the body. A brief chronology of some of the events that laid the foundation for modern hernia repair is presented below.

Time Period	Breakthrough
2800 BC	Herodotus reported that physicians specialized in treating hernia.
1700 BC	Hammurabi described hernia reduction.
400 BC	Hippocrates described hernia as a tear in the abdomen.
200 BC	Galen described anatomy of the abdominal wall.
AD 100	Celsus described clinical signs to differentiate a hernia from a hydrocele.
1559	Maupassius performed the first surgical intervention to correct a strangulated hernia.
1724	Heister described direct hernias.
1804	Astley Cooper defines a hernia as a protrusion of any viscus from its proper cavity.
1814	Scarpa described sliding hernias.
1881	Lucas-Championniere laid the basis for the most important inguinal hernia repair procedure—reinforcing the posterior wall of the inguinal canal and narrowing the internal inguinal ring.
1887	Bassini introduced his repair technique that involved suturing the conjoined tendon to the inguinal ligament up to the inguinal ring; he is considered the father of modern-day hernia surgery.
1898	Lotheissen modified the Bassini repair, recommending the oblique internus and transversus abdominis muscles be attached to the Cooper ligament. (Cooper was the first to describe the superior pubic ligament, although he never used it to surgically repair a groin hernia.)
1918	Nursing textbook listed instruments for femoral, inguinal, umbilical, and ventral herniorrhaphy.
1940	Shouldice introduced multilayer closure; founded Shouldice Hospital near Toronto. Local anesthetic was used; patients walked to and from the OR.
1942	McVay again described Lotheissen repair; it became known as the *McVay/Cooper repair.*
1958	Usher introduced use of "Marlex" mesh for repair of both primary and recurrent hernias, describing it as "tension-eliminating."
1971	Nursing textbook described the Gallie method, in which fascia lata is removed from the thigh and stitched around the hernial orifice.
1982	Ger performed the first laparoscopic herniorrhaphy.

RESEARCH HIGHLIGHT

Prioritizing General Surgery Procedures for Quality Improvement Efforts

Despite growing reliance on quality improvement measures, there is no established protocol for determining which general surgical procedures should be the focus of these efforts. In this study, researchers sought to prioritize procedures for quality improvement efforts in general surgery in terms of morbidity, mortality, and excess length of stay. Using data from the American College of Surgeons' National Surgery Quality Improvement Program, they identified 129,233 patients who underwent general surgery between 2005 and 2006.

Patients were placed in 36 procedure groups. Of these, 10 groups accounted for 62% of complications and 54% of excess length of stay. Patients undergoing ventral hernia repair accounted for only 5% of complications. In contrast, the colectomy group accounted for the highest number of adverse events (24%), followed by small intestine resection (8%), inpatient cholecystectomy (6%), and pancreatic resection (4%).

In looking at ambulatory surgery, outpatient inguinal hernia repair, cholecystectomy, breast procedures, thyroidectomy, and parathyroidectomy accounted for 34% of procedures but only 6% of complications and less than 1% of excess hospital days.

Based on their analysis, researchers concluded that a relatively small number of general surgery procedures account for a disproportionate share of the morbidity, mortality, and excess hospital days. Therefore focusing quality improvement efforts on those procedures may be an effective strategy for improving care and reducing cost.

Adapted from Schilling PL et al: Prioritizing quality improvement in general surgery, *J Am Coll Surg* 207:698-704, 2008.

external oblique aponeurosis forms the inguinal (Poupart's) ligament, which runs from the anterior superior iliac spine to the pubic tubercle. Structures that traverse the inguinal canal enter it from the abdomen by the internal ring, a natural opening in the transversalis fascia, and exit by the external ring, an opening in the external oblique aponeurosis, to go to either the testis or the labium. If the external oblique aponeurosis is opened and the cord or round ligament is mobilized, the floor of the inguinal canal is exposed. The posterior inguinal floor is the structure that becomes defective and is susceptible to indirect, direct, or femoral hernias.

The key component of the important posterior inguinal floor is the transversalis muscle of the abdomen and its associated aponeurosis and fascia. The posterior inguinal floor can be divided into two areas. The superior lateral area represents the internal ring, whereas the inferior medial area represents the attachment of the transversalis aponeurosis and fascia to the Cooper ligament (iliopectineal line). The Cooper ligament is the

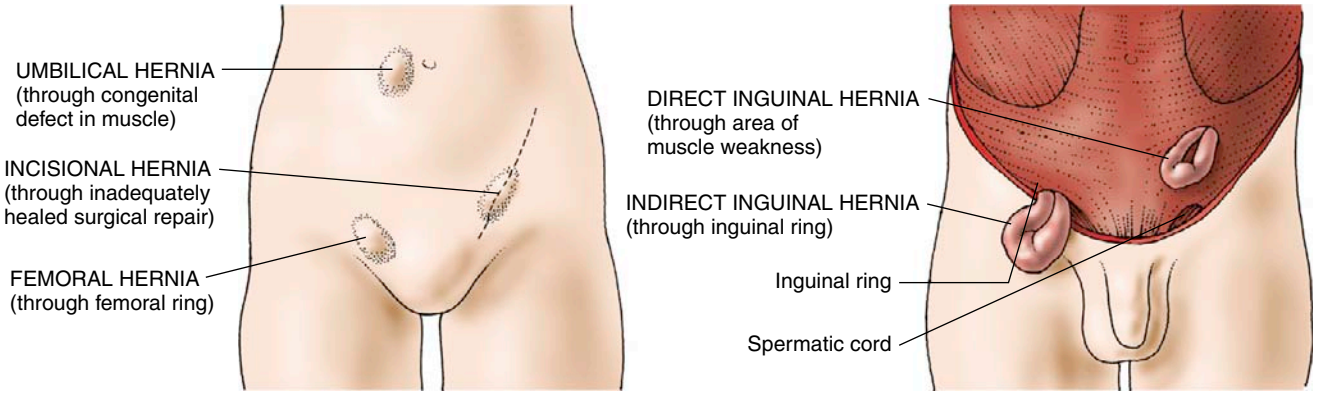


FIGURE 12-1 Types of abdominal hernias.

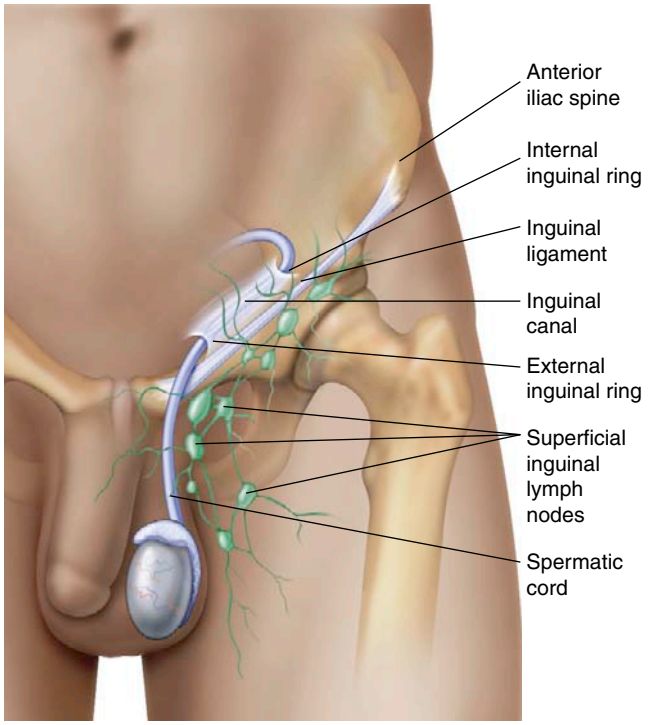


FIGURE 12-2 Structures of the inguinal area.

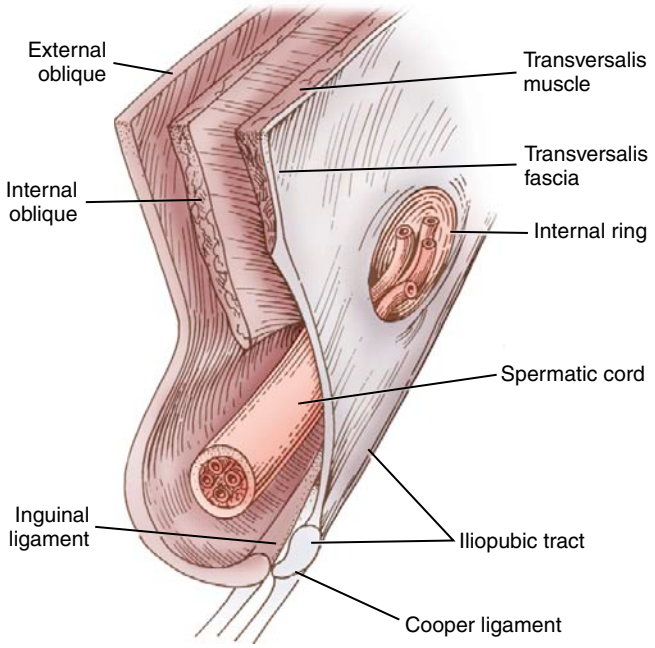


FIGURE 12-3 Right inguinal region, parasagittal section. Roof of inguinal canal is formed by external oblique aponeurosis, and floor is formed by transversalis aponeurosis and fascia.

site of the insertion of the transversalis aponeurosis along the superior ramus from the symphysis pubis laterally to the femoral sheath. The inguinal portion of the transversalis fascia arises from the iliopsoas fascia and not from the inguinal ligament.

Medially and superiorly the transversalis muscle becomes aponeurotic and fuses with the aponeurosis of the internal oblique muscle to form anterior and posterior rectus sheaths. As the symphysis pubis is approached, the contributions from the internal oblique muscle become fewer and fewer. At the pubic tubercle and behind the spermatic cord or round ligament, the internal oblique muscle makes no contribution and the posterior inguinal wall (floor of the inguinal canal) is composed solely of aponeurosis and fascia of the transversalis muscle.

None of the three groin hernias (direct and indirect inguinal hernias and femoral hernia) develops in the presence of a strong transversus abdominis layer and in the absence of persistent stress on the connective tissue layers. When a weakening or a tear in the aponeurosis of the transversus abdominis and the transversalis fascia occurs, the potential for development of a direct inguinal hernia is established.

Femoral Hernias

When the transversus abdominis aponeurosis and its fascia are only narrowly attached to the Cooper ligament, a femoral hernia may develop. This results in an enlarged femoral ring and canal, which allows for the prominence of the iliofemoral vessels, resulting in femoral herniation (Lawrence, 2006).

The walls of the femoral sheath are formed anteriorly and medially from the transversalis fascia, posteriorly from the pectineus and psoas fascia, and laterally from the iliaca fascia. The pelvis ostium consists of a relatively fixed rim of bone and connective tissue: anteriorly and medially the iliopubic tract, posteriorly the superior ramus, and laterally the iliopectineal arch.

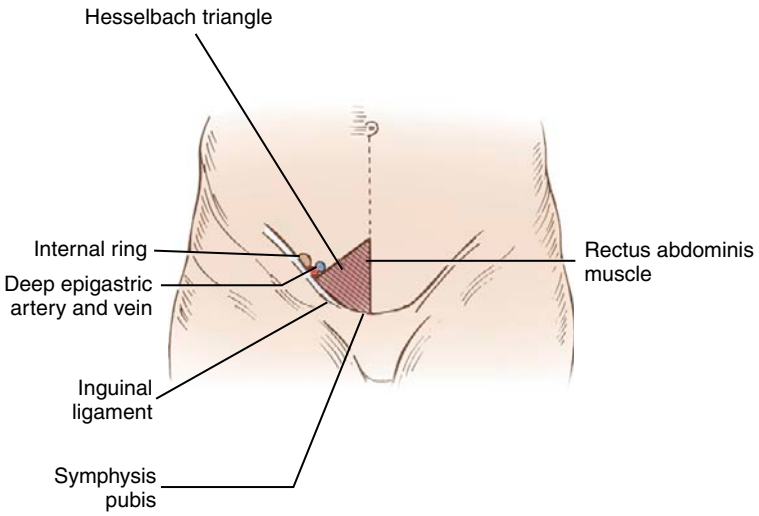


FIGURE 12-4 Schema of the Hesselbach triangle. Boundaries of the Hesselbach triangle are deep epigastric vessels laterally, inguinal ligament inferiorly, and rectus abdominis muscle medially.

The femoral sheath is subdivided into three compartments. The lateral compartment contains the femoral artery, and the intermediate compartment contains the femoral vein. The medial compartment is the smallest and constitutes the femoral canal, which is formed anteriorly and medially by the iliopubic tract. This opening is bound laterally by the iliofemoral vessels and posteriorly by the superior pubic ramus and pectineus fascia. Superiorly, laterally, and inferiorly the fossa is formed by the falciform margin of the fascia lata.

Abdominal Hernias

The anterior abdominal wall is composed of external abdominal oblique muscles attached to a thick sheath of connective tissue called the *rectus sheath*. The linea alba extends superiorly and inferiorly from above the xiphoid process to the pubis. Beneath the rectus sheath lies the rectus abdominis muscles, laterally to the right and left of the linea alba. Lateral to the rectus abdominis is the linea semilunaris. The transversus abdominis muscles originate from the seventh to the twelfth costal cartilages, lumbar fascia, iliac crest, and the inguinal ligament, and insert on the xiphoid process, the linea alba, and the pubic tubercle. The third layer of abdominal wall includes the internal abdominal oblique muscles originating from the iliac crest, inguinal ligament, and lumbar fascia, and inserting on the tenth to twelfth ribs and rectus sheath.

Direct and Indirect Inguinal Hernias

The deep epigastric vessels (inferior epigastric) arise from the external iliac vessels and enter the inguinal canal just proximal to the internal ring. The triangle formed by the deep epigastric vessels laterally, the inguinal ligament inferiorly, and the rectus abdominis muscles medially is referred to as the *Hesselbach triangle* (Figure 12-4). Hernias that occur within the Hesselbach triangle are called *direct inguinal hernias*. Indirect inguinal hernias occur laterally to the deep epigastric vessels. Both direct and indirect hernias represent attenuations or tears in the transversalis fascia (Figure 12-5).

Direct hernias protrude into the inguinal canal but not into the cord and therefore rarely into the scrotum. Direct inguinal hernias usually result from heavy lifting or other strenuous activities. Indirect hernias leave the abdominal cavity at the internal inguinal ring and pass with the cord structures down the inguinal canal. Consequently, the indirect hernia sac may be found in the scrotum. Indirect hernias may be either congenital, representing a persistence of the processus vaginalis, or acquired. In a congenital hernia, the hernia sac has a small neck, is thin-walled, and is closely bound to the cord structures. In an acquired indirect hernia, the neck is wide and the sac is both short and thick-walled. When both direct and indirect hernias are present, the defect is called a *pantaloon hernia* after the French word for "pants," which this situation suggests.

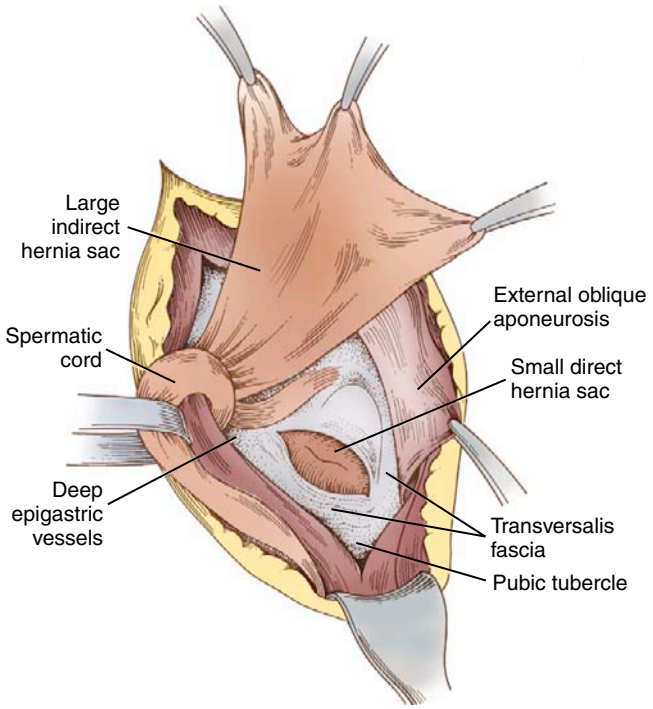


FIGURE 12-5 Defect in transversalis fascia, medial to deep epigastric vessels, results in direct hernia. Defect lateral to deep epigastric vessels results in indirect hernia.

Perioperative Nursing Considerations

Assessment

Assessment of the patient with a hernia begins with a thorough patient history. This should include the history of previous surgeries related to the herniated area. Information relating to a familial history of hernias, the patient's nutritional status, the duration of the symptoms, and a history of obesity, increased intraabdominal pressure, chronic cough, constipation, benign prostatic hypertrophy, intestinal obstruction, colon malignancy, and, for women, pregnancy should be obtained. A list of the patient's current medications should be collected, as well as a history of chronic illness and allergies, including latex allergies (because a Penrose drain may be used during the procedure). The patient's occupation and physical activities should also be determined. If it is part of institutional protocol, verification of preoperative showering should be done during assessment (Evidence for Practice).

Pain is often a notable symptom for the patient; it may be described as a burning sensation. An accurate description of the type and degree of pain is included in the assessment; obtain general information about onset, duration, severity, and quality of pain and about exacerbating and remitting factors (Barclay and Murata, 2008). Patients often describe the feeling of a foreign body, or mass, at the hernia site. This may appear on arising in the morning and disappear while sleeping.

The diagnosis of hernias should be accompanied by clinical physical examination. Palpation of the herniated area reveals the contents of the hernia sac. Fingertip palpation allows the nurse to feel the edges of the external ring or abdominal wall. Having the patient stand and cough or prolonged strain during the examination also assists in the evaluation of the herniated area. If a definitive diagnosis is not confirmed, ultrasonic scanning and imaging techniques (e.g., computerized tomography [CT], herniography, standard radiography) may be employed.

In some patients, a hernia may cause no symptoms; its only sign may be a swelling or protrusion in a restricted area of the abdominal wall. If the hernia is unilateral, the patient notes the lack of a protrusion on the other side in comparison. The area may be visible when the patient stands or coughs and may disappear on reclining. Femoral hernias can be difficult to diagnose and may resemble an enlarged lymph node.

Preoperative testing for hernia repair facilitates safe and efficient perioperative care. Baseline data are obtained by a complete blood count. Patients older than 40 years may need an electrocardiogram (ECG) and chest radiograph. Patients with a history of more complex medical problems must be fully evaluated with appropriate laboratory tests. Preoperative assessment may also involve consultation with a pulmonologist and/or cardiologist to ascertain whether or not surgical intervention is medically safe (this is referred to as "clearance" in patients with potential pulmonary or cardiac problems).

Nursing Diagnosis

Nursing diagnoses related to the care of the patient undergoing hernia surgery might include the following:

- Activity Intolerance related to pain
- Risk for Urinary Retention
- Risk for Ineffective Tissue Perfusion of the scrotal area
- Deficient Knowledge related to disease process (hernia) and convalescence

Outcome Identification

Outcome measurement and management are important parts of perioperative nursing care. Outcomes identified for the selected nursing diagnoses could be stated as follows:

- The patient will return to his or her previous level of activity.
- The patient will not experience urinary retention.
- The patient will be free of or manage scrotal edema.
- The patient and family or significant others will verbalize knowledge regarding the disease process (hernia) and convalescence.

Planning

The perioperative nurse formulates a plan of care for the patient undergoing herniorrhaphy by assimilating knowledge pertaining to the anatomy involved, principles of asepsis, the

EVIDENCE FOR PRACTICE

Effectiveness of Preoperative Showers in Reducing Risk of Surgical Site Infections

First recommended by the CDC in 1999, preoperative showers have long been considered an important strategy for reducing the risk of surgical site infections. AORN's recommended practice for preoperative patient skin antisepsis states that patients undergoing open class I ("clean") surgical procedures below the level of the chin, such as inguinal hernia repair, have two preoperative showers with chlorhexidine gluconate (CHG) (AORN, 2009). This study from the Medical College of Wisconsin, Milwaukee, was conducted to validate effective skin surface concentrations of CHG using a standardized, timed protocol. It compared skin surface concentrations of CHG measured after showering with a 4% CHG liquid soap, as recommended by AORN, to those measured after cleansing the skin surface with a 2% CHG-impregnated polyester cloth. Researchers found that a timed, standardized preoperative shower was effective in achieving high skin surface levels of CHG that exceeded the concentration required to inhibit the growth of *Staphylococcus aureus,* the most common organism causing surgical site infections, and *Staphylococcus epidermidis*. Compared to use of 4% CHG soap, use of 2% CHG-impregnated polyester cloths resulted in considerably higher skin concentrations with no gaps in antiseptic coverage. CHG provides excellent activity against gram-positive organisms, and good antimicrobial activity with gram-negative bacteria and viruses, providing excellent residual activity. The researchers concluded that preoperative antiseptic showers are valuable in reducing surface skin colonization, which can play an important role in reducing the risk of surgical site infections.

Adapted from Association of periOperative Registered Nurses: Recommended practices for patient skin antisepsis. In *Perioperative standards and recommended practices,* Denver, 2009, The Association; Edmiston CE et al: Preoperative shower revisited: can high topical antiseptic levels be achieved on the skin surface before surgical admission? *J Am Coll Surg* 207:233-239, 2008.

planned surgical procedure, and requisite information provided/gained during planning specific to the surgical patient (Box 12-1). Instrumentation, draping, and positioning for the patient's surgery depend on the type of hernia and repair to be performed—for example, open versus laparoscopic.

A Sample Plan of Care for a patient having surgery for repair of a hernia is shown on p. 403.

Implementation

The patient undergoing hernia repair may receive a general anesthetic, an inguinal nerve block, a field block, a spinal or epidural block, a regional anesthetic with sedation, or a local anesthetic with sedation. Routine monitoring equipment, such as a three-lead or five-lead electrocardiogram (ECG), oxygen-saturation monitor, and blood pressure cuff, is used for a hernia repair. An intravenous (IV) line is inserted for fluid replacement and medication administration. The surgical site is marked as part of the preoperative verification process and rechecked during the time-out. In 2008 the World Health Organization (WHO) issued a surgical safety checklist as part of its "Safe Surgery Saves Lives" initiative (see Chapter 2). As part of the time-out, it recommends that all members of the surgical team identify themselves and their roles and ask simple questions such as, "Does everyone agree that this is Patient X, undergoing a right inguinal hernia repair?" The initiative also recommends an active role for the perioperative nursing team, who should review critical information such as confirming sterility of the instruments and supplies (including indicator results); discussing any equipment issues or concerns; noting whether antibiotic prophylaxis has been given within the last 60 minutes, if applicable; and verifying whether essential imaging is displayed, if applicable (WHO, 2008). Before the time-out, surgical team members may share any concerns about the planned procedure during a preoperative briefing (Research Highlight).

BOX 12-1

Planning Patient-Centered Care

Regardless of the type of planned hernia repair, discussions between the patient and their anesthesia provider, perioperative nurse, and surgeon should cover specific topics to ensure that the patient knows what to expect and what is expected of the patient. Patient-centered care emphasizes involving the patient in selecting the type of anesthesia for surgery and discussion about postoperative pain management before surgery. Educational resources, such as www.youranaesthetic.info or www.asahq.org/patientEducation.htm, can inform patients about their forthcoming anesthesia procedure and provide information about different anesthetics and pain-relief techniques. The information can be downloaded so patients and their caregivers can review it together preoperatively.

TOPICS FOR DISCUSSION

- Preoperative dietary recommendation
  - Targeted nutritional and dietary advice for obese patients in the weeks before surgery—weight loss may improve anesthetic management and postoperative rehabilitation
- Immediate preoperative preparation
  - Continuation, alteration, or cessation of normal medications
  - Need for fasting
- Choice of anesthetic technique
  - General anesthesia (with or without peripheral nerve blocks)
  - Central neuraxial anesthesia (spinal or epidural) with or without sedation
  - Inguinal nerve block/field block/local infiltration with or without sedation
  - Risks and benefits of recommended techniques on an individual patient basis
  - Possibility of converting regional techniques to general anesthesia
- Informed consent
  - Provide adequate information regarding surgical, anesthetic, and postoperative pain management, including benefits and complications
- Potential surgical complications
  - General complications such as deep vein thrombosis (DVT), pulmonary embolism, pneumonia, infection, and seroma
- Information on pain management

Patient attitudes and expectations may be influenced by preexisting pain and therefore must be assessed. In addition, if early postoperative pain is intense, rehabilitation and ambulation may be delayed unless pain is appropriately treated. Different techniques may be used to manage different levels of pain immediately following surgery, within the first postoperative day, and thereafter. Thus pain management often involves a "step-down" approach.

- For successful pain management outcomes:
  - Patients need to have a reasonable expectation of their likely postoperative stay
  - Information must be given on postoperative pain assessment, such as the use of visual analogue scale (VAS)
  - Patients require a realistic expectation of the intensity and duration of postoperative pain
  - Pain management techniques that require patient involvement (intravenous patient-controlled analgesia, patient-controlled epidural analgesia, pain pumps) need to be properly demonstrated
  - Patients will require information about all medications to be taken after discharge (medication reconciliation) as well as medications/strategies for management of pain and postoperative nausea
- After surgery patients should know what to expect with regard to:
  - Location and size of the surgical incision, dressings, and any drains
  - Intravenous fluids (as appropriate)
  - Possibility of a urinary catheter
  - Associated postoperative symptoms, such as postoperative nausea and vomiting (PONV; see Chapter 9)
  - When to return to normal oral fluids and nutrition
- Information on their recovery (see Patient and Family Education box on p. 404 for detailed information)
  - Approximate timetable for return to normal physical activities—both personal and professional
  - Advice for other postoperative care
  - Contact numbers for use after discharge and information on follow-up calls or appointments with the surgeon

Adapted from Hobbs JL: A dimensional analysis of patient-centered care, *Nurs Res* 58(1):52-60, 2009; PROSPECT (Procedure Specific Postoperative Pain Management), available at www.postoppain.org/extraPage.aspx?epid=33. Accessed April 2, 2009.

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Activity Intolerance related to pain

OUTCOME
The patient will return to his or her previous level of activity.

INTERVENTIONS
- Determine the patient's baseline activity level.
- Encourage early postoperative ambulation.
- Instruct the patient to use prescribed pain medications before physical activity and as needed.
- Advise the patient to gradually increase activity as tolerated.
- Explain anticipated postoperative activity recommendations and limitations (see Patient and Family Education).

NURSING DIAGNOSIS
Risk for Urinary Retention

OUTCOME
The patient will not experience urinary retention.

INTERVENTIONS
- Encourage patient to void before surgery.
- Monitor and record intake and output status.
- Assess bladder postoperatively for signs of urinary retention (palpable bladder or patient discomfort).
- Encourage and assist patient with early ambulation.
- Maintain adequate oral fluid intake without nausea or vomiting before discontinuing IV fluids.
- Catheterize the patient if urinary retention occurs.

NURSING DIAGNOSIS
Risk for Ineffective Tissue Perfusion of the scrotal area causing scrotal edema

OUTCOME
The patient will be free of or manage scrotal edema.

INTERVENTIONS
- Discuss the possibility of swelling and ecchymosis during preoperative assessment.
- Apply scrotal support intraoperatively.
- Assess scrotum for evidence of swelling, ecchymosis, and redness.
- Apply ice packs as prescribed.
- Elevate the scrotum on a soft pillow to prevent or control swelling.
- Reassure the patient, and instruct him on the importance of wearing the scrotal support.
- Reassure the patient that the swelling and ecchymosis will subside.

NURSING DIAGNOSIS
Deficient Knowledge related to disease process (hernia) and convalescence

OUTCOME
The patient and family or significant others will verbalize an understanding of the disease process (hernia) and convalescence.

INTERVENTIONS
- Review possible contributing factors (as individualized for type of hernia and specific patient) to hernia formation.
- Discuss postoperative pain management strategies during recovery at home.
- Describe and verify patient understanding of surgical site or incision care and reportable signs and symptoms (e.g., temperature, wound redness, tenderness at incision site, swelling, drainage). Use language such as, "Can you tell me, in your own words, how you will take care of this at home and when you should call your doctor?"
- Determine patient's dietary habits; discuss importance of fiber (fruits, vegetables, grains) to prevent constipation.
- Provide written discharge instructions. Review these with patient and family or significant others to validate understanding.
- Provide opportunity for "teach back" (Patient Safety) by the patient or family. Have them repeat discharge instructions in their own words.
- Allow time for questions; provide (or reinforce) answers and clarification.
- Verify that patient has or knows how to schedule follow-up appointment.

PATIENT SAFETY

Surgical Consent and "Teaching Back"

There is considerable evidence that many patients leave medical encounters with a poor understanding of their disease and the recommended treatment. Informed consent is a central element of safe surgical patient care. The National Quality Forum (NQF) has identified Safe Practice 5 for informed consent, recommending that each patient or legal surrogate "teach back," in his or her own words, key information about the proposed treatments or procedures for which he or she is being asked to provide informed consent. Recommended elements of this safe practice for informed consent include:

- Ask each patient or his or her legal surrogate to recount what he or she has been told during the informed consent discussion.
- Use informed consent forms written in simple sentences and in the primary language of the patient or legal surrogate.
- Engage the patient in a discussion about the nature and scope of the procedure covered by the consent form. For example, when describing hernia surgery the nurse might state the following:
  "Before surgery, you will be given a sedative to make you drowsy. A local or spinal numbing medicine (anesthesia) will be used so you do not feel pain during the procedure. In some cases, the procedure is done while you are under general anesthesia (unconscious and pain-free). The surgeon makes a cut over the area of the hernia. The bulging tissue or organ is placed back inside the muscle wall, the muscle tissue is repaired, and the skin is closed. In many inguinal hernia repairs, a small piece of plastic mesh is used to repair the defect in the muscle tissue."
- Provide an interpreter or reader to assist non–English-speaking patients or legal surrogates, vision-impaired or hearing-impaired patients, and low-literacy patients.
- Verify that the patient and/or family member/legal surrogate can state the name of the procedure and, using their own words, describe it.

Modified from Clarke ME, Degannes CN: *Cultural competency in healthcare: a clinical review and video vignettes from the National Medical Association,* available at Cme.Medscape.Com/Viewprogram/12540. Accessed August 1, 2009; Kemp EC et al: Patients prefer the method of "tell back-collaborative inquiry" to assess understanding of medical information, *J Am Board Fam Med* 21(1):24-30, 2008; National Quality Forum: *National Quality Forum Safe Practices 2009,* Washington, DC, 2009, Author, available at http://Psnet.Ahrq.Gov/Resource.Aspx?Resourceid=9757&Sourceid=1&Emailid=12706. Accessed August 1, 2009.

The patient is usually positioned supine (see Chapter 5) with basic prepping and draping procedures followed (see Chapter 3). As with any surgical procedure, the prep solution must dry before the start of the surgical procedure as part of fire safety measures. To maintain the patient's dignity and modesty, expose only the part of the patient's body necessary for antimicrobial skin preparation (Beyea, 2007). Instruments used for herniorrhaphies are those found in standard laparotomy sets, laparoscopy sets, or minor sets. Additional supplies and anticipatory preparation for other patient care needs depend both on the perioperative nurse's knowledge of the planned procedure as well as communication and teamwork. Research suggests that interventions designed to improve OR teamwork and communication may have beneficial effects both on technical performance and on patient outcome, due in part to the leadership and management skills of perioperative nurses (Catchpole et al, 2008) (Risk Reduction Strategies).

A self-retaining retractor, such as a Weitlaner, facilitates the separation of tissue layers. A moistened Penrose drain is often used to retract the spermatic cord structures for better exposure. Because the peritoneal cavity may be entered in this procedure, sponge, sharp, and instrument counts are recommended.

With a sliding hernia or an incarcerated hernia, the possibility of having to enter the peritoneal cavity must be considered. If the hernia is strangulated, necrotic bowel must be resected and instruments for performing a bowel anastomosis must be

RESEARCH HIGHLIGHT

Effect of Preoperative Briefings on OR Delays

In one study (Nundy et al, 2008), researchers at The Johns Hopkins University School of Medicine, Baltimore, sought an answer to the following question: "Do preoperative briefings reduce unexpected OR delays through improved teamwork and communication?" They implemented a preoperative briefing program in which the attending surgeon led OR personnel in a 2-minute discussion using a standardized format designed to familiarize team members with each other and with the operative plan. The researchers evaluated unexpected delays before and after the initiation of the OR briefings using an assessment tool that was distributed to OR personnel at the end of each surgical procedure. The tool was completed by 422 respondents. The use of preoperative OR briefings was associated with a 31% reduction in unexpected delays. A total of 36% of OR personnel reported delays before implementation of the briefings, and 25% reported delays after implementation. Among surgeons alone, an 82% reduction in unexpected delays was observed. Significantly, a 19% reduction in communication breakdowns leading to delays was associated with the briefings.

In another study (Lingard et al, 2008), Canadian researchers assessed whether structured team briefings that incorporated a preoperative checklist would improve communication in the OR. Over a 13-month period, surgeons, nurses, and anesthesia providers at a Canadian academic medical center completed a short team briefing guided by a checklist before 302 general surgery procedures. They found the mean number of communication failures per procedure declined from 3.95 to 1.31. A total of 34% of the briefings demonstrated utility, meaning they identified a problem, filled a critical knowledge gap, provoked a change in plan, or promoted follow-up actions.

Research shows that poor communication is the single most frequent cause of adverse events in healthcare. As in other research, these studies concluded that preoperative briefings reduce unexpected delays and decrease the frequency of communication breakdowns. Preoperative briefings have the potential to increase OR efficiency, improve quality of care, and reduce costs.

Adapted from Lingard L et al: Evaluation of a preoperative checklist and team briefing among surgeons, nurses, and anesthesiologists to reduce failures in communication, *Arch Surg* 143:12-17, 2008; Nundy S et al: Impact of preoperative briefings on operating room delays, *Arch Surg* 143:1068-1072, 2008.

RISK REDUCTION STRATEGIES

Teamwork and Communication on Surgical Teams

Despite almost universal endorsement and knowledge of The Joint Commission's *Universal Protocol for Preventing Wrong-Site, Wrong-Procedure, Wrong-Person Surgery,* avoidable surgical errors continue to occur in U.S. healthcare facilities. Research has focused on communications' failures as the underlying cause of many errors. The Medical Team Training Questionnaire was developed as part of a national program in the Department of Veterans Affairs (VA) to improve communication. It assesses organizational culture, communication, teamwork, and awareness of human factors engineering principles. The questionnaire was pilot-tested with 300 healthcare clinicians. The final version of the questionnaire was then administered to an interdisciplinary group of 384 surgical staff in 6 facilities. Analysis of questionnaire results determined that nurses and anesthesia providers tend to perceive their environment similarly, and both differ significantly from surgeons' perceptions. Surgeons perceive their environment more positively, believing there is a stronger organizational culture for patient safety—that all team members are comfortable intervening in a procedure if they have concerns about what is occurring. Surgeons also perceive better communication—that during surgical and diagnostic procedures, everyone on the team is aware of what is happening. Consistent with their positive beliefs, surgeons similarly perceive that there is good teamwork—that morale on their team is high and everyone on the team is comfortable giving feedback to other team members. Nurses and anesthesia providers did not agree with the positive perceptions of the surgeons.

According to the researchers, such disparities between team members pose a problem. If team members have disparate perceptions about how well they communicate or collaborate with each other, they do not collaborate optimally during care of their patients. Thus use of this or a similar questionnaire may prove helpful in identifying hidden problems with communication and may be useful in focusing efforts, such as team training, for improvement.

Adapted from Mills P et al: Teamwork and communication in surgical teams: implications for patient safety, *J Am Coll Surg* 206:107-112, 2008.

PATIENT AND FAMILY EDUCATION

Home Care for the Hernia Patient

HOME CARE

- Give the patient and the caregiver *verbal* and *written* instructions. Provide them with the name and telephone number of a physician or nurse to call if questions arise.
- General information
  - Review any explanation about the procedure and specific follow-up care. Verify that the patient can state the name of the procedure performed.
  - Explain and discuss the development of hernias, causes or contributing factors, care and treatment, and prevention.
- Wound/incision care
  - Discuss and demonstrate proper wound management and dressing changes: procedures, frequency, and signs to report.
- Warning signs
  - Stress the importance of seeking emergency care if bleeding from the incision or wound dehiscence with exposure of deep wound tissue occurs.
  - Review the signs and symptoms that should be reported to a physician or nurse.
    - Infection: fever, pain, edema, erythema, warmth, purulent drainage, foul odor from the incision
    - Abdominal distention, nausea, vomiting
    - Separation of wound edges
    - Hernia recurrence: firm, tender, globular, irreducible swelling in the groin or midabdomen
- Special instructions
  - Apply and demonstrate to the male patient scrotal support or ice packs to decrease scrotal edema and discomfort.
  - Assist the patient in obtaining appropriate supplies, such as sterile dressings.
  - Advise the patient with diabetes that optimal glucose level control promotes wound healing.
- Medications
  - Explain the purpose, dosage, schedule, and route of administration of any prescribed drugs, as well as side effects to report to a physician or nurse.
    - Analgesics
    - Stool softeners
    - Laxatives
- Activity
  - Encourage the patient to discuss allowances and limitations with respect to occupation, recreation, or activities.
  - Instruct the patient to avoid coughing, straining, stretching, constipation, heavy lifting (>10 lb), strenuous exercise, and sports for 6 weeks.
  - Demonstrate splinting the incision manually or with a pillow during coughing, sneezing, or hiccups.
  - Stress the importance of activity restrictions and splinting the incision for up to 6 weeks after surgery.
  - Demonstrate proper body mechanics for moving and lifting.
  - Advise returning to work in 2 weeks for desk work and 6 weeks for heavy labor.
  - Advise that sexual activity should be avoided for several weeks to avoid strain on the incision and discomfort to the scrotum, if edematous.
- Diet
  - Advise the patient to plan a high-fiber diet to help prevent constipation; provide the patient with a list of high-fiber foods.
  - Advise the patient to drink plenty of fluids, up to 2 to 3 liters per day, unless contraindicated.
  - Stress the importance of weight loss if the patient is obese.

ALTERNATIVE THERAPY

- Advise the patient to avoid yoga exercises for 6 weeks postoperatively.
- Advise the patient and family to refrain from applying lotions and creams to the incision until wound edges are completely closed and healed.
- Discuss strategies for pain management, including music therapy and guided imagery, to minimize use of narcotics, which can cause constipation.

ELDER CARE

- The older adult may be at greater risk for delayed wound healing because of preexisting cardiac disease or nutritional deficits.
- Vitamin supplements may promote wound healing, if not contraindicated.

PSYCHOSOCIAL CARE

- Encourage the verbalization of fears and concerns about altered sexual function secondary to impaired blood supply to the vas deferens.
- Encourage active participation in plan of care.

FOLLOW-UP CARE

- Stress the importance of regular follow-up visits. Make sure the patient has the necessary names and telephone numbers.
- Stress the importance of smoking cessation to eliminate the smoker's cough as a contributing factor to hernia development.

REFERRAL

- Provide information and refer the patient to community resources for weight loss and smoking cessation, if indicated.

From Canobbio MM: *Mosby's handbook of patient teaching,* ed 3, St Louis, 2006, Mosby.

available. For this procedure, antibiotics may be added to the irrigation to prevent an infection. Safe medication practices must be followed. All medications and solutions on and off the sterile field must be labeled. When the antibiotic solution is passed to the surgeon, the surgical technologist or other scrub person should announce the name and strength of the antibiotic solution to be used for irrigation.

Repair of an inguinal hernia includes approximation of the transversalis fascia with a heavy nonabsorbable type of suture; mesh may also be used. With some indirect hernias, only two or three sutures may be necessary. In other cases, however, up to 10 sutures in succession may be needed. Scarpa's fascia is approximated with absorbable sutures, and the skin is closed by one of several methods. Several types of prosthetic mesh are available and often used to support hernia repair.

A laparoscopic hernia repair is technically similar to an open laparotomy, but the instrumentation includes laparoscopic equipment. There is always a possibility that a laparoscopy may become a laparotomy, and instrumentation for this change in procedure must always be available.

Evaluation

Evaluation of the patient having repair of a hernia should include examination of all skin surfaces to assess variances with preoperative assessment data. The patient should awaken from general anesthesia, if it is used, in a reasonable amount of time without exhibiting signs of anxiety or extreme disorientation. Extubation should be timely to avoid stress on the repaired hernia site. The evaluation of the patient's status can be phrased in outcome statements such as the following:

- The patient will return to his or her previous level of activity.
- The patient will not experience urinary retention.
- The patient will remain free of or manage scrotal edema.
- The patient and family or significant others will verbalize understanding of hernia and recommendations for convalescence and will be able to describe possible complications (infection, seroma formation, hematoma, or postoperative neuralgia) that are to be reported to the physician.

When the patient's care is transferred to the postanesthesia care unit (PACU) nurse, the perioperative nurse gives a hand-off report pertaining to relevant events and patient status during the operative procedure.

Urinary retention may occur after a herniorrhaphy, and measures must be taken to prevent overdistention of the bladder. Early ambulation is encouraged to facilitate resumption of bladder and bowel functions, as well as lung expansion for patients who were intubated for induction of general anesthesia. If the bowel has been resected because of strangulation, a nasogastric (NG) tube and suction may be required to reduce the incidence of postoperative vomiting and distention with subsequent strain on the suture line.

Patient and Family Education and Discharge Planning

Greater involvement of patients in their care increases the likelihood of achieving the best outcomes and simultaneously supports a quality-improved, cost-conscious environment. For the hernia patient to assume such responsibilities, plans for patient and family education along with plans for discharge and home recovery need to be designed. Issues such as open or laparoscopic repair techniques, surgical and recovery times, analgesic requirements, complication rates, and times for return to full activity become part of informed consent (see Patient Safety). Once the patient and surgeon have decided on the surgical approach, perioperative nursing responsibilities for teaching the patient initial postoperative management strategies become crucial. Preferably, discharge planning is begun before admission. This becomes increasingly important because hernia repair is commonly performed as an ambulatory procedure. Anticipated postoperative care, including incision care, incisional splinting as appropriate to the repair approach, and the importance of early ambulation and deep breathing, is reviewed. Pain management is important as a part of discharge planning; frequently, surgical patients report inadequate pain management during their postoperative recovery and convalescence. The Patient and Family Education box presents specific home care requirements. The Ambulatory Surgery Considerations box presents information on safe use of postoperative pain pumps.

AMBULATORY SURGERY CONSIDERATIONS

Safe Use of Post-Op Pain Pumps for Surgical Analgesia

Elastomeric pumps, such as the ON-Q PainBuster, deliver local anesthetic intended to reduce pain after surgery to the tissue around the surgical site. The popular ON-Q PainBuster Post-Op Pain Relief System provides continuous infusion of a local anesthetic directly into the patient's surgical site for effective, non-narcotic postoperative pain relief for up to 5 days. Four pump models are available with this pain-relief system: one with a fixed flow rate that cannot be changed; one that delivers a basal infusion and also allows delivery of on-demand boluses; one that allows the user to adjust the flow rate within a predetermined range; and one with an adjustable rate controller and bolus device. Various sizes and types of catheters are available to deliver the medication. Pumps such as ON-Q pumps are used in many general surgical procedures. The following safe practice recommendations should be implemented to improve safety when using elastomeric pumps such as ON-Q pumps.

BEFORE USING THE PUMPS

- Establish protocols for use of ON-Q pumps, including indications; models and tubing to be used for each indication; steps for prescribing, preparing, and dispensing the pump of all associated medications; required testing of knowledge and skills; hand-off communication between providers; patient/family education; and patient monitoring.
- Have a committee, such as the Pharmacy and Therapeutics Committee, approve the drugs that can be administered through the ON-Q pump, taking into consideration the accuracy of the infusion rate (±15% to 20% of desired rate) and conditions that could influence the rate (e.g., heat and cold).
- Ensure clinical staff education before use. Include the signs of bupivacaine, ropivacaine, and lidocaine cardiotoxicity and risks associated with pump use (Rapid Response Team box).

Continued

AMBULATORY SURGERY CONSIDERATIONS

Safe Use of Post-Op Pain Pumps for Surgical Analgesia—cont'd

PRESCRIBING THE PUMPS

- Establish standard order sets for prescribing the pumps and specific medications. Specify any concomitant analgesics that are acceptable or should be avoided. Require activation of the appropriate order set before the patient is transferred from the OR.

PLACING THE CATHETERS AND SETTING UP THE PUMPS

- Ensure proper insertion of the catheter(s) in the tissue and/or adjacent nerves surrounding a wound. Do not insert the catheter directly into a joint.
- Label the pump with the name of the drug, its concentration, infusion rate (in milliliters per hour and dose per hour), and start date.
- Ensure that the adjustable rate controller (available on some models) is clicked into place under the specified rate of infusion.
- Apply an occlusive dressing over the catheter insertion site.
- Tape the flow restrictor to the patient's skin. Do not tape over the filter.

DISPENSING PUMPS AND MEDICATION

- Establish standard concentrations for the local anesthetics (and other drugs, if appropriate) used in the pumps. Also establish pharmacy compounding procedures for preparing any mixtures of drugs.
- Establish order sets in the pharmacy computer that will facilitate automated screening of the drug(s) being used for appropriate dose, drug interactions, allergies, and duplicate therapy.
- Require pharmacy preparation of the medication reservoir balls following a protocol that specifies the exact amount of solution to instill based on the duration of therapy and expected rate of infusion.

PERIOPERATIVE NURSING CONSIDERATIONS FOR PATIENTS WITH PUMPS

- Ensure that all medications administered via the pump are listed on the intraoperative nursing record.
- Ensure the occlusive dressing over the catheter site is intact.
- Check that the flow restrictor is taped to patient's skin for accurate flow rates.
- Include information about the pump in the hand-off report to PACU or other discharge unit.

EDUCATING PATIENTS ABOUT PUMPS

- Educate patients and caregivers about how the pump works and items to periodically check (e.g., flow restrictor is taped to the skin, medication ball appears to be getting smaller each day, pain is under control).
- Educate patients about the signs of cardiotoxicity, when to call the physician, and how to clamp the tubing to prevent further drug administration, if necessary (Surgical Pharmacology).
- Send the Patient Guidelines provided by the manufacturer home with patients.

Modified from Institute for Safe Medication Practices (ISMP) Safety Alert: *Process for handling elastomeric pain relief balls (ON-Q PainBuster and others) requires safety improvements,* July 16, 2009, Newsletter, available at www.ismp.org/Newsletters/acutecare/articles/20090716.asp. Accessed August 1, 2009.

RAPID RESPONSE TEAM

Tim Johnson had an inguinal hernia repair performed in an ambulatory surgery center. At the conclusion of the surgical procedure, an ON-Q pump was inserted and the reservoir filled with a local anesthetic. He had an uncomplicated stay in PACU and was sent to the phase II recovery area for discharge preparation. Ten minutes after his arrival there, he began to complain of blurred vision, difficulty breathing, dizziness, and light-headedness. His wife activated the rapid response team (RRT), who arrived to find Tim in cardiac arrest. The RRT noticed that the medication reservoir ball of the ON-Q pump was empty. The device label indicated it had been started an hour earlier with 30 ml of bupivacaine. The surgeon arrived after the RRT activation and confirmed that the reservoir should not be empty. CPR was instituted and a lipid rescue administered. Mr. Johnson was transferred to the inpatient ICU and eventually recovered. A local anesthetic drug level was drawn and found to be markedly elevated. Fortunately, rescue efforts were successful and the patient was later discharged without any complications.

RRTs are a part of a rapid response system to intervene at the earliest possible moment in a patient's deteriorating clinical condition. In some institutions, family members as well as staff may activate the RRT call when they notice something is "not right" with the patient; numbers are listed on the walls of patient rooms so that family members may also initiate the system. The RRT is often composed of a multidisciplinary team of intensive care–trained staff who intervene in situations like Mr. Johnson's and prevent patient harm from an adverse event. Fortunately for Mr. Johnson, the ambulatory surgery center was part of an acute care hospital. In part because the OR staff followed safe medication practices, the RRT was able to determine what had been in the pump reservoir and take immediate action.

Adapted from Institute for Safe Medication Practices (ISMP) Safety Alert: *Process for handling elastomeric pain relief balls (ON-Q PainBuster and others) requires safety improvements,* July 16, 2009, Newsletter, available at www.Ismp.Org/Newsletters/Acutecare/Articles/20090716.Asp. Accessed August 1, 2009; Moldenhauer K et al: Clinical triggers: an alternative to a rapid response team, *Jt Commiss J Qual Patient Saf* 35(3):164-174, 2009.

Surgical Interventions

SURGERY FOR REPAIR OF GROIN HERNIAS

Repair of Inguinal Hernias

Several operative procedures for repair of inguinal hernias are currently used. Approaches that reestablish the integrity of the transversalis fascia and simultaneously reestablish and strengthen the posterior inguinal floor are favored. A surgical repair in which transversalis fascia is sewn to the Poupart ligament accomplishes this goal.

Procedural Considerations. The patient is in the supine position for abdominal wall and inguinal or femoral hernia repairs. Arms are placed on padded armboards with the palms up and fingers extended. Armboards are maintained at less than a 90-degree angle to prevent brachial plexus stretch. If there are

SURGICAL PHARMACOLOGY

Bupivacaine, Ropivacaine, and Lidocaine Cardiotoxicity

Lidocaine (Xylocaine), bupivacaine (Marcaine), and ropivacaine (Naropin) all have similar actions. They produce analgesic effects via nerve conduction blockage. They are contraindicated in patients with hypersensitivity to amide local anesthetics (see Chapter 4). Compared to other local anesthetics, bupivacaine is markedly cardiotoxic. However, adverse drug reactions (ADRs) are rare when it is administered correctly. Most ADRs relate to systemic exposure, such as with pain pump failure.

Systemic exposure to excessive quantities of bupivacaine mainly result in central nervous system (CNS) and cardiovascular effects. CNS effects may include CNS excitation (nervousness, tingling around the mouth, tinnitus, tremor, dizziness, blurred vision, or seizures) followed by depression (drowsiness, loss of consciousness, respiratory depression, and apnea). Bupivacaine and ropivacaine are look-alike/sound-alike drugs.

Ropivacaine is found to have less cardiotoxicity than bupivacaine in animal models. Compared to bupivacaine, ropivacaine has similar CNS and cardiovascular effects.

Perioperative nurses providing discharge instructions to patients with pain pumps filled with one of these local anesthetics should be sure the medication is part of discharge medication reconciliation. An information sheet should be printed for the patient and their caregiver, and they should have one to take to their primary care physician. Be specific and direct in providing information about cardiotoxicity. Use descriptions of signs and symptoms that the patient can understand. For instance, you might tell the patient:

"The following symptoms may represent a serious medical condition. Immediately close the clamp on the pump tubing and call your doctor or 911 if you have any of the following:

- Difficulty breathing
- Dizziness, light-headedness
- Blurred vision
- Ringing, buzzing in your ears
- Metal taste in your mouth
- Numbness and/or tingling around your mouth, fingers, or toes
- Drowsiness
- Confusion"

surgical reasons to tuck the arms at the side, as may occur in laparoscopic hernia repair, the elbows are padded to protect the ulnar nerve, the palms face inward, and the wrist is maintained in a neutral position (Denholm, 2009). A drape secures the arms. It should be tucked snuggly under the patient, not under the mattress. This prevents the arm from shifting downward intraoperatively and resting against the OR bed rail.

The patient's skin surface area from above the umbilicus to midthigh is exposed, prepped with antimicrobial solution, and draped with sterile drapes. A sterile drape should be placed under the scrotum if it becomes necessary to enter the scrotum. Safe practices when using devices that generate surgical smoke, such as the electrosurgical unit (ESU), require the use of a smoke evacuation system and accessories in both open and laparoscopic procedures (AORN, 2009a) (see Chapter 7).

Operative Procedures

McVAY, OR COOPER, LIGAMENT REPAIR. A McVay, or Cooper, ligament repair approximates transversalis fascia superior to the inferior insertion of the transversalis fascia along the Cooper ligament. It is accompanied by a relaxing incision to reduce tension on the suture line.

1. A transverse suprainguinal skinfold incision is made; some surgeons prefer an oblique incision, made parallel to the inguinal ligament, ending two fingerbreadths lateral to the pubic tubercle (Figure 12-6).
2. The incision is carried through the superficial and deep (Scarpa) fascia to the external oblique aponeurosis. Hemostasis is maintained with fine ties or electrocoagulation.
3. The external oblique aponeurosis is opened by way of a small incision over the inguinal canal, lateral to the inguinal ring and in the direction of its fibers, to the external ring. The aponeurotic flaps are reflected back along the iliohypogastric and ilioinguinal nerves, which are identified and preserved from injury (see Figure 12-6). The ilioinguinal nerve is a sensory nerve that innervates the medial thigh and the scrotum.
4. The cremaster muscles that form an envelope around the spermatic cord and represent the continuation of the internal oblique muscles are opened, and the cord is exposed. The medial fibrous portion of the internal oblique is called the *conjoined tendon.*
5. The cord and surrounding structures are dissected and freed circumferentially from the canal, and a moistened Penrose drain is often used to gently retract the vessels and vas deferens. The cord is then examined for an indirect hernia, the sac of which is located adjacent to the cord; the sac originates from the internal ring lateral to the inferior epigastric vessels and is initially adherent to the cord.
6. If an indirect sac is identified, it is carefully dissected away from the cord until the neck of the hernia is clearly delineated (Figure 12-7).
7. The sac is opened, and any abdominal contents are returned to the peritoneal cavity.
8. A suture ligature or purse-string suture is placed high in the neck of the sac, and the excess peritoneum of the hernia is excised. The ligated stump quickly retracts into the peritoneal cavity. (If the sac is long, the distal segment may be splayed open and left in place.) The inguinal floor is then inspected for evidence of a direct hernia. If only a direct sac is present, usually no resection of the hernia is done because the sac easily returns to the abdominal cavity.

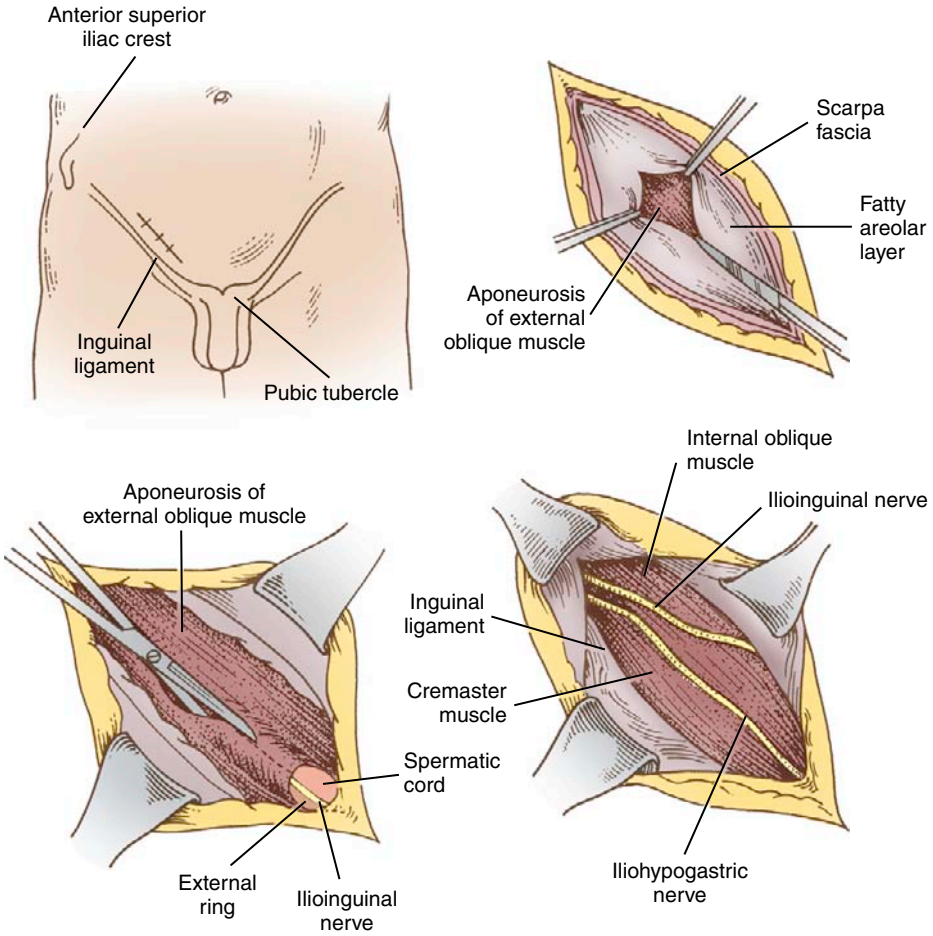


FIGURE 12-6 Skin incision with division of superficial muscle and fascial layers.

9. If transversalis fascia is present on both sides of the hernia defect, it is sutured together or a piece of mesh is interposed (Figure 12-8). Suturing begins at the pubic tubercle and continues laterally to the internal ring. If the inferior transversalis fascia is weak or not present, the superior portion is sutured to the Cooper ligament, the site of insertion of the transversalis fascia. In this case, suturing again begins at the pubic tubercle and is continued laterally along the Cooper ligament to the medial border of the femoral sheath, where a transition stitch is placed. The repair is then carried laterally, approximating transversalis fascia to inguinal ligament (Figure 12-9).
10. When the transversalis fascia is pulled down to the Cooper ligament, a relaxing incision in the rectus sheath is sometimes necessary to relieve excess tension. Essentially this incision is 5 to 7 cm long in the anterior rectus sheath. The incision begins immediately above the pubic crest, approximately 1 cm from the midline, and extends cephalad, following the line of fusion of the external oblique aponeurosis with the rectus sheath. The posterior rectus sheath and the rectus muscle itself guard against later herniation at the point where the relaxing incision is made. If too much tension makes direct approximation undesirable, a synthetic surgical mesh may be sutured in place as the new inguinal floor ("tension-free" mesh repair). The caudad edge of the mesh is sutured to the shelving edge of the inguinal ligament, the cephalad edge sutured to the conjoined tendon, and the lateral edge of the mesh split to accommodate the spermatic cord.
11. After the integrity of the posterior inguinal floor has been reestablished, the cremaster muscles are reapproximated around the cord. Repair is completed with the approximation of the external oblique aponeurosis, the Scarpa fascia, and the skin.

BASSINI REPAIR. The Bassini repair was introduced in 1887 and was formerly the standard of repair. In this procedure the conjoined tendon and the shelving edge of the inguinal ligament are sutured together up to the internal ring (Bascom, 2004). The major difference with this repair is that the superior transversalis fascia is sutured to the inguinal ligament with no attempt made to approximate it to the inferior portion of the transversalis fascia or the Cooper ligament (pectineal ligament). Critics of this procedure claim that it is not anatomic because layers that originally are not integrated (transversalis fascia and inguinal ligament) now are approximated. Nonetheless, this repair has been used successfully by many surgeons.

SHOULDICE REPAIR. More than 250,000 hernias have been repaired at the Shouldice Hospital in Ontario, Canada, with a recurrence rate of less than 1%. In the Shouldice repair a double layer of transversalis fascia is sutured to the inguinal ligament. It is reinforced by a layer of internal oblique muscle

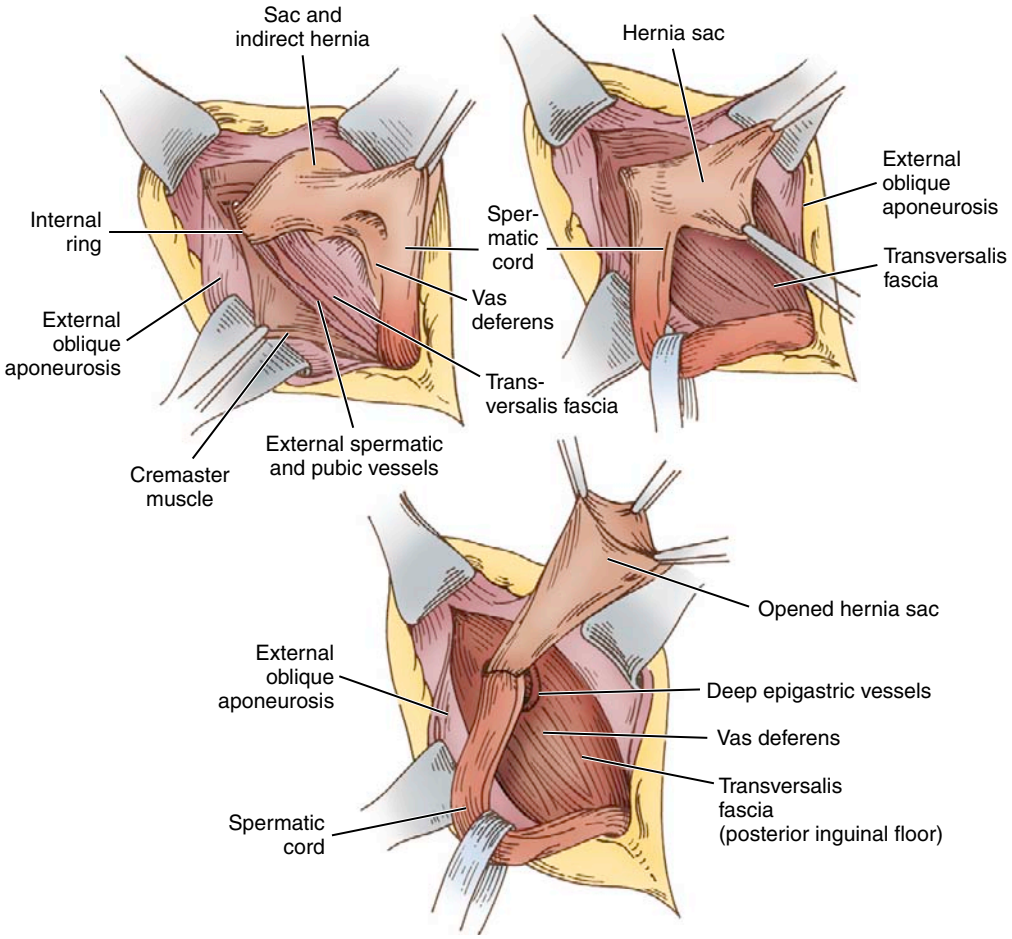


FIGURE 12-7 Indirect hernia sac is identified along with cord structures and dissected away from cord. Neck of hernia sac is clearly delineated, and sac is opened to check for abdominal contents.

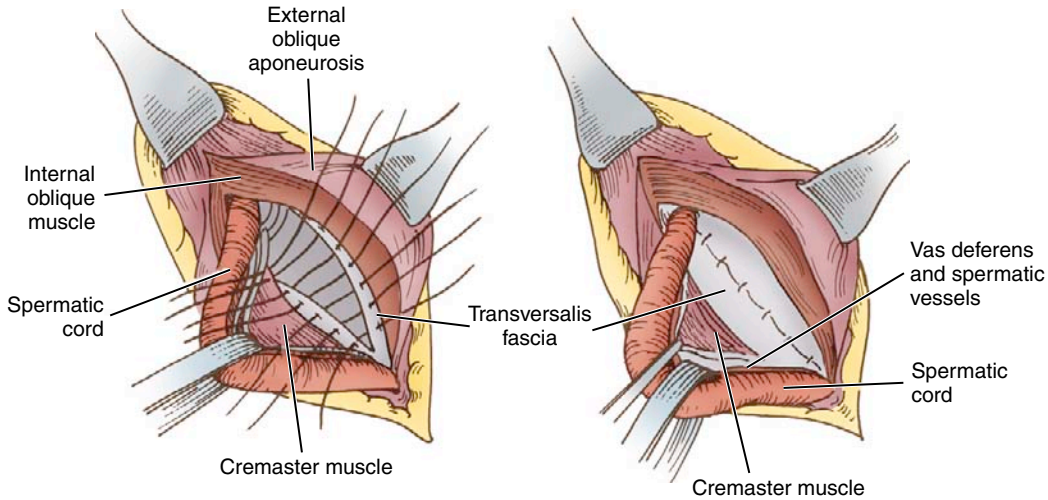


FIGURE 12-8 Transversalis fascia on either side of large hernia defect is approximated.

and conjoined tendon approximated to the undersurface of the fascia of the external oblique.

MESH-PLUG REPAIR. The mesh-plug technique has been recommended for the treatment of primary and recurrent direct and indirect inguinal hernias. The various hernia types as classified by Gilbert have a corresponding relationship to the use of mesh plugs (Gilbert et al, 2009). Types I, II, and III are indirect hernias. Type I is characterized by a tight internal ring through which any size peritoneal sac can pass. The sac, when surgically reduced, is held within the abdominal cavity by the

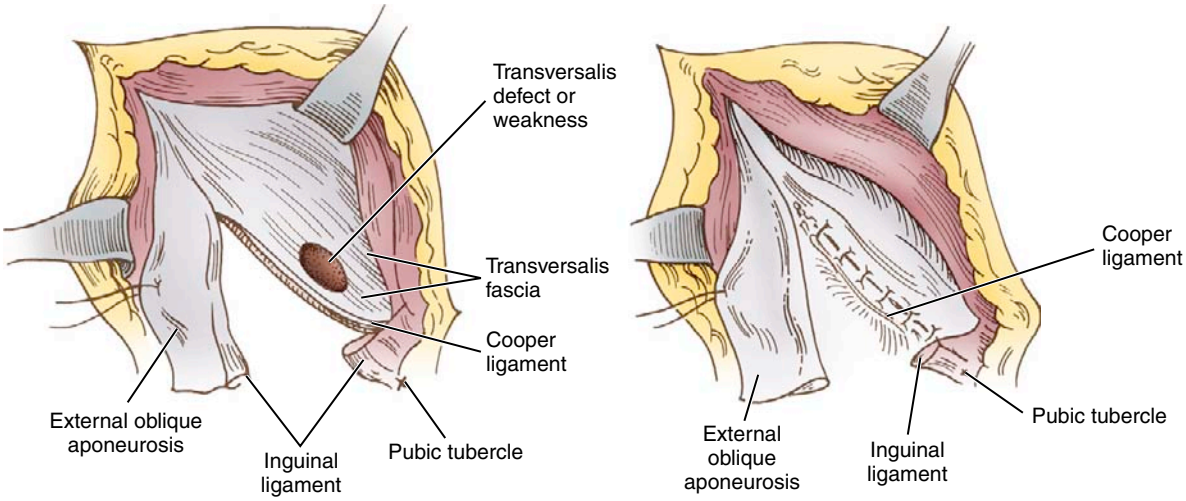


FIGURE 12-9 Defect in transversalis fascia repaired by approximation of fascia to the Cooper ligament.

intact internal ring. Type II hernias have a moderately enlarged internal ring, 4 cm or smaller. Type III hernias have a patulous internal ring larger than 4 cm. In this type, the sac can have a sliding component that impinges on the direct space. Type IV and type V hernias are direct hernias. In type IV hernias, the defect involves virtually the entire floor of the inguinal canal. Type V is a diverticular defect of the floor and is generally in a suprapubic position, resembling a punched-out recurrent hernia. Type VI includes components of both indirect and direct hernias. Femoral hernias are classified as type VII.

Regardless of the hernia type, the mesh-plug technique is performed on an ambulatory basis, through a small incision, often laparoscopically. Repair of inguinal hernias with the mesh-plug technique has provided significant advantages when compared with conventional suture technique. A plug repair requires less overall dissection, has a decreased chance of nerve injury, and ensures a tension-free hernioplasty. These factors increase patient comfort, speed rehabilitation, and contribute to a very low recurrence rate.

Surgical Technique Using the PerFix Plug

1. An oblique incision, 6 cm in length, is made, and the external oblique fascia is opened through the external ring. Exposure is obtained by use of a self-retaining retractor (e.g., a Beckman); a handheld retractor such as a Gouley may also be required. Hemostasis is usually achieved with the use of electrocoagulation.
2. The spermatic cord is mobilized, as previously described in the McVay repair. The ilioinguinal and genital femoral nerves are identified and preserved. The medial external oblique fascia is separated from the underlying transversus abdominis aponeurosis with a sweeping motion of the index finger.
3. An indirect sac and any lipoma of the cord are dissected free (Figure 12-10, *A*). The sac and lipoma are allowed to drop back through the internal ring and into the abdominal cavity. Rarely is the sac opened except for incarcerated hernias.
4. Using the Gilbert classification, the internal ring is sized and the tapered end of the mesh plug is inserted through the internal ring and positioned just beneath the crura. The plug is designed such that its fluted outer layer, combined with its inside configuration of eight mesh petals, maintains its overall contour while allowing it to conform tension-free to the configuration of the internal ring (Figure 12-10, *B*).
5. *Repair of indirect hernias.* Type I indirect hernias require one or two synthetic absorbable sutures; in type II and type III hernias, more sutures are required because of the increased size of the internal ring.
6. *Repair of direct hernias.* In direct hernias, the fusiform or saccular defect is circumscribed near its base with an electrosurgical device and the hernia is reduced, providing a surrounding margin of intact tissue for securing the plug. The plug is then inserted through the floor of the defect (Figure 12-10, *C*). With type IV and type V (direct) hernias, the mesh plug is routinely secured with up to 10 interrupted synthetic absorbable sutures. Where there are both indirect and direct hernias (type VI), two mesh plugs may be needed. Type VII defects are treated similarly with mesh plugs.
7. *Repair of femoral hernias.* In femoral hernias, a small or medium size plug is secured in position after the sac has been reduced.
8. In most types of mesh-plug hernia repairs, a second piece of flat mesh is used for reinforcement. The piece is cut to match the shape of the inguinal canal and then placed without sutures on the anterior surface of the posterior wall of the inguinal canal. The proximal portion is split to provide an opening for the spermatic cord, and the mesh tails are united with sutures to form a new internal ring (Figure 12-10, *D*).
9. With the spermatic cord structures placed on top of this flat mesh, the external oblique fascia is reapproximated over the structures with a running synthetic nonabsorbable suture.
10. An interrupted suture of a similar size is used to integrate the subcutaneous tissue, and the skin is closed with a subcuticular stitch.

LAPAROSCOPIC HERNIA REPAIRS. Ger was the first surgeon to perform a laparoscopic herniorrhaphy. In 1982 he described a laparoscopic transabdominal hernia approach. Variations in techniques for laparoscopic hernia repair continue to develop as surgeons gain experience with these procedures.

Techniques used today for laparoscopic herniorrhaphy include the transabdominal preperitoneal patch (TAPP) repair, the totally extraperitoneal patch (TEP) repair, and the intraperitoneal onlay mesh (IPOM) repair. The difference

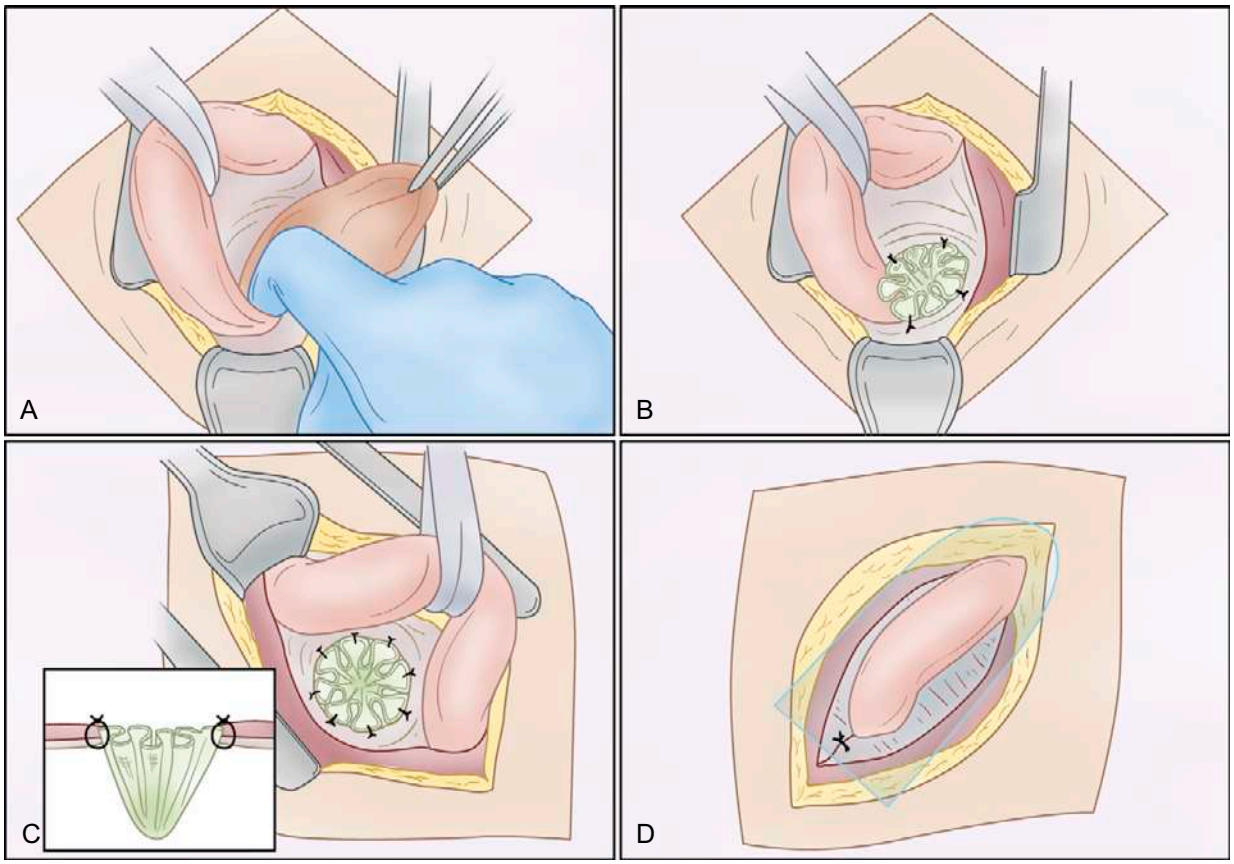


FIGURE 12-10 Mesh-plug repair using the PerFix Plug. **A**, The hernia sac is dissected free of the cord structure to the level of the internal ring. **B**, Typically, a large plug is used. Some of the internal petals may be removed if the plug is too bulky. **C**, Large or extra-large PerFix Plug is inserted. The plug should not be stretched to fill the defect. Typically, 8 to 10 sutures are used. **D**, Sutureless onlay patch. The tails of the onlay patch are taken around the cord and sutured together. The onlay patch is not sutured to the floor of the inguinal canal.

between TAPP and TEP is the manner in which access is gained to the preperitoneal space. The TAPP uses intraperitoneal trocars and the creation of a peritoneal flap over the posterior inguinal region. TEP provides access to the preperitoneal space without entering the peritoneal cavity (Research Highlight).

Studies indicating long-term postoperative hernia recurrence and complication rates with these approaches vary. The average recurrence rate for TAPP ranges from 2% to 7%; for TEP it approximates 1.8%. A laparoscopic hernia repair allegedly has the advantages of a quicker return to normal activity and some reduction of postoperative adhesions related to the minimal dissection required. Analysis of postoperative pain and paresthesia associated with laparoscopic hernia repair suggests that most patients experience minimal immediate postoperative pain and, after postoperative day 1, have minimal need for analgesics. In general, the procedure requires the placement of operative cameras and ports, identification of the inguinal floor, removal of an indirect hernia sac, insertion of mesh to fit around the spermatic cord and form a new inguinal floor, and closure of ports (Lawrence, 2006).

In 2007 the FDA granted 510(k) clearance for a hernia repair device (Rebound HRD, Minnesota Medical Development, Inc.) for the repair and/or reinforcement of hernia or other soft tissue defects where weakness exists and where the

RESEARCH HIGHLIGHT

Comparison of Different Types of Hernia Repair

This study was done to determine whether laparoscopic methods are more effective and cost-effective than open mesh methods of inguinal hernia repair. A secondary analysis was an exploration of whether laparoscopic transabdominal preperitoneal patch (TAPP) repair was more effective and cost-effective than laparoscopic totally extraperitoneal patch (TEP) repair. Laparoscopic repair was associated with a faster return to usual activities and less persisting pain and numbness. There also appeared to be fewer cases of wound or superficial infection and hematoma. However, operation times were longer, and there appears to be a higher rate of serious complications (e.g., bowel, bladder, and vascular injuries) with laparoscopic methods. Mesh infection is very uncommon, with similar rates noted among the surgical approaches. There is no apparent difference in the rate of hernia recurrence. The increased adoption of laparoscopic techniques may allow patients to return to usual activities faster. Economic savings in the form of fewer days of work missed and reduced workers' compensation have been reported.

Modified from McCormack K et al: Laparoscopic surgery for inguinal hernia repair: systematic review of effectiveness and economic evaluation, *Health Technol Assess* 9(1):218, 2005.

support of a nonabsorbable material is preferred. The device is a self-expanding framed/surgical mesh made of Nitinol, a family of intermetallic materials containing a nearly equal mixture of nickel and titanium that offers both superelasticity and shape memory. The device can be folded and inserted laparoscopically, after which it "rebounds" to its original shape for quick and easy placement over the hernia defect. Although ideally suited for laparoscopic surgery, the device also may used in an open incisional approach (Taylor, 2007).

Procedural Considerations. After induction of general anesthesia the patient is placed in supine position with the arms tucked at the sides and padded. The anesthesia screen is moved as far to the head of the bed as possible to improve surgeon ability to maneuver the laparoscope. The skin is prepped and draped to include the lower abdomen, genital area (manipulation of the scrotal sac may be necessary), and upper thighs. Following introduction of the laparoscope, the patient is placed in deep Trendelenburg's position (see Chapter 5 for positioning precautions) so that viscera fall away from the inguinal area (Feldman et al, 2007). Appropriately sized trocars and scopes, depending on the type of repair planned, ESU and appropriate smoke evacuation system, mesh, and the primary monitor and video cart are required. If the patient has voided preoperatively, urinary catheterization can be avoided.

Operative Procedure—Totally Extraperitoneal Patch (TEP) Approach (Figure 12-11)

1. An infraumbilical incision is made. The anterior rectus sheath is incised and the ipsilateral rectus abdominis muscle is retracted laterally.
2. With blunt dissection, a space is created beneath the rectus.
3. A dissecting balloon (preperitoneal distention balloon, PDB) is inserted deep to the posterior rectus sheath, tunneled and advanced to the pubic symphysis, and inflated under direct laparoscopic vision.
4. The space is opened and the PDB removed and replaced with a blunt-tip trocar. The preperitoneal space is insufflated under low pressure and additional trocars are placed.

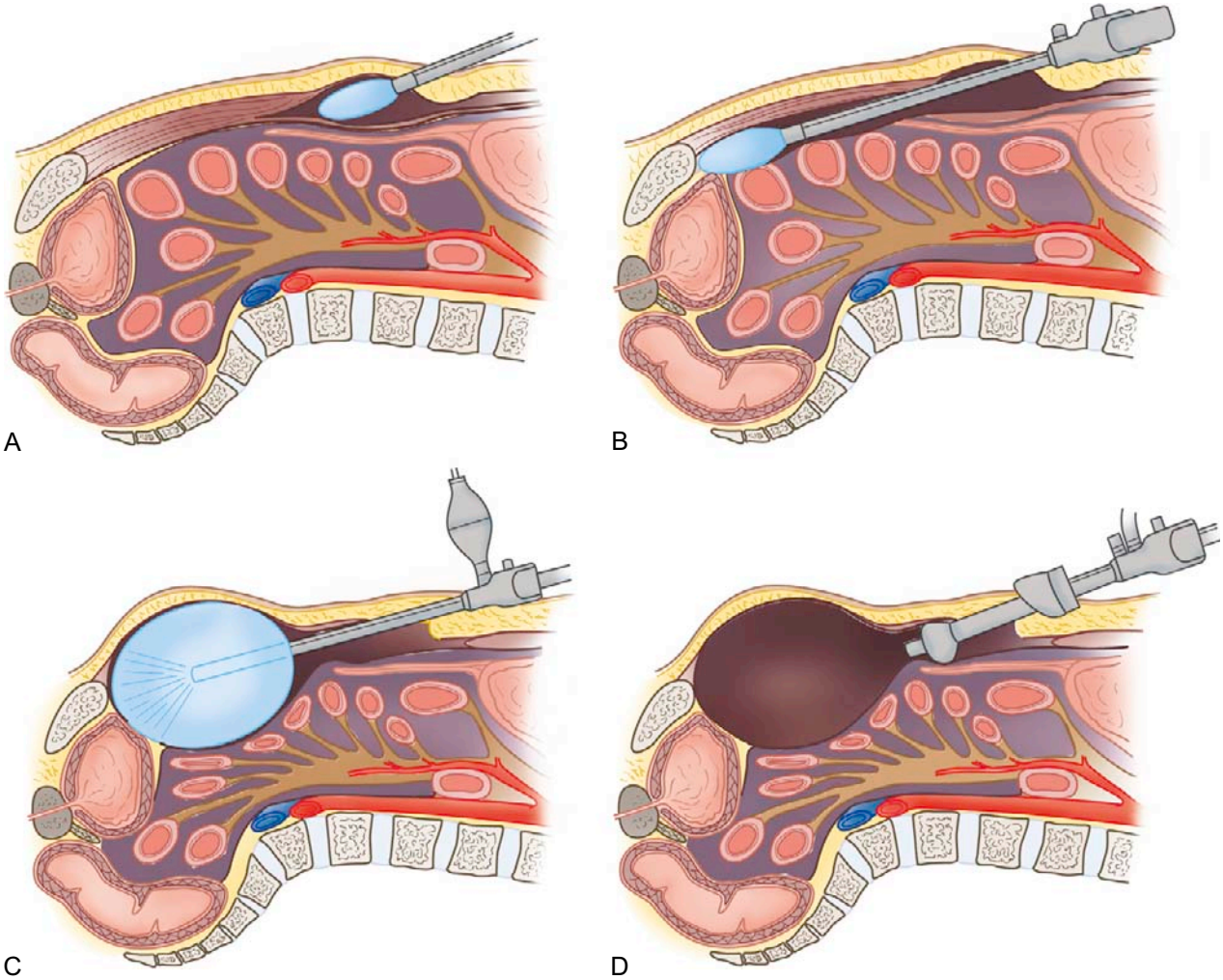


FIGURE 12-11 Totally extraperitoneal patch (TEP) laparoscopic hernia repair. **A**, The TEP approach for laparoscopic hernia repair is demonstrated. Access to the posterior rectus sheath is gained in the periumbilical region. A balloon dissector is placed on the anterior surface of the posterior rectus sheath. **B**, The balloon dissector is advanced to the posterior surface of the pubis in the preperitoneal space. **C**, The balloon is inflated, thereby creating an optical cavity. **D**, The optical cavity is insufflated by carbon dioxide, and the posterior surface of the inguinal floor is dissected.

5. Using a 30-degree telescope, the inferior epigastric vessels and lower portion of the rectus sheath are identified and retracted anteriorly.
6. The Cooper ligament is cleared from the pubic symphysis medially to the level of the external iliac vein.
7. The iliopubic tract is identified. Care is taken to avoid injury to the femoral branch of the genitofemoral nerve and the lateral femoral cutaneous nerve.
8. Lateral dissection is carried out to the anterior superior iliac.
9. The spermatic cord is skeletonized.
10. A *direct hernia sac* is gently reduced by retraction if it has not already been reduced by balloon expansion of the peritoneal space. A *small indirect sac* is mobilized from the spermatic cord and reduced into the peritoneal cavity. *A large sac* may be divided with electrocoagulation near the internal ring. The proximal peritoneal sac is closed with a loop ligature to prevent pneumoperitoneum from occurring. A piece of polypropylene mesh is inserted; unfolded to cover the direct, indirect, and femoral spaces and rest over the cord structures; and carefully secured with a tacking stapler.

REPAIR OF INGUINAL HERNIAS IN FEMALES. Regardless of the specific technique used, the initial approach to the repair of a hernia in the female is the same as that used in the male. After the cremaster muscles are opened to expose the round ligament, variations that may be encountered include the following: (1) with the sac exposed and cleared from the round ligament, the round ligament and accompanying vessels are dissected free from the inguinal floor to the labium; (2) at the labium the round ligament is clamped, ligated, and divided; (3) the sac at the internal ring is opened, checked to be sure that no abdominal contents are present, and ligated at its neck, together with the round ligament and associated vessels; or (4) the sac distal to the ligature is removed with the distal round ligament, while the ligated stump retracts promptly into the abdomen. The remainder of the repair is the same as that previously described.

REPAIR OF FEMORAL HERNIAS. A femoral hernia protrudes from the groin below the inguinal ligament into the thigh (Figure 12-12). In its most obvious form, a femoral hernia is an inflamed, tender mass below the inguinal ligament. Unfortunately, the presentation is frequently more subtle and the diagnosis is completely missed or confused with enlarged inguinal lymph nodes, a psoas muscle abscess, a saphenous varix, a lipoma, or an indirect or direct inguinal hernia. The defect is usually small and frequently nonreducible. Femoral hernias are highly likely to become incarcerated and strangulated; elective repair is clearly indicated unless serious contraindications to surgery exist.

Operative Procedure. The general approach is surgical treatment to free the tightly bound hernia, closely examine the contents of the hernia for ischemic change, and repair the hernia defect. The principles for repair of this type of hernia are the same as those described for inguinal herniorrhaphies. Ultimately, the defect must be obliterated. Repair of a femoral hernia requires approximating the aponeurotic margins of the femoral canal. The sutures are placed through the iliopubic tract superiorly and through the Cooper ligament and pectineus fascia inferiorly. Care is taken to not compromise the femoral artery and vein.

PREPERITONEAL (PROPERITONEAL) REPAIR—OPEN APPROACH. Preperitoneal (properitoneal) repair also is based on the essential role of the transversalis fascia in the cause and subsequent correction of a hernia. This repair is suitable for direct, indirect, and femoral hernias. It is particularly applicable in dealing with recurrent hernias and bilateral hernias, because exposure is obtained by operating through virgin surgical fields rather than through previous scars.

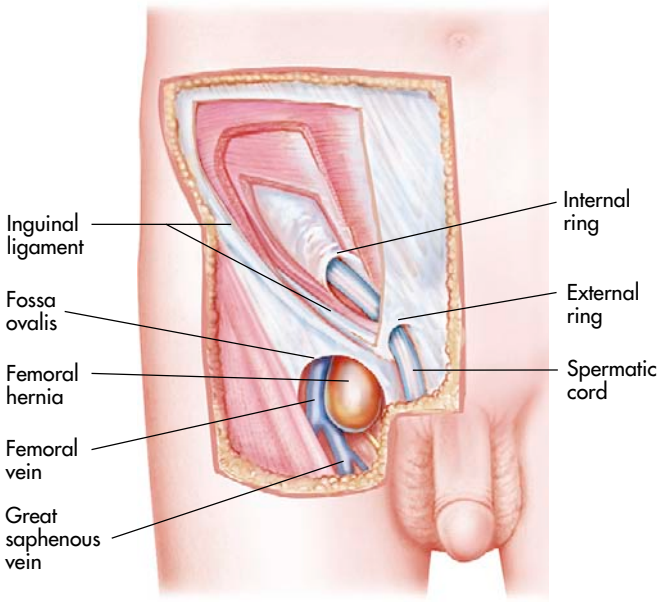


FIGURE 12-12 Bulge from femoral hernia occurring below inguinal ligament.

Operative Procedure

1. A transverse incision is made 2 cm above the symphysis pubis, through the rectus abdominis muscle on the affected side (Figure 12-13, *A*).
2. The wound is deepened by cutting the external oblique, internal oblique, and transversalis muscles.
3. The transversalis fascia is then cut, and the preperitoneal space is entered. This is the proper plane of dissection for the remainder of the operation.
4. Retraction on the lower side of the incision reveals the posterior inguinal wall and the hernia defect.

Variations in the procedure are performed for different types of hernias.

1. If the hernia is direct, it can be reduced easily and the superior edge of the hernia defect (the transversalis fascia) is sutured to the iliopubic tract (origin of the transversalis fascia) (Figure 12-13, *B*).
2. In an indirect hernia, the sac is gently retracted from the inguinal canal. A purse-string suture is placed around the peritoneal defect as the sac is excised (Figure 12-13, *C*). The lateral aspect of the internal abdominal ring is closed, and the posterior wall is reinforced as with the direct hernia.
3. In repair of a femoral hernia, the sac is again reduced by traction. After the sac is inspected for contents, a high ligation is performed. As it approaches the Cooper ligament, the defect in the posterior inguinal floor is clearly identified and is repaired by direct approximation (Figure 12-13, *D*).

After repair of any of the aforementioned hernias, the preperitoneal space is irrigated with saline solution and the appropriate layers are approximated.

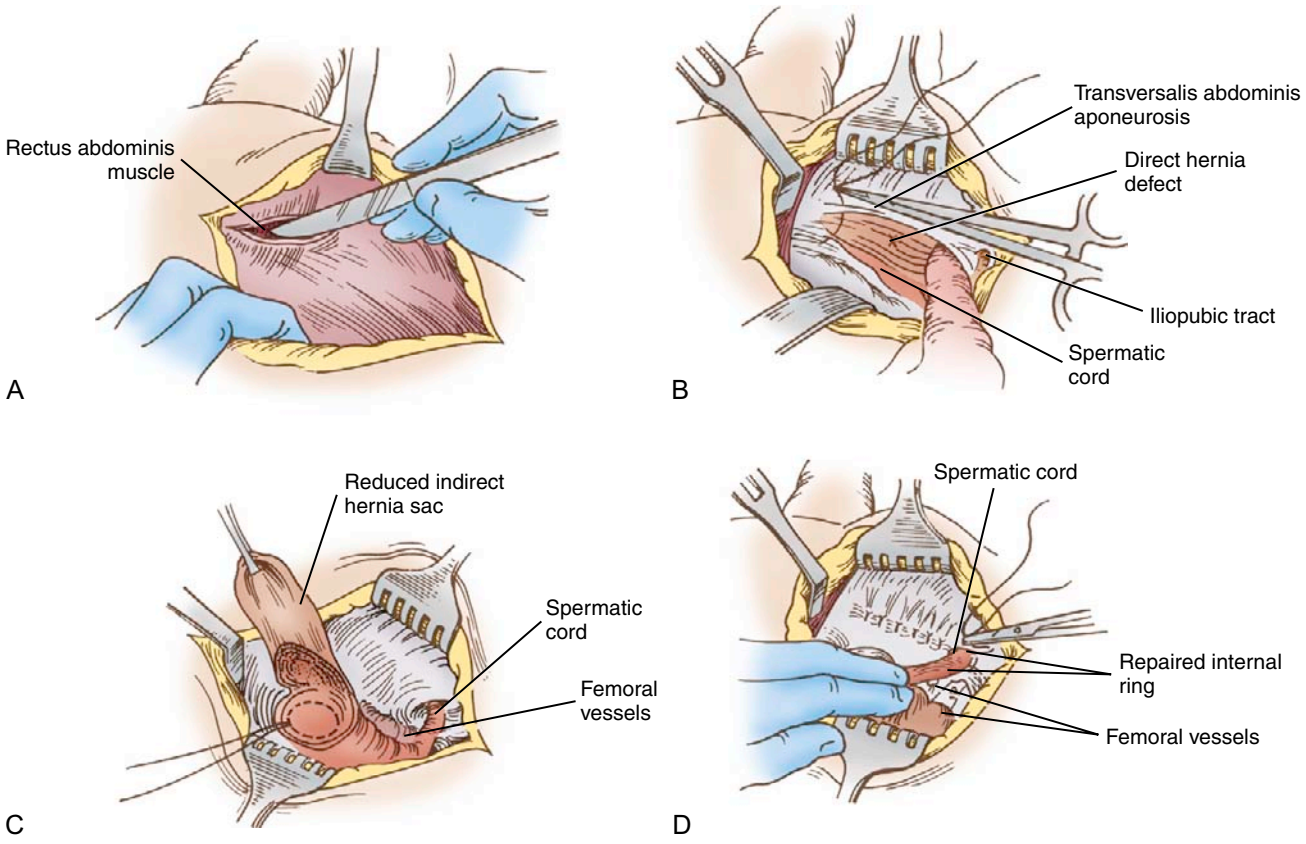


FIGURE 12-13 Preperitoneal repair. **A**, Skin incision starts 2 cm above symphysis pubis and is extended through external oblique, internal oblique, and transversalis muscles. **B**, With finger in direct hernia defect, the surgeon sutures the transversalis abdominis aponeurosis to the iliopubic tract. **C**, In case of indirect defect, the sac is reduced and then excised, with high ligation being achieved by use of a purse-string suture. **D**, Internal ring is tightened after transversus abdominis aponeurosis has been approximated to iliopubic tract.

REPAIR OF SLIDING HERNIAS. Direct or indirect hernias may occur as sliding hernias. A sliding inguinal hernia occurs when the wall of a viscus forms a portion of the wall of the hernia. The most common sliding hernias involve the bladder in direct hernias, the sigmoid colon in left indirect hernias, and the cecum in right indirect inguinal hernias (Figure 12-14). This hernia must be recognized early in the repair because attempts at surgical removal of the entire sac will injure the sliding viscus.

Operative Procedure. All operations designed to repair sliding hernias adhere to the basic principle of repairing the defect in the transversalis fascia. To free the bowel from the sac, the following steps must be taken:

1. The sac is opened in an area where no bowel is present and is excised medially and laterally to a point at which the bowel can be mobilized (Figure 12-15).
2. The lateral and medial peritoneal margins are approximated.
3. The bowel is reduced to the peritoneal cavity, and high ligation of the sac is performed.
4. Repair of the transversalis fascia is done by one of the methods previously described.

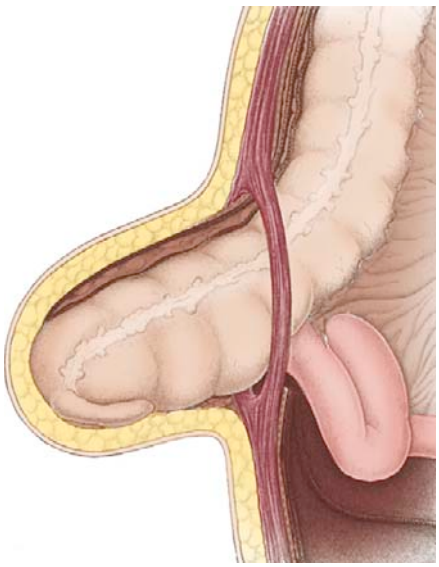


FIGURE 12-14 Sliding hernia.

LITTRE, MAYDL, AND RICHTER HERNIAS. An inguinal hernia containing a Meckel's diverticulum is called a *Littre hernia,* and one containing two loops of bowel is called a *Maydl hernia.* A special type of strangulated hernia is a *Richter hernia* (Figure 12-16). In this hernia, only a part of the circumference of the bowel is incarcerated or strangulated in the hernia. Frequently it is described as a knuckle of bowel that becomes trapped and ischemic. Because initially a very small area is necrotic, diagnosis may be delayed. A Richter hernia most frequently occurs in femoral hernias because of the small size and

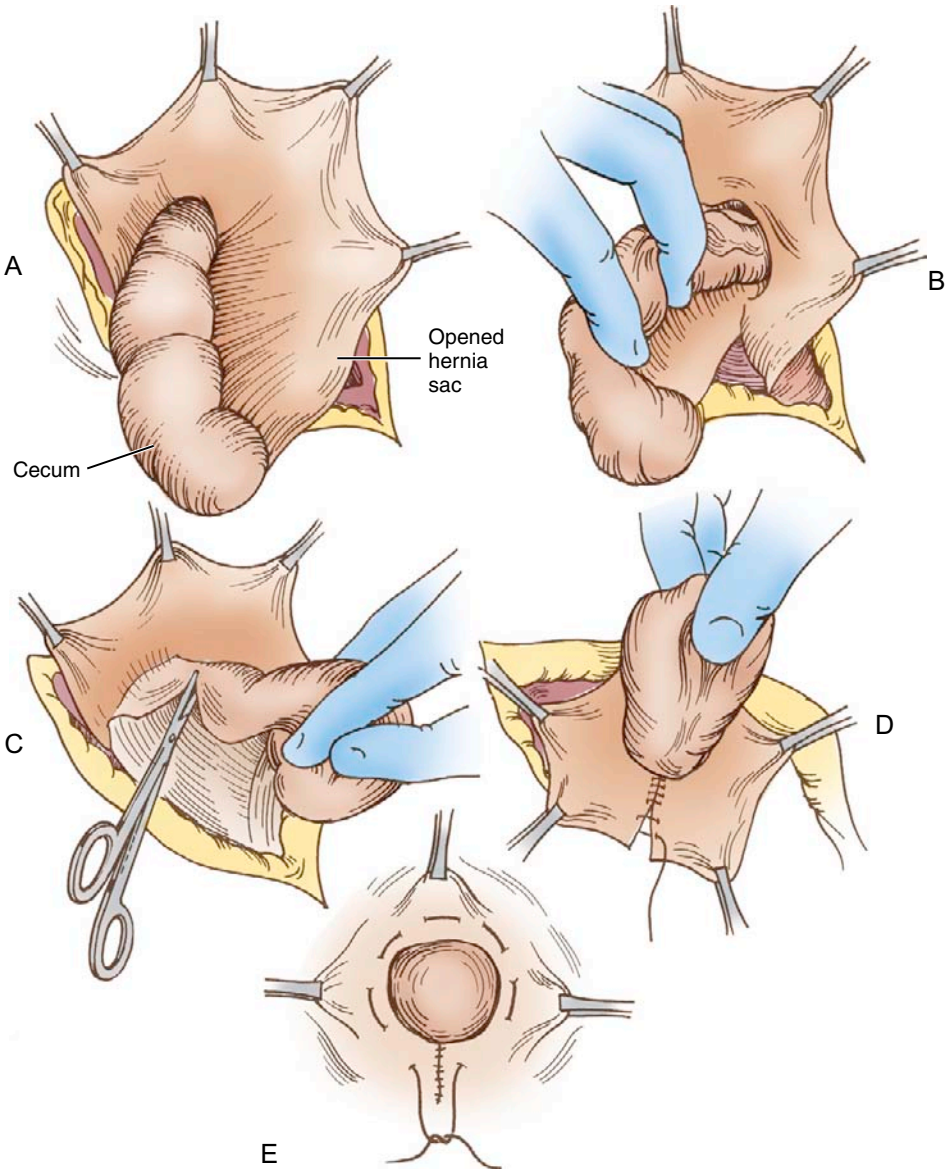


FIGURE 12-15 Right sliding hernia. **A**, Cecum forms posterior wall of hernia sac. **B**, Peritoneum is excised medially (**C**) and laterally (**D**) to allow mobilization of cecum for subsequent reduction to peritoneal cavity. Lateral and medial margins are approximated. **E**, After reduction, high ligation is accomplished using a purse-string suture.

sharp, relatively inflexible nature of the fascial ring in this area. A strangulated Richter hernia may be reduced spontaneously, and the gangrenous piece of intestine may be overlooked at the time of operation. Most commonly, the distal ileum is involved in a Richter hernia; however, omentum is frequently encountered in the sac. The favored approach for repair is through the preperitoneal space.

SURGERY FOR REPAIR OF HERNIAS OF THE ANTERIOR ABDOMINAL WALL

Ventral or Incisional Hernias

Ventral hernias can appear either spontaneously or after previous operations. Spontaneously occurring ventral hernias include epigastric and umbilical hernias. Postoperative ventral hernias, called *incisional hernias,* appear more frequently when the original incision was T shaped or a vertical midline. Operations that involve a potential for contamination, such as that for acute perforated ulcer or other perforated abdominal viscera, or wounds that become infected, are more prone to developing subsequent ventral hernias. Patients taking steroids or diagnosed with chronic obstructive pulmonary disease (COPD), as well as patients with a poor nutritional state and resulting hypoproteinemia, are predisposed to ventral hernia formation. Finally, faulty surgical technique, such as the choice of inappropriate suture materials, may result in the ultimate appearance of a ventral hernia.

Several methods have been developed for repairing ventral hernias (Research Highlight). If all layers of the abdominal wall are easily identified, anatomic layer-by-layer repair may be done.

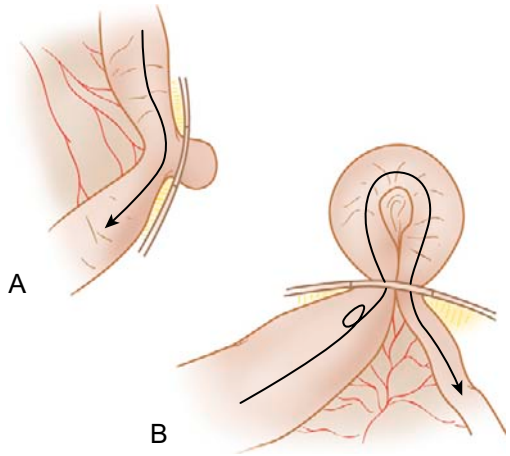


FIGURE 12-16 **A**, Richter hernia. Only a portion of bowel passes through hernial ring; arrow indicates that bowel need not be obstructed mechanically even with strangulation. **B**, Incarcerated hernia. Distended bowel in hernia cannot return to abdomen through narrow fascial defect.

Frequently a type of overlap method for repair is employed. Vertical and transverse overlap procedures are referred to as *vest-over-pants repair*. For large defects, in which approximation of tissue would result in closure with excessive tension or would cause either circulatory or respiratory compromise, synthetic materials such as surgical mesh or patches are employed.

When a very large fascial defect is present, a technique that extrapolates on the principles of tissue expansion may be used. A Tenckhoff catheter is placed percutaneously into the peritoneal cavity. Gradual expansion of the abdominal fascia is accomplished by insufflation of the abdomen with 1 to 2 liters of nitrous oxide gas, similar to the procedure for laparoscopy. The patient's vital signs are monitored during and after the insufflation procedure, which may be performed on a nursing unit or possibly in an outpatient clinical setting. The graduated expansion of the tissues sometimes allows for primary closure of the defect without the use of synthetic mesh or a patch.

Umbilical Hernias

Umbilical hernias are extraperitoneal and occur as small fascial defects under the umbilicus. They are common in children and frequently disappear spontaneously by 2 years of age. If the defect persists, a simple approximation of the overlying fascia is all that is necessary for repair (see Chapter 25 for a description of hernia repair in children). In adults, umbilical hernias represent a defect in the linea alba just above the umbilicus. These hernias tend to occur more frequently in obese people, making diagnosis more difficult. Umbilical hernias are potentially dangerous because they have small necks and frequently become incarcerated. Surgical repair is indicated for all adults with both symptomatic and asymptomatic umbilical hernias.

Epigastric Hernias

Epigastric hernias are protrusions of fat through defects in the abdominal wall between the xiphoid process and the umbilicus. Patients with epigastric hernias can have nausea, vague abdominal pain, or epigastric pain similar to that observed with cholecystitis or duodenal ulcers. Surgical repair of epigastric hernias is simple and very successful.

RESEARCH HIGHLIGHT

Comparison of Laparoscopic versus Open Incisional Hernia Repair

In the United States, approximately 4 to 5 million laparotomies are performed annually, leading to at least 400,000 to 500,000 incisional hernias. Approximately 200,000 of these incisional hernias require surgical repair. This study focused on the United Kingdom (UK), where more than 124,000 laparotomies and 7000 subsequent incisional hernia repairs were performed from 2005 to 2006 using both open and laparoscopic techniques. UK researchers undertook a meta-analysis to compare the outcomes of laparoscopic versus open incisional hernia repair, examining surgical time, duration of hospital stay, perioperative complications, postoperative surgical site pain, and recurrence rates.

The analysis included 5 randomized controlled trials that involved 366 patients—183 in the open group and 183 in the laparoscopic group. Open repair was associated with significantly higher complication rates and longer hospital stays, as well as longer surgical times than laparoscopic repair. There was no statistical difference in surgical site pain or recurrence rates. The researchers concluded that laparoscopic repair of incisional hernias is a safe, feasible, and effective alternative to open repair techniques.

Adapted from Sajid MS et al: Laparoscopic versus open repair of incisional/ventral hernia: a meta-analysis, *Am J Surg* 197:64-72, 2009.

Spigelian Hernias

The linea semilunaris, often referred to as the *Spigelius line*, marks the transition from muscle to aponeurosis in the transversus abdominis muscle. The area of aponeurosis that lies between the linea semilunaris and the lateral edge of the rectus muscle is referred to as the *spigelian zone*. Protrusion of a peritoneal sac, preperitoneal fat, or other abdominal viscera through a congenital or acquired defect in this area is called a *spigelian hernia* (Menon, 2008). It is usually located between the different muscle layers of the abdominal wall. For this reason a spigelian hernia may be referred to as an *interstitial* or *intramuscular hernia*.

Spigelian hernias are uncommon and are generally difficult to diagnose. Ultrasonic scanning has improved the diagnosis of such hernias. When ultrasonic scanning is not conclusive, CT can better visualize the hernia orifice.

Interparietal Hernias

An interparietal hernia lies between the layers of the abdominal wall. These hernias may be classified by dividing them into those that present with ventral swelling and those without ventral swelling. Diagnosis is often made during an exploratory laparotomy for symptoms of intestinal obstruction.

Repair follows the same procedure as that done for a strangulated hernia. The sac contents are closely examined for ischemia, the sac is resected, and the defect is repaired.

Synthetic Mesh and Patch Repairs

An ideal prosthetic mesh should not be physically modified by tissue fluids; be chemically inert, noncarcinogenic, and nonallergenic; resist mechanical strain; be permeable, allowing tissue ingrowth; and be pliable. Synthetic meshes, such as Mersilene,

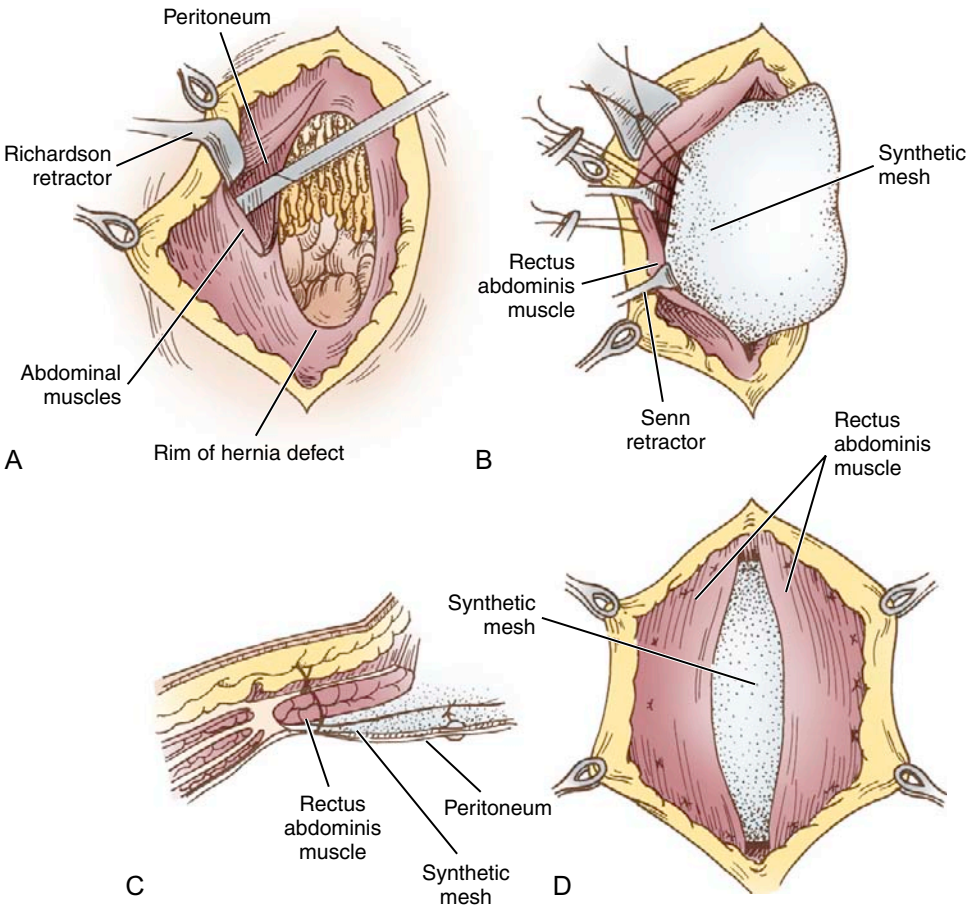


FIGURE 12-17 Use of mesh in hernia repair. After layers of abdominal wall surrounding ventral hernia are identified (**A**), mesh is inserted between rectus and peritoneum (**B**). **C**, Mesh is sutured into place on one side. **D**, With moderate tension, mesh is inserted between appropriate layers on opposite side and is sutured into place.

Marlex, Prolene, and Dacron, have been particularly helpful in repairing recurrent or large ventral hernias. Closure of the defect is obtained with minimal or no tension on the suture line. These synthetic materials are strong and durable, promoting fibrovascular growth within their pores, which lends extra strength to the repair. Single-dose antibiotic prophylaxis may be used to reduce wound infection rates with prosthetic hernia repair. Although there are studies that indicate that routine use of prophylactic antibiotics is not recommended for open non-implant herniorrhaphy, there is little direct clinical evidence on which to base recommendations when implantable mesh is used.

Another synthetic material, the Gore-Tex patch, has become popular for the reconstruction of abdominal wall defects and repair of soft tissue. Gore-Tex soft tissue patches are available in both 1-cm and 2-cm thicknesses. Impregnation of Gore-Tex patches with an antimicrobial agent has been associated with reduced incidence of infection. Gore-Tex is, however, very expensive, and surgical services departments should evaluate products such as surgical mesh with consideration to its performance, cost, effect on quality patient care, and value analysis (AORN, 2009b).

Essential to the use of mesh or patch in a hernia repair are the identification and cleaning of tissue planes to which the mesh or patch will be attached (Figure 12-17, *A*). In a ventral hernia, the peritoneum is dissected from the undersurface of the rectus abdominis muscle and the mesh or patch is placed between the peritoneum and the rectus (Figure 12-17, *B*). After the mesh or patch is positioned, it is sutured in place on one side, using the synthetic suture material compatible with the type of mesh or patch employed (Figure 12-17, *C*).

At this point the peritoneum can be closed, if possible. If the peritoneum cannot be closed, the mesh or patch can be placed directly over the omentum. The mesh or patch is then placed and sutured to the other side of the defect, with moderate tension maintained (Figure 12-17, *D*). If possible, the mesh or patch is then covered with a fascial or muscular layer before the subcutaneous fat and skin are closed. Closed-wound drainage catheters may be placed in the wound, and antibiotics are frequently used prophylactically. Using mesh or a patch to repair inguinal hernias is based on the same principles used for closing ventral hernias. With inguinal hernias, the mesh or patch is sutured to transversalis fascia on both sides of the defect.

REFERENCES

Association of periOperative Registered Nurses (AORN): Recommended practices for a safe environment of care. In *Perioperative standards and recommended practices*, Denver, 2009a, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for product selection in perioperative practice settings. In *Perioperative standards and recommended practices*, Denver, 2009b, The Association.

Barclay L, Murata P: Evaluation of acute abdominal pain reviewed. From Medscape Medical News, April 18, 2008, available at http://cme.medscape.com/viewarticle/573206. Accessed August 1, 2009.

Bascom J: Inguinal hernia. In Harken AH, Moore EE, editors: *Abernathy's surgical secrets*, ed 5, Philadelphia, 2004, Hanley & Belfus.

Beyea SC: *Perioperative nursing data set, revised*, Denver, 2007, Association of Perioperative Registered Nurses (AORN).

Catchpole K et al: Teamwork and error in the operating room: analysis of skills and roles, *Ann Surg* 247:699–706, 2008.

Denholm B: Tucking patient's arms and general positioning, *AORN J* 89(4):755–757, 2009.

Feldman LS et al: Laparoscopic hernia repair. In Souba WW et al., *ACS surgery principles & practice,* ed 6, New York, NY, 2007.

Gilbert AI et al: Inguinal hernia: anatomy and management, available at www.surgery.medscape.com/ viewarticle/357. Accessed July 30, 2009.

Lawrence PF: *Essentials of general surgery*, ed 4, Philadelphia, 2006, Lippincott Williams & Wilkins.

Menon AS: Hernia reduction. eMedicine specialties, April 8, 2008, available at www.emedicinehealth.com/hernia/article_em.htm. Accessed August 1, 2009.

Read RC: Inguinal herniation in the adult, defect or disease: a surgeon's odyssey, Pioneers in Hernia Surgery, *Pioneer* 8:296–299, 2004.

Taylor J: FDA device clearances: hernia repair device, cryoablation system, automated perimetry device, available at www.medscape.com/viewarticle/562089. Accessed July 31, 2009.

World Health Organization. Implementation Manual WHO Surgical Safety Checklist (First edition), 2008, available at www.who.int/patientsafety. Accessed August 1, 2009.

CHAPTER 13

Gynecologic and Obstetric Surgery

DONNA R. McEWEN

Whereas changes in science and technology have impacted every area in medicine over the past century, changes in the specialty of women's health have had enormous influence over the way women live. At some point in their lives, many women face the prospect of surgery. Surgical procedures on the structures of the female reproductive system are performed for diagnostic, therapeutic, or cosmetic purposes; for conditions such as abnormal bleeding from the reproductive organs; for suspected malignant or benign neoplasms; and for infertility. Procedures are also performed to remove or repair weakened anatomic structures. Recent statistics show the majority of surgical procedures performed in the United States were performed on females (Healthcare Cost and Utilization Project [HCUPnet], 2007). A holistic approach with sensitivity to the special needs of this population is an essential component of perioperative care.

Surgical Anatomy

The female reproductive organs and their relationships are shown in Figures 13-1 and 13-2. The adult female structures associated with the process of reproduction are the external organs (vulva), the associated ligaments and muscles, the soft tissues and contents of the pelvic cavity, and the bony pelvis.

FEMALE EXTERNAL GENITAL ORGANS (VULVA)

The external organs, referred to collectively as the *vulva,* include the mons pubis, the labia majora and labia minora, the clitoris, the vestibular glands, the vaginal vestibule, the vaginal opening, and the urethral opening (Figure 13-3).

The mons pubis is a mound of adipose tissue covered by skin and, after puberty, by hair. It is situated over the anterior surface of the symphysis pubis.

The labia majora are two folds of adipose tissue covered with skin that extend downward and backward from the mons pubis. Varying in appearance according to the amount of adipose tissue, they unite below and behind the mons pubis to form the posterior commissure and in front of the mons pubis to form the anterior commissure. The labia minora are the two hairless, flat, delicate folds of skin that lie within the labia majora. Each labium splits into lateral and medial parts. The lateral part forms the prepuce of the clitoris, and the medial part forms the frenulum. The posterior folds of the labia are united by a delicate fold extending between them. This forms the fossa navicularis.

The clitoris is the homologue of the penis in the male. It hangs freely and terminates in a rounded glans (small, sensitive vascular body). Unlike the penis, the clitoris does not contain the urethra. The vaginal vestibule is a smooth area surrounded by the labia minora, with the clitoris at its apex and the fossa navicularis at its base. It contains openings for the urethra and the vagina.

The urethra, which is about 4 cm long in the premenopausal woman, is close to the anterior vaginal wall and connects the bladder with the urethral meatus. Two small paraurethral ducts, which are commonly known as *Skene's ducts,* lie on either side of the urethral meatus and drain *Skene's glands.*

The vaginal opening lies below the urethral meatus. The hymen surrounds the vaginal opening and may be circular, crescentic, or fimbriated.

Bartholin's glands and ducts are located on each side of the lower end of the vagina. These narrow ducts open into the vaginal orifice on the inner aspects of the labia minora. The glands secrete mucus and can become infected or inflamed.

PELVIC CAVITY

Uterus

The uterus is a pear-shaped organ situated in the pelvic cavity between the bladder and the rectum. It gains much of its support from its direct attachment to the vagina and from indirect attachments to nearby structures, such as the rectum and pelvic diaphragm. The uterus is supported on each side by the broad, round, cardinal, and uterosacral ligaments and levator ani muscles. The upper lateral points, the uterine cornua, receive the fallopian tubes. The fundus of the uterus is the upper, rounded portion positioned above the level of the tubal openings and just below the pelvic brim. Below, the body, or corpus, of the uterus joins the cervix. The corpus is separated from the cervix by a slight constriction (canal) called the *isthmus.* The cervix lies at the level of the ischial spines. The body of the uterus communicates with the cervical canal at the internal orifice, called the *internal os.* The constriction (canal) ends at the vaginal portion of the cervix at the external orifice, called the *external os.* The external os varies in appearance and may be oval, round, slitlike, or everted.

The uterine body has three layers: (1) the outer peritoneal, or serous, layer, which is a reflection of the pelvic peritoneum; (2) the myometrium, or muscular layer, which houses involuntary muscles, nerves, blood vessels, and lymphatics; and (3) the endometrium, or mucosal layer, which lines the cavity of the uterus.

Fallopian Tubes (Oviducts)

The Greek word *salpinx,* meaning "trumpet" or "tube," is used to refer to the fallopian tubes (Figure 13-4). The tubes are paired and consist of a musculomembranous channel about

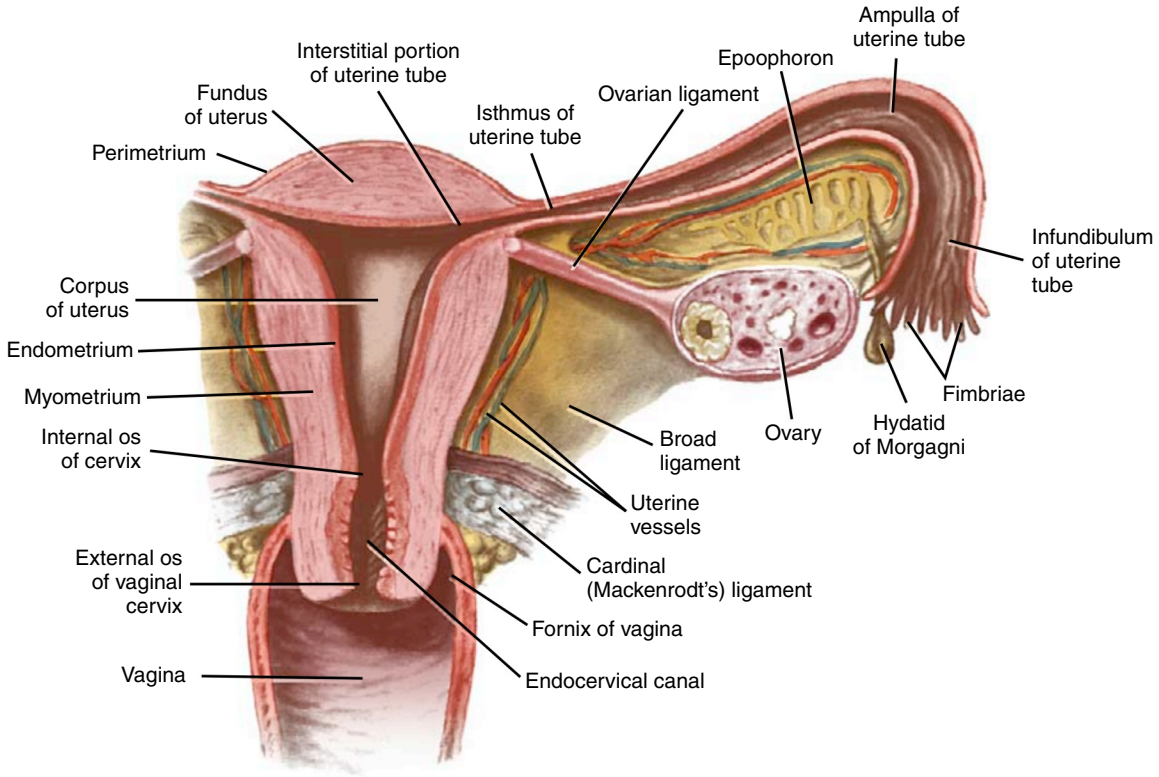


FIGURE 13-1 Female reproductive organs.

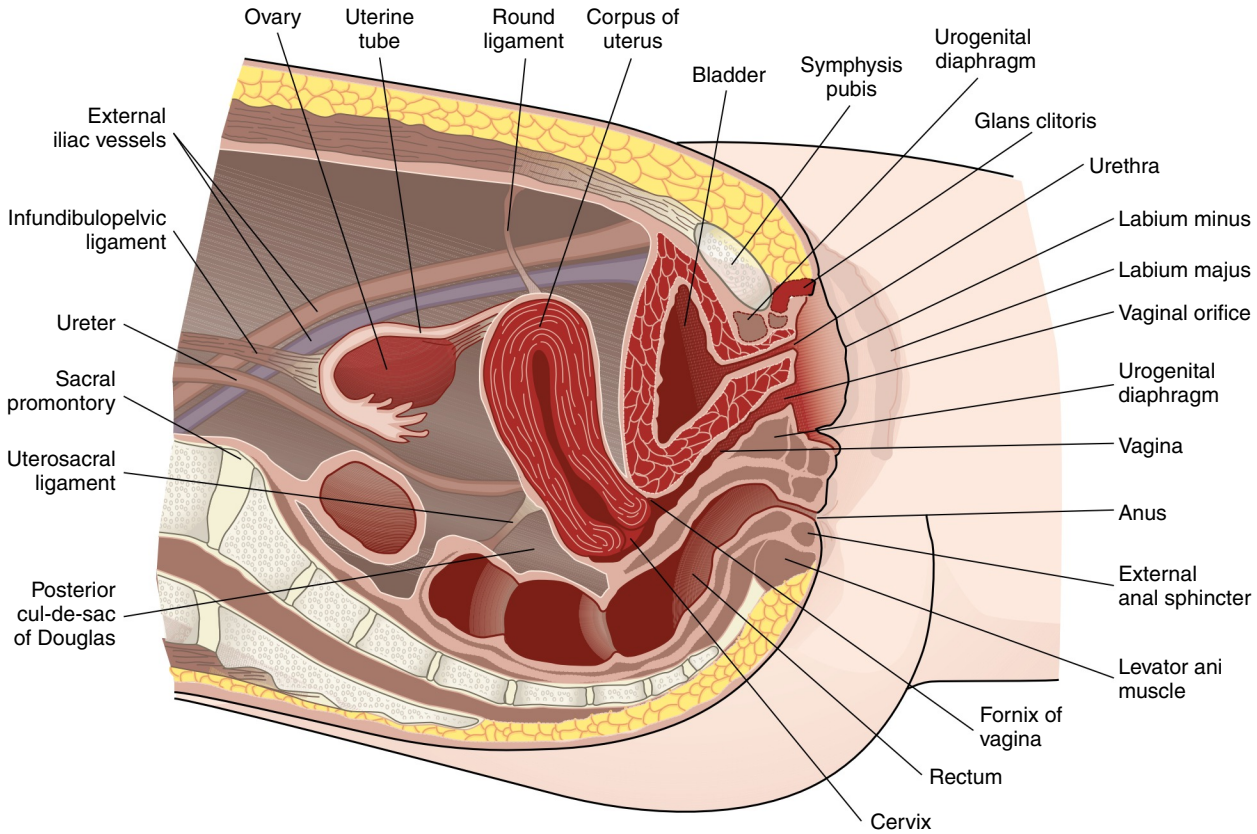


FIGURE 13-2 Female pelvic organs as viewed in midsagittal section.

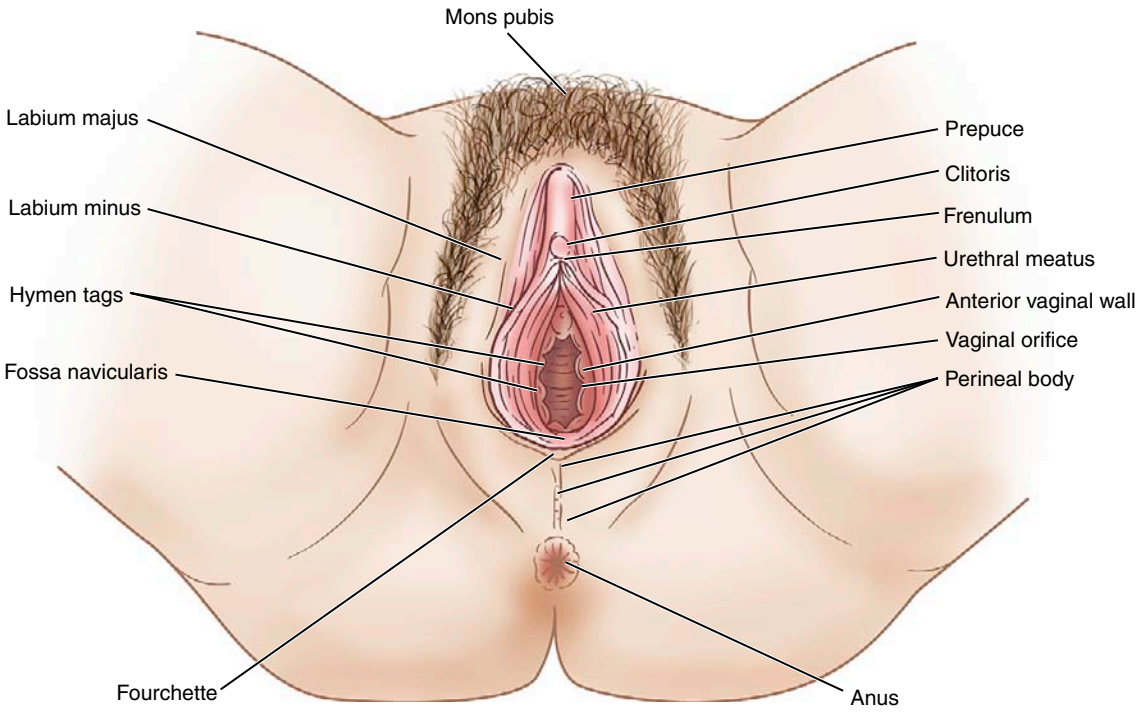


FIGURE 13-3 The structures of the external genitalia that are collectively called the *vulva.*

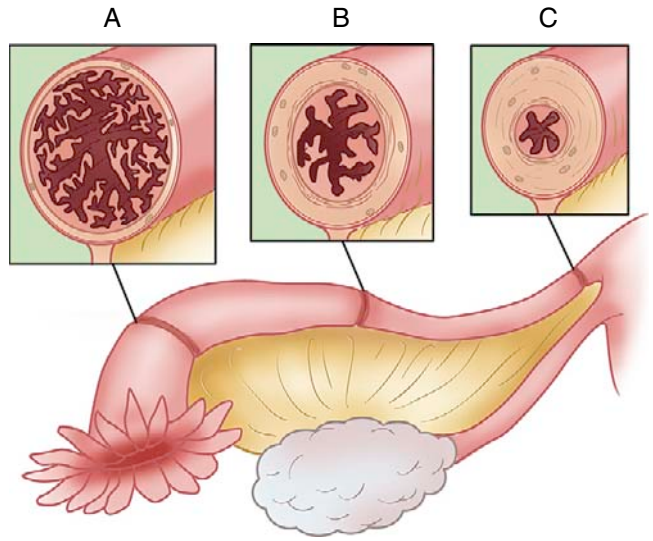


FIGURE 13-4 The longitudinal folds of the fallopian tube seen in cross section. **A**, Infundibulum. **B**, Ampulla. **C**, Isthmus.

10 to 13 cm long, forming the canals through which the ova are conveyed to the uterus from the ovaries. The outer surfaces of the tubes are covered by peritoneum. The inner layers are composed of muscular tissue lined with ciliated epithelium. Each tube receives its blood supply from the branches of the uterine and ovarian arteries and has four parts. The infundibulum is trumpet-shaped, opens into the abdominal cavity, and has fingerlike projections called *fimbriae.* The ampulla forms more than half of the tube and is thin-walled and tortuous. The isthmus is cylindric and forms approximately one third of the tube. The remainder of the tube is the uterine portion. Measuring approximately 1 cm in length, it passes through the wall of the uterus.

It has been theorized that the transfer of the ova from the ruptured follicles into the uterus is accomplished through vascular changes that occur with contraction of the smooth muscle fibers of the tube. The peristaltic action of the muscular layer and the ciliary movement propel the ova toward the uterus.

The right tube and ovary are in close relationship to the cecum and appendix; the left tube and ovary are situated near the sigmoid flexure. The fallopian tubes are also in proximity to the ureters.

Ovaries

The ovaries are located on each side of the uterus. The ovaries and tubes are collectively known as the *adnexa.* Each ovary lies within a depression (ovarian fossa) on the lateral wall of the pelvic cavity and above the broad ligament (see Figure 13-1). The anterior border of each ovary is attached to the posterior layer of the broad ligament by a peritoneal fold (mesovarium) and is suspended by the ovarian ligament.

The ovaries are small, almond-shaped organs composed of an outer layer, known as the *cortex,* and an inner vascular layer, known as the *medulla.* The medulla consists of connective tissue containing nerves, blood vessels, and lymph vessels. The ovary is covered by epithelium, not peritoneum. The cortex contains ovarian (graafian) follicles in different stages of maturity. After ovulation, the corpus luteum arises from the graafian follicle that expelled the ovum.

The ovaries are homologous with the testes of the male. They produce ova after puberty and also function as endocrine glands, producing hormones such as estrogen, secreted by the ovarian follicles. Estrogen controls the development of the secondary sexual characteristics and initiates growth of the lining of the uterus during the menstrual cycle. Progesterone, which

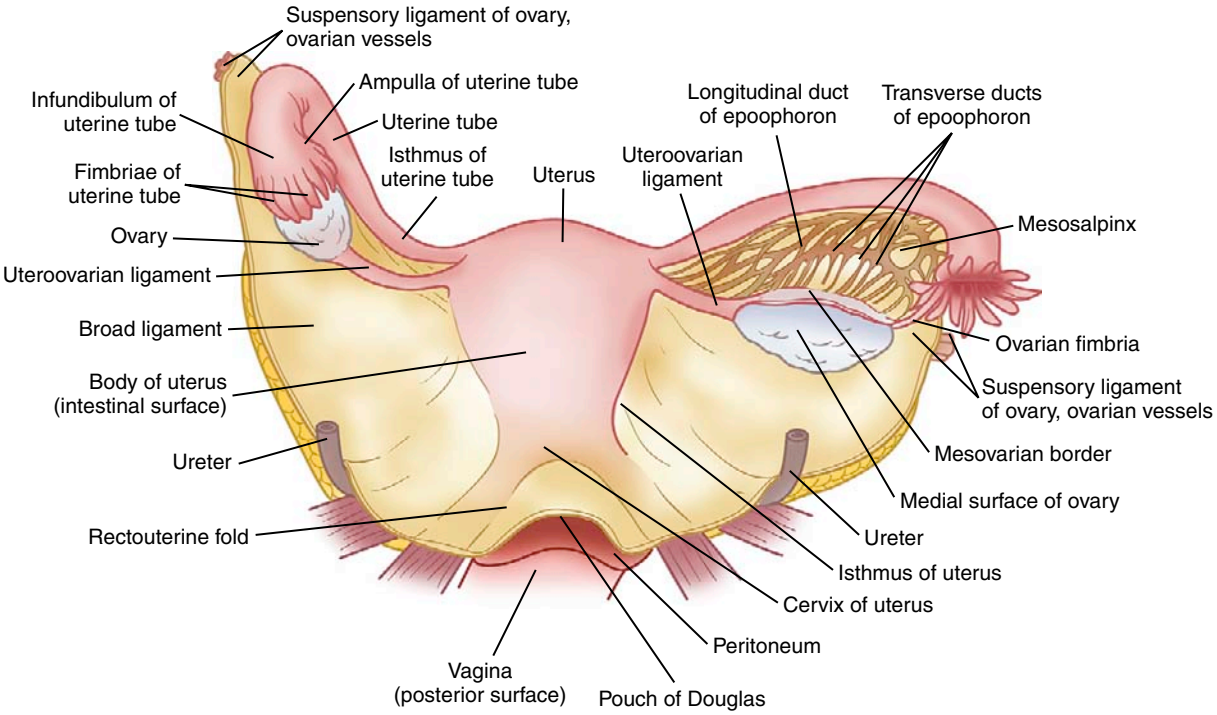


FIGURE 13-5 Schema of the broad ligament, posterior view. Note the many structures contained within the broad ligament. Note the posterior aspect of the rectouterine fold, called the *cul-de-sac*, or *pouch, of Douglas*.

is secreted by the corpus luteum, is essential for the implantation of the fertilized ovum and for the development of the embryo.

Ligaments of the Uterus

The uterine ligaments are the broad, round, cardinal, and uterosacral ligaments (Figure 13-5).

The pelvic peritoneum extends laterally, downward, and posteriorly from each side of the uterus. A double fold of pelvic peritoneum forms the layers of the broad ligament, enclosing the uterus. These layers separate to cover the floor and sides of the pelvis. The fallopian tube is situated within the free border of the broad ligament. The free margin of the upper division of the broad ligament, lying immediately below the fallopian tube, is termed the *mesosalpinx*. The ovary lies behind the broad ligament.

Round ligaments are fibromuscular bands attached to the uterus. Each round ligament passes forward and laterally between the layers of the broad ligament to enter the deep inguinal ring.

Cardinal ligaments are composed of connective tissue with smooth muscle fibers and provide strong support for the uterus.

Uterosacral ligaments are a posterior continuation of the peritoneal tissue. The ligaments pass posteriorly to the sacrum on either side of the rectum.

Vagina

The vagina is a rugated musculomembranous tube. It carries the menstrual blood from the uterus, serves as the organ for sexual intercourse, and is the terminal portion of the birth canal. The anterior wall measures 6 to 8 cm in length and the posterior wall 7 to 10 cm (see Figures 13-1 and 13-2). The anterior wall of the vagina is in proximity to the bladder and urethra. The lower posterior wall is anteriorly adjacent to the rectum. The upper portion of the vagina lies above the pelvic floor and is surrounded by visceral pelvic fascia. The lower half is surrounded by the levator ani muscles.

Cervix

The cervix consists of a supravaginal portion, which is closely associated with the bladder and the ureters, and a vaginal portion, which projects downward and backward into the vaginal vault. The projection of the cervix into the vaginal vault divides the vault into four regions, called *fornices:* anterior, posterior, right lateral, and left lateral.

The posterior fornix is in contact with the peritoneum of the pouch, or cul-de-sac, of Douglas. The rectovaginal septum lies between the vagina and rectum. The dense connective tissue separating the anterior wall of the vagina from the distal urethra is termed the *urethrovaginal septum.*

BONY PELVIS

The pelvis is that portion of the trunk below and behind the abdomen. The bony pelvis is composed of the ilium, symphysis pubis, ischium, sacrum, and coccyx. The so-called *pelvic brim* divides the abdominal false portion, located above the arcuate line, from the true portion of the pelvis, located below this line. The bony pelvis accommodates the growing fetus during pregnancy and the birth process.

The true pelvis may be considered to have three parts: inlet, cavity, and outlet. The muscles lining the pelvis facilitate movement of the thighs, give form to the pelvic cavity, and provide a firm elastic lining to the bony pelvic framework. All organs

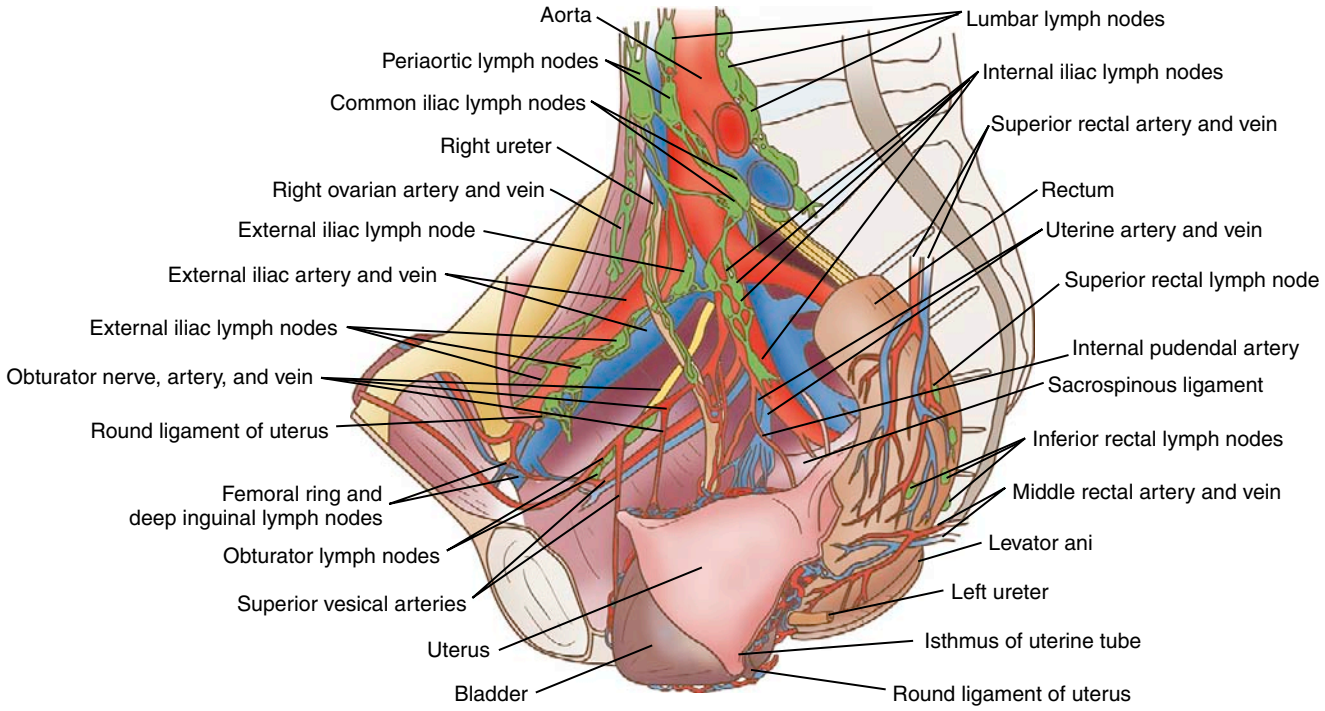


FIGURE 13-6 A lateral view of the female pelvis demonstrating the extensive lymphatic network. Note that most of the lymphatic channels follow the courses of the major vessels.

located in the pelvis are covered by pelvic fascia, which is extremely important in the maintenance of normal strength in the pelvic floor.

The fascia covering the muscles is usually dense and firm, whereas that covering organs is often thin and elastic. The nerves, blood vessels, and ureters coursing through the anatomic structures are closely associated with muscular and fascial structures.

PELVIC FLOOR

The pelvic floor acts as a supportive sling for the pelvic contents. The pelvic fascia may be divided into three general groups: parietal, diaphragmatic, and visceral. The parietal pelvic fascia covers the muscles of the true pelvic wall and perineum. The diaphragmatic fascia covers both sides of the pelvic diaphragm, which is made up of the levator ani and coccygeal muscles. The visceral fascia is thin and flexible and covers the pelvic organs. The floor of the pelvis, known as the *pelvic diaphragm,* gives support to the abdominal pelvic viscera in this region. It consists of the levator ani and coccygeal muscles with their respective fascial coverings; it separates the pelvic cavity from the perineum.

The levator ani muscles, varying in thickness and strength, may be divided into three parts: the iliococcygeal, the pubococcygeal, and the puborectal muscles. The fibers of the levator ani muscles blend with the muscle fibers of the rectum and vagina. The pubovaginal fibers of the pubococcygeal portion of the levator ani muscles, lying directly below the urinary bladder, are involved in the control of micturition. The pubococcygeal fibers of the levator ani muscles control and pull the coccyx forward and assist in the closure of the pelvic outlet. The fibers pull the rectum, vagina, and bladder neck upward toward the symphysis pubis in an effort to close the pelvic outlet and are responsible for the flexure at the anorectal junction. Relaxation of the fibers during defecation permits a straightening at this junction. During parturition, the action of the levator ani muscles directs the fetal head into the lower part of the passageway.

Vascular, Nerve, and Lymphatic Supply of the Reproductive System

The blood supply of the female pelvis is derived from the internal iliac branches of the common iliac artery and is supplemented by the ovarian, superior rectal, and median sacral arteries—branches of the aorta.

The nerve supply of the female pelvis comes from the autonomic nerves, which enter the pelvis in the superior hypogastric plexus (presacral nerve). The lymphatics of the female pelvis either follow the course of the vessels to the iliac and preaortic nodes or empty into the inguinal glands (Figure 13-6).

Perioperative Nursing Considerations

Assessment

The provision of quality perioperative nursing care depends on thorough assessment and planning. Data about the gynecologic patient are gathered through the review of systems, physical examination, nursing and medical histories, and diagnostic test results in the patient record (Table 13-1).

Application of interpersonal communication techniques is vital during nursing assessment. The interview may be conducted on the patient care unit or in the holding area of the surgical suite. Privacy must be maintained to facilitate

TABLE 13-1

Common Laboratory Studies Used in the Reproductive Assessment

Test	Normal Range for Adults	Significance of Abnormal Findings
Follicle-stimulating hormone (FSH) (follitropin)	Follicular phase, 1.37-9.9 milliinternational units/ml Midcycle, 6.17-17.2 milliinternational units/ml Luteal phase, 1.09-9.2 milliinternational units/ml Postmenopause, 19.3-100.6 milliinternational units/ml	Decreased levels indicate possible infertility, anorexia nervosa, neoplasm. Elevations indicate possible Turner's syndrome.
Luteinizing hormone (LH)	Follicular phase, 1.68-15 milliinternational units/ml Midcycle, 21.9-56.6 milliinternational units/ml Luteal phase, 0.61-16.3 milliinternational units/ml Postmenopause, 14.2-52.3 milliinternational units/ml	Decreased levels indicate possible infertility, anovulation. Increased levels indicate possible ovarian failure, Turner's syndrome.
Prolactin	0-20 ng/ml; 20-400 ng/ml in pregnancy	Increased levels indicate possible galactorrhea, pituitary tumor, disease of hypothalamus or pituitary gland, hypothyroidism.
Estradiol	Follicular phase, 20-350 pg/ml Midcycle, 150-750 pg/ml Luteal phase, 30-450 pg/ml Postmenopause, ≤20 pg/ml	Increased levels indicate normal pregnancy, precocious puberty, ovarian tumor. Decreased levels indicate failing pregnancy, Turner's syndrome, menopause, anorexia nervosa.
Progesterone	Follicular phase, <50 ng/dl Luteal phase, 300-2500 ng/dl Postmenopause, <40 ng/dl	Increased levels indicate possible ovarian luteal cysts. Decreased levels indicate possible inadequate luteal phase, amenorrhea.
Testosterone	<1 ng/dl	Increased levels indicate possible adrenal neoplasm, polycystic ovaries, ovarian tumors, trophoblastic tumors, idiopathic hirsutism.

Modified from Lowdermilk DL: Assessment of the reproductive system. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, Philadelphia, 2010, Saunders.

discussion. Questions about reproduction and gynecologic history may embarrass the patient. The perioperative nurse uses open-ended questions, progressing from general to specific, throughout the assessment interview process. For example, the nurse may initially inquire about the patient's understanding of the surgical intervention to be performed and then proceed to questions pertaining to intraoperative positioning, such as the presence of back pain and limitations in joint mobility.

The nurse will solicit the gynecologic patient's chief complaint, present problem, social history, sexual history, and relevant medical and surgical histories. A family history includes information such as maternal use of diethylstilbestrol and deaths related to gynecologic disorders, cancer, hypertension, diabetes, and heart disease. Cultural, psychologic, and religious beliefs are identified and incorporated into the plan of care. Throughout this process the perioperative nurse must remain open and supportive to help establish a trusting therapeutic relationship. Establishing a trusting relationship also facilitates the nurse's assessment for intimate partner violence (IPV). IPV is a major health concern with estimates of more than 1 million women being assaulted by an intimate partner annually (WHO, 2008). Awareness of the scope of the problem and warning signs for abuse will serve the perioperative nurse well in assessing women for IPV concerns and providing for their safety during the perioperative period and beyond (Patient Safety).

The gynecologic patient's history includes a chronologic listing of each pregnancy with length of gestation, type of delivery, complications during pregnancy, duration of labor, and fetal weight. The menstrual cycle is discussed to include age at onset, length of each cycle, amount of flow, duration of bleeding, and pain or discomfort associated with menses. The amount of flow is described in relation to the number of pads and tampons used. Additional considerations for the gynecologic assessment are noted in Box 13-1.

A medication history is taken, including use of analgesics, oral contraceptives, estrogen therapy, diuretics, antihypertensives, and cardiac medications and use of herbal medications/neutraceuticals. Medication frequency, dosage, and duration of use are noted.

Gynecologic disorders may be associated with urinary problems. The perioperative nurse should inquire about stress incontinence or loss of urine while coughing, sneezing, or laughing as well as any pain or burning sensations on urination. Gynecologic surgery is performed in proximity to the kidneys, ureters, and bladder and may warrant preoperative studies such as an intravenous pyelogram (IVP) to establish an anatomic baseline.

The nurse reviews the results of the physical examination. Baseline vital signs; height; weight; and findings from assessment of the thyroid, chest, heart, lungs, breasts, abdomen, pelvis, and rectum are analyzed for their relationship to planning intraoperative care.

The gynecologic patient may undergo numerous diagnostic studies. The studies performed depend on the gynecologic problem or disorder. A laparoscopy may be performed for

PATIENT SAFETY

Assessment Techniques for Intimate Partner Violence (IPV)

IPV can be defined as the actual or threatened physical, sexual, psychologic, or emotional abuse by a spouse, ex-spouse, boyfriend, girlfriend, ex-boyfriend, ex-girlfriend, date, or cohabitating partner. IPV may also include rape and stalking. Abuse or violence crosses all ages and segments of society; it is not limited to certain economic groups or educational level.

Nurses and other healthcare providers may represent the first and only contact that an isolated woman will seek outside of the abusive relationship and are a primary source of relief; therefore screening for IPV should be an integral part of the perioperative assessment. A variety of screening tools are available and are summarized in the CDC publication, *Intimate Partner Violence and Sexual Violence Victimization Assessment Instruments for Use in Healthcare Settings*. Characteristics common to the tools include trying to normalize the conversation with neutral opening statements, such as "The staff at our facility are concerned about your safety. We know that many things can happen in our lives that affect our mental and physical health." In addition, healthcare providers should use direct questions when violence is suspected, such as "Are you with a partner who threatens or physically harms you?"

Cues to abuse include delay in seeking medical assistance (hours or days), vague explanations of injuries, nonspecific complaints, a partner who seems reluctant to leave the woman alone with the healthcare provider, and substance abuse. Physical signs include new and old injuries to the face, breasts, abdomen, and buttocks; fractures that have a suspicious etiology; injuries at various stages of healing; and patterns that indicate injuries made by biting or fist/hand patterns. Pregnant women have an increased risk for IPV and therefore should be thoroughly assessed by the perioperative nurse.

If the nurse suspects IPV, he/she is mandated in most states to report the abuse. Domestic violence is considered a crime in all states, but the category (e.g., misdemeanor or felony) varies by state definition. Nurses must be aware of the reporting requirements for the state in which they reside. In addition to reporting the abuse or suspected abuse, the nurse must document the findings in the medical record. If appropriate to the situation, photographs can be taken and included in the record.

The nurse must assess the patient's safety before she is discharged and provide her with written information about her legal options, shelters, crisis intervention services, and counseling. The National Domestic Violence Hotline (1-800-799-SAFE) is available 24 hours a day/7 days a week. Nurses can also facilitate patient safety by providing education to women and empowering them to understand that abuse is a violation of their basic human rights; promoting assertiveness; and recommending resources that will enhance independence.

Modified from Centers for Disease Control and Prevention: *Intimate partner violence and sexual violence victimization assessment instruments for use in healthcare settings,* available at www.cdc.gov/ncipc/dvp/ipv/ipvandsv-screening.pdf. Accessed July 2, 2009; Rhynerson B: Violence against women. In Lowdermilk DL, Perry SE, editors: *Maternity and women's health care,* ed 9, St Louis, 2007, Mosby; World Health Organization (WHO): *Violence against women fact sheet,* 2008, available at www.who.int/mediacentre/factsheets/fs239/en/. Accessed July 2, 2009.

diagnostic or therapeutic reasons, such as infertility, pelvic pain, pelvic inflammatory disease, ova retrieval for in vitro fertilization (IVF), lysis of adhesions, evaluation of pelvic mass, removal of ectopic pregnancy, or sterilization.

Pelvic ultrasonography helps diagnose ectopic pregnancy and adnexal and uterine disease. Uterine fibroids and blood or fluid in the pelvis may be identified by means of ultrasonography. Computerized tomography (CT) scanning and magnetic resonance imaging (MRI) may be used in evaluation of the patient with suspected malignancy in the retroperitoneal lymph nodes or bone.

The gynecologic patient may have a hysterosalpingogram preoperatively to identify abnormalities in the uterine cavity and occlusions in the tubal folds. This diagnostic tool is useful in detecting potential reasons for infertility.

A colposcopy, with colpomicroscopy, is often performed in the physician's office. This examination is indicated for the patient with an abnormal Papanicolaou (Pap) smear suggestive of dysplasia. It identifies cellular abnormalities that may involve the vulva, vagina, or cervix and helps identify areas of dysplasia and carcinoma in situ. Endocervical curette samples may be obtained during the colposcopic procedure to rule out invasive carcinoma or to detect early adenocarcinoma.

Gynecologic Carcinoma. Gynecologic cancers commonly occur in the endometrium, the cervix, the ovaries, or the vagina. Less common sites are the vulva and fallopian tubes. Risk factors associated with the development of these cancers are noted in Table 13-2.

Endometrial cancer (Figure 13-7) is the most common gynecologic cancer and is responsible for approximately 42,160 new cases of cancer each year in the United States. Patients with this type of cancer may be asymptomatic, or they may experience postmenopausal bleeding as their primary symptom (American Cancer Society [ACS], 2009).

Cervical cancer is the third most common cause of death related to gynecologic cancers. In its early, preinvasive stage, cervical cancer may be asymptomatic or associated with painless vaginal spotting or bleeding. During the early preinvasive stage, the disease may be described as dysplasia. From dysplasia, the disease progresses to carcinoma in situ (CIS). Preinvasive cancers may also be designated as cervical intraepithelial neoplasia (CIN) and classed according to severity (ACS, 2009; Lowdermilk, 2007a):

CIN 1: Mild
CIN 2: Moderate
CIN 3: Severe, to carcinoma in situ (Figure 13-8)

Ovarian cancer is often accompanied by symptoms attributable to other disease processes. It is the leading cause of death from gynecologic malignancies. These tumors are generally epithelial in nature and are associated with a poor prognosis (Figure 13-9). They spread directly to other organs in the pelvic space and distally to the lymphatics, or they seed into the peritoneum (ACS, 2009).

Vulvar cancer (Figure 13-10) represents the fourth most common gynecologic cancer and is typically slow-growing. It appears most often in women in their middle 60s to 70s. In younger women, the incidence is often linked to genital

BOX 13-1

Focused Assessment for Gynecologic Patients

GYNECOLOGIC HISTORY
- Prior Papanicolaou (Pap) smears and results
- Prior abnormal Pap smears, how treated, follow-up
- Recent gynecologic procedures
- Past gynecologic procedures or surgery (e.g., tubal ligation, hysterectomy, oophorectomy, laparoscopy, cryosurgery, conization)
- Sexually transmitted infections (STIs)
- Pelvic inflammatory disease
- Vaginal infections
- Cancer of reproductive organs

MENSTRUAL HISTORY
- Age at menarche
- Date of last normal menstrual period: first day of last cycle
- Number of days in cycle and regularity of cycle
- Character of flow: amount (number of pads/tampons used in 24 hours), duration, presence, and size of clots
- Dysmenorrhea: characteristics, duration, frequency (occurs with each cycle?), relief measures
- Intermenstrual bleeding or spotting: amount, duration, frequency, timing in relation to phase of cycle
- Intermenstrual pain: severity, duration, timing, association with ovulation

ABNORMAL BLEEDING
- Character: shortened interval between periods (<19-21 days), lengthened interval between periods (>37 days), amenorrhea, prolonged menses (>10 days), bleeding between periods
- Change in flow: nature of change, number of pads/tampons used in 24 hours (tampons/pads soaked?), presence of clots
- Associated symptoms: pain, cramping, abdominal distention, pelvic fullness, change in bowel habits, weight loss or gain
- Medications: prescription or nonprescription; oral contraceptives

PAIN
- Sequence: date and time of onset, sudden versus gradual onset, course since onset, duration, recurrence
- Character: specific location, type, and intensity of pain
- Associated symptoms: vaginal discharge or bleeding, gastrointestinal symptoms, abdominal distention or tenderness, pelvic fullness
- Association with menstrual cycle: timing, location, duration, changes
- Relationship to body functions and activities: voiding, eating, defecation, flatus, exercise, walking up stairs, bending, stretching, sexual activity
- Aggravating or relieving factors
- Previous medical care for this problem
- Efforts to treat
- Medications: prescription or nonprescription

VAGINAL DISCHARGE
- Character, amount, color, odor, consistency, changes in characteristics
- Occurrence: acute or chronic
- Douching habits
- Clothing habits: use of cotton or ventilated underwear and pantyhose, tight pants or jeans
- Presence of discharge or symptoms in sexual partner
- Use of condoms
- Associated symptoms: pruritus; tender, inflamed, or bleeding external tissues; dyspareunia; dysuria or burning on urination; abdominal pain or cramping; pelvic fullness
- Efforts to treat: antifungal vaginal cream
- Medications: prescription or nonprescription; oral contraceptives; antibiotics

SEXUAL HISTORY
- Sexual activity: number of current and previous partners; number of their partners; gender of partner or partners
- Method of contraception: current and past; satisfaction level
- Use of barrier protection for STIs
- Prior STIs

OBSTETRIC HISTORY
- G: **g**ravida: total number of pregnancies
- T: number of **t**erm pregnancies
- P: number of **p**reterm pregnancies
- A: number of **a**bortions, spontaneous or induced
- L: number of **l**iving children
- Complications of pregnancy, delivery, abortion, or with fetus or neonate
- Duration of labor, fetal weight
- Diabetes (gestational)

INFERTILITY
- Length of time attempting pregnancy, sexual activity pattern, knowledge of fertile period in menstrual cycle
- Abnormalities of vagina, cervix, uterus, fallopian tubes, ovaries
- Contributing factors: stress, nutrition, chemical substances
- Factors relating to partner's fertility
- Diagnostic evaluation to date

MENOPAUSAL HISTORY
- Age at menopause or currently experiencing
- Associated symptoms: menstrual changes, mood changes, tension, hot flashes
- Postmenopausal bleeding
- Birth control measures during menopause
- General feelings about menopause: self-image, effect on intimate relationships
- Mother's experience with menopause
- Medications: hormone replacement therapy (HRT), related side effects, breast tenderness, bloating, vaginal bleeding, other medications—prescription or nonprescription, including herbal remedies

Modified from Seidel HM et al: *Mosby's guide to physical examination,* ed 6, St Louis, 2006, Mosby.

TABLE 13-2

Risk Factors for Cancers of the Reproductive System

Risk Factor	Endometrial Cancer	Cervical Cancer	Ovarian Cancer	Vulvar Cancer	Vaginal Cancer	Fallopian Tube Cancer
Age	50-65 yr	CIS: 30-40 yr Invasive: 40-60 yr	Infrequent before 35 yr; range usually is 40-65 yr	After 40 yr; peak is 60-70 yr	Most after 50 yr; adenocarcinoma: 14-30 yr	Most after 50 yr; range is 18-80 yr
Family history	Increased risk	—	Increased risk	—	DES exposure in utero	—
Personal history	Diabetes, hypertension	—	Breast, bowel, or endometrial cancer	Cervical cancer, diabetes, vulvar disease	Vulvar or cervical cancer	Ovarian or uterine cancer, infertility
Race	Caucasian	African American, Native American	Caucasian	—	—	—
Mother's age at delivery	—	<18 yr	>30 yr	—	—	—
Body size	Obese	—	—	Possibly obese	—	—
Parity	Nulliparity	Multiparity	Nulliparity	—	Multiparity	Nulliparity
Estrogen use	Prolonged use >3 yr after menopause	Possibly long-term birth control pill use	—	—	—	—
Smoking	Possibly increased risk	Possibly double the risk	—	—	—	—
Infection (STI)	—	Possibly STI (herpes simplex virus type 2 or papillomavirus infection)	—	Possibly STI (papillomavirus infection)	STI (herpes simplex virus type 2 or papillomavirus infection)	PID, chronic salpingitis

CIS, Carcinoma in situ; *DES,* diethylstilbestrol; *PID,* pelvic inflammatory disease; *STI,* sexually transmitted infection.
Modified from Gingrich PM: Interventions for clients with gynecologic problems. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, Philadelphia, 2010, Saunders.

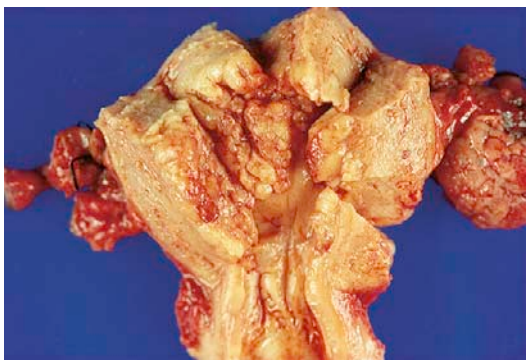


FIGURE 13-7 Endometrial cancer on posterior wall of uterus.

warts (condylomata acuminata) caused by human papillomavirus (HPV). Symptoms include irritation and pruritus in the perineal area or nonhealing lesions (ACS, 2009; Lowdermilk, 2007a).

Vaginal cancer ranks fifth of gynecologic cancers, causing fewer than 1000 deaths per year (ACS, 2009). This form of cancer is rare as a primary diagnosis and is usually an extension of cervical, endometrial, or vulvar cancers. It is generally asymptomatic in the early stages and may be accompanied by pain, foul-smelling discharge, painless bleeding, pruritus, and urinary symptoms in the later stages (Lowdermilk, 2007a).

Fallopian tube cancer is very rare, with an incidence of less than 1%. It is seen primarily as a metastasis from ovarian and endometrial cancers (Lowdermilk, 2007a).

Nursing Diagnosis

Perioperative nursing care is a planned process that is implemented to ensure safe, quality patient outcomes. Nursing diagnoses are formulated after reviewing the patient record and conducting a patient assessment. All significant data collected are reviewed and prioritized and then incorporated into the perioperative plan of care. The gynecologic patient may have multiple nursing diagnoses that warrant perioperative nursing intervention, which may include the following:

- Anxiety related to planned surgical intervention
- Risk for Urinary Retention related to edema, anesthesia, opioids, or pain
- Risk for Infection at the surgical site related to operative or other invasive procedures
- Disturbed Body Image related to surgery
- Risk for Perioperative Positioning Injury

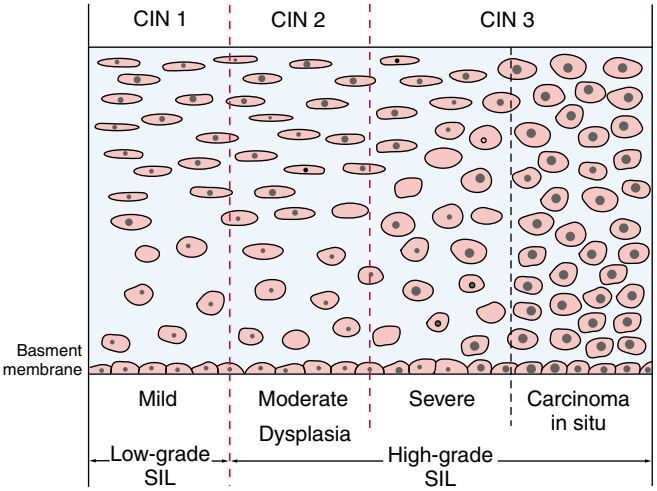


FIGURE 13-8 Diagram of cervical epithelium showing progressive changes and various terms used. *SIL,* Squamous intraepithelial lesion.

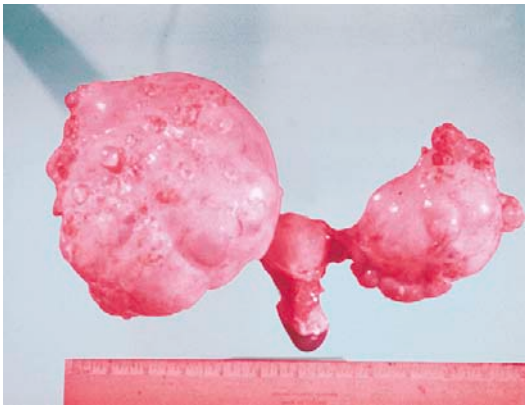


FIGURE 13-9 Bilateral ovarian carcinoma.

Outcome Identification

Outcomes identified for the selected nursing diagnoses could be stated as the following:

- The patient will verbalize reduced or controlled anxiety.
- The patient will maintain or regain normal patterns of urinary elimination.
- The patient will remain free from surgical site infection.
- The patient will acknowledge feelings regarding her body image (as applicable).
- The patient will be free from injury related to surgical positioning.

Planning

Planning enables the perioperative nurse to provide patient care in an organized and individualized manner. Planning involves preparation for both the psychosocial and physiologic needs of the gynecologic patient. Part of planning efficient and effective patient care is the gathering of the required equipment and supplies, positioning accessories, devices, and adjuncts requisite to the specific gynecologic surgical intervention. For example, if the gynecologic patient is undergoing a lengthy surgical intervention, the perioperative nurse will plan to have a forced-air warming device, pressure-reducing positioning

FIGURE 13-10 Vulvar/perineal carcinoma.

devices, antiembolic stockings, and sequential compression devices (SCDs) available. These actions will help maintain the patient's body temperature, promote skin integrity, and prevent venous stasis. Similar nursing interventions that will help the gynecologic patient reach the desired outcomes are identified for each patient. Examples of interventions for the gynecologic patient are shown in the Sample Plan of Care on p. 429.

Implementation

During implementation of the plan of care, the perioperative nurse performs the identified nursing interventions. Implementation includes gathering the appropriate instruments and patient care supplies, positioning the patient on the OR bed, performing antimicrobial skin preparation, inserting urinary catheters, draping the patient, creating and maintaining a sterile field, initiating safety measures, and monitoring the patient. Data continue to be collected, the plan of care is adjusted as required and documented, and reports are given to relief personnel, ensuring continuity of the patient's plan of care.

Instrumentation. A basic vaginal instrument set is required for vaginal and vulvar surgery. A basic abdominal gynecologic instrument set is required for abdominal gynecologic surgery. Laparoscopic, hysteroscopic, and robotic specific instrumentation may also be used. Surgeons' instrument preferences may vary, and the instrumentation described in this chapter is not meant to be all-inclusive.

For most abdominal gynecologic procedures, a dilation and curettage (D&C) set should be available.

Positioning. Principles and methods of patient positioning for different types of surgical procedures are described in Chapter 5. Stirrups for the lithotomy position may support

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Anxiety related to planned surgical intervention

OUTCOME
The patient will verbalize reduced or controlled anxiety.

INTERVENTIONS
- Determine the patient's previous experience with surgery and her level of knowledge related to the current planned surgical intervention.
- Assess the patient's level of anxiety and physical reactions to anxiety (e.g., tachycardia, tachypnea, nonverbal expressions of anxiety); classify her anxiety as low, moderate, or high.
- Use presence and touch (if welcome) to communicate comfort and caring.
- Provide time for and encourage expression of concerns or clarification of needs.
- Explore coping skills previously used by the patient to relieve anxiety (e.g., relaxation, deep breathing, imagery); reinforce these skills and facilitate their use.
- Explain the sequence of perioperative nursing activities and procedures, using nonmedical terms and clear, concise speech. Allow time for questions and concerns.
- Minimize environmental stimuli and noise.
- If conducive to anxiety reduction, provide patient with a means to listen to music in the preoperative period and intraoperatively, as applicable.

NURSING DIAGNOSIS
Risk for Urinary Retention related to edema, anesthesia, opioids, or pain

OUTCOME
The patient will maintain or regain normal patterns of urinary elimination.

INTERVENTIONS
- Before surgery, explain that an indwelling catheter will be inserted (if applicable).
- Verify the absence of any latex allergy; a latex-free catheter will be required for latex-allergic patients.
- Insert indwelling catheter using aseptic technique.
- Secure tubing to prevent inadvertent stretching or stress on catheter.
- Document size of catheter inserted.
- Keep drainage bag below the level of the bladder.
- Observe and document the color and amount of urine; report abnormalities.
- Check patency of catheter and drainage system whenever patient is repositioned.
- Discuss with the patient the importance of adequate postoperative fluid intake and early ambulation.
- Review elements of catheter care, management of drainage system, catheter removal, and signs and symptoms of urinary tract infection.
- Clarify any patient misconceptions.
- Encourage the patient to verbalize feelings and concerns regarding inability to void postoperatively, presence of indwelling catheter, and catheter removal.

NURSING DIAGNOSIS
Risk for Infection at the surgical site related to operative or other invasive procedures

OUTCOME
The patient will remain free from surgical site infection.

INTERVENTIONS
- Administer and document antibiotic prophylaxis as prescribed. Follow safe practices for all medication administered.
- Initiate measures to warm patient and maintain normothermia.
- Prepare surgical site with an antiseptic solution; document skin condition at surgical site and solution used.
- Apply dressing to surgical site before sterile drapes are removed to prevent contamination of incision.
- Follow Standard Precautions and infection prevention and control practices.
- Maintain aseptic technique, and monitor members of the surgical team for breaks in technique.
- Correctly classify surgical wound at end of procedure.
- Document the presence, location, and type of any drains inserted during surgical intervention.
- Review with patient signs and symptoms of infection at surgical site:
  - Redness
  - Swelling
  - Warmth
  - Tenderness
  - Pain
- Discuss the importance of proper handwashing techniques when changing dressings at surgical site, as applicable.

NURSING DIAGNOSIS
Disturbed Body Image related to surgery

OUTCOME
The patient will acknowledge feelings regarding her body image (as applicable).

INTERVENTIONS
- Determine the patient's expectations of her planned surgery.
- Correct unrealistic perceptions of the planned surgical intervention (as appropriate).
- Encourage the patient to express feelings about her diagnosis and surgery and how she believes it will affect her body image; clarify any misconceptions.
- Acknowledge denial, anger, or depression as normal feelings when adjusting to changes in body image or function.
- Determine the influence of cultural beliefs, norms, and values on the patient's body image.
- Maintain the patient's privacy.
- Demonstrate empathy and positive regard.
- Reinforce information provided by other healthcare team members.

NURSING DIAGNOSIS
Risk for Perioperative Positioning Injury

OUTCOME
The patient will be free from injury related to surgical positioning.

INTERVENTIONS
- Note and document any preexisting patient considerations (e.g., nutritional status, weight, preoperative chemotherapy, limitations in mobility or range of motion, neurovascular impairments) that place the patient at risk for positioning injury.
- Use adequate numbers of personnel to transfer and position the patient.
- Secure the patient to the OR bed without friction or pressure at restraining straps.
- Assess and document condition of dependent skin areas.
- Use pressure-reducing positioning devices.
- Pad and protect bony prominences and dependent pressure sites.
- Maintain proper body alignment.
- Provide support stockings or antiembolic device, such as sequential compression devices (SCDs), as indicated.
- Reassess padding and protection during any positional changes.

only the patient's feet (canvas, fabric, or gel-pad ankle straps) or may cradle and support the thighs, popliteal spaces, and lower legs. Padded cradle stirrups promote maintenance of skin integrity and assist in preventing nerve injury. The nurse may anticipate that patient positions may be modified based on the surgical procedure and surgeon's preference. The patient is placed in the lithotomy position for most vaginal and vulvar surgery. Careful attention must be focused on placing the patient in the lithotomy position to prevent injury and vascular changes. The perioperative nurse must seek assistance during positioning the patient in lithotomy to ensure the legs are raised and lowered simultaneously. For abdominal gynecologic surgery, Trendelenburg's position may be used. Some surgeons use the low lithotomy position with the Trendelenburg position for abdominal oncology procedures to facilitate access to pelvic and para-aortic nodes. Patients placed in Trendelenburg's position for prolonged gynecologic procedures are at increased cardiovascular risk because of decreased pulmonary compliance and functional residual capacity (FRC) (Faust et al, 2005). Whenever possible the nurse positions the patient's arms on padded armboards with the palms up and fingers extended. Armboards are maintained at less than a 90-degree angle to prevent stretching of the brachial plexus. If there are surgical reasons to tuck the arms at the side, the nurse pads the patient's elbows to protect the ulnar nerve, faces the palms inward, and maintains the wrists in a neutral position (Denholm, 2009). A drape secures the arms. It should be tucked snuggly under the patient, not under the mattress. This prevents the arm from shifting downward intraoperatively and resting against the OR bed rail. Care should be taken to protect all patients from integumentary, musculoskeletal, and nerve injury while ensuring adequate circulatory, renal, and respiratory functions.

Because pelvic and vaginal procedures involve manipulation of the ureters, bladder, and urethra, indwelling urinary drainage is frequently established before or during surgery with an indwelling urethral catheter or a suprapubic cystostomy catheter, depending on the type of procedure. The size of sutures, needles, and drains also varies, depending on the surgical procedure, surgeon preference, and patient needs.

Prepping. Skin preparation and routine draping procedures are described in Chapter 3. Care must be taken not to cross-contaminate when prepping multiple areas, such as for an abdominal hysterectomy. The nurse always preps the abdomen before beginning the vaginal prep. Two separate prep trays should be used and the prep setups should be kept separate. The perioperative nurse should take care when performing vaginal preps on patients who have been experiencing vaginal bleeding and may have clots in the vaginal vault. The clots and any gross blood on the thighs or vulva should be removed before beginning the prep to allow full contact of the prepping solution.

Examination Under Anesthesia (EUA). Many physicians will perform a pelvic examination after the patient is anesthetized and positioned. The perioperative nurse should anticipate this examination and ensure that nonsterile gloves and an appropriate lubricant are available. Culture specimens (e.g., gonococcal, chlamydial, trichomonal) and a Pap smear may be obtained during the examination. Verify with the surgeon that the prep agent and lubricant used are compatible with cytologic evaluation.

Dressings, Drains, and Packing. Various dressings are used in gynecologic surgery and may range from simple (e.g., wound closure tapes) to complex (e.g., multilayer gauze, ostomy appliances, binders). Perineal pads are used after vaginal surgery.

Closed and open drains are used. The surgeon may insert a Penrose drain through the vaginal cuff after a hysterectomy. Indwelling and suprapubic catheters are also commonly employed in gynecologic surgery. All drains and catheters should be secured for patient comfort and to avoid dislodgment. Verify that the patient has no latex allergy, as many of these drains contain latex.

Packing may be used in fistulas or other created cavities or to support and stent the vagina, absorb postoperative drainage, or aid in hemostasis. Products used for vaginal packing can include narrow fine-mesh gauze in various yardage, iodoform packing, and large-mesh gauze. Vaginal packing is usually moistened with saline or coated with antibiotic or antifungal cream before insertion. Packing must be placed with care to avoid distention of the vault and compression of its vasculature.

Evaluation

During the evaluation phase the perioperative nurse determines whether the patient met the established outcomes. Some outcomes can be reached during the preoperative and intraoperative phases of care; they are evaluated before the patient's discharge from the OR. Others require ongoing monitoring and measurement in the postoperative phase; these are denoted by the word "will" to indicate their ongoing nature. Part of the perioperative nursing report to the postanesthesia care unit (PACU) or ambulatory recovery should include the outcomes of the nursing plan of care. They can be phrased as follows:

- The patient's anxiety was reduced; she verbalized concerns and used personally effective coping strategies.
- Urinary elimination patterns were maintained; urinary output was adequate; and catheter patency was maintained.
- The patient's skin integrity was maintained; she verbalized understanding of the signs and symptoms of infection to report to her physician and acknowledged measures to prevent infection (e.g., handwashing).
- The patient will effectively cope with her disturbance in body image; questions will continue to be answered and misconceptions clarified.
- There was no evidence of injury related to surgical positioning; range of motion and neurovascular status were consistent with preoperative levels.

Patient and Family Education and Discharge Planning

Patient and family education, along with discharge planning, is a critical perioperative nursing activity. Many gynecologic surgical procedures are performed on an ambulatory basis, and for those that require an inpatient admission, length of stay continues to decrease. Thus patient education and discharge planning often begin before any admission, be it ambulatory or inpatient. Regardless of the gynecologic procedure performed, the perioperative nurse should begin patient and family education with necessary postoperative care information. The goal of this information is to restore normal body function

and may include areas such as early ambulation, prevention of respiratory complications, incision care, anticipated postoperative discomfort, managing postoperative pain, restrictions in activity, diet, and any other patient concerns. Areas such as progression of activities, emotional and physical issues, sexual activity, general nutritional needs, and health maintenance guide the education process. Gynecologic patients should also be provided specific information regarding signs and symptoms to report, especially in relation to vaginal bleeding and the surgical site, along with restrictions related to douching and vaginal penetration (tampons or sexual intercourse). With the growth in same-day surgery, many types of hysterectomies, some myomectomies, and even laparotomies are now same-day, or 23-hour–stay procedures (Ambulatory Surgery Considerations). Simple, clear information and instructions such as those presented in the Patient and Family Education box are helpful to enhance patient learning and retention.

LASERS IN GYNECOLOGIC SURGERY

Carbon dioxide (CO_2), neodymium:yttrium-aluminum-garnet (Nd:YAG), and argon lasers are used in gynecology to treat extrauterine disease such as pelvic endometriosis, cervical dysplasia, condylomata acuminata, pelvic adhesive disease, and premalignant diseases of the vulva and vagina. Lasers are generally used in conjunction with the colposcope and operating microscope, or the laparoscope. A laser plume evacuator or suction system is necessary to remove smoke and fumes from the operative field (AORN, 2009). All accessories and instrumentation used should be laser-safe and secure, and tested or examined for working order before use. Safety precautions must be implemented by the OR team when the laser is used. For example, if the argon laser is used, pressure-relief valves must be used to prevent increased intraabdominal pressure (see Chapter 7 for a full discussion of lasers and laser safety).

AMBULATORY SURGERY CONSIDERATIONS

Minimally Invasive Gynecologic Surgery

A variety of gynecologic surgical procedures can be performed using minimally invasive techniques. An advantage of minimally invasive surgery (MIS) is that patients can be discharged on the same day of surgery or within 23 hours of admission. Nurses who are involved in MIS gynecologic ambulatory surgical procedures should consider the following factors when planning and implementing care.

PREOPERATIVE CARE

Preoperative care of patients undergoing MIS should focus on patient teaching. The nurse should provide patients with written and verbal instructions to prevent misconceptions about the procedures, alleviate concerns or confusion about the robot (if used), and provide some postoperative teaching during the preoperative phone call. Teaching should focus on the following issues:

- Explaining the specifics of the particular procedure: Unfortunately, there is limited information available on robotics written for consumers, except that which is provided by the robotics' manufacturers.
- Alleviating anxiety: The nurse should make sure the patient understands that the physician is controlling the robot and that the robot is just a surgical tool that helps the surgeon be more efficient and effective.
- Explaining postoperative pain and activity limitations: It is important to remember that patients and their families will be providing postoperative care in the early days after surgery. This self-care includes recovery from anesthetic agents; return of gastrointestinal and urologic function; and management of pain, possible complications, and activity level.
- Explaining possible complications and ensuring that the patient knows when to contact her healthcare provider about problems.
- Teaching about care of the operative site: The nurse should provide written instructions to help the patient better remember what has been taught since preoperative anxiety may distract the patient. The nurse will reinforce these instructions postoperatively.

Preprocedural screening of patients is aimed at identifying risks for infection. The patient's general health is assessed to ensure that the patient can tolerate the procedure. These particular surgeries use gas (usually CO_2) to create visual space in the peritoneum—a pneumoperitoneum. The insufflation with CO_2 can cause cardiopulmonary and hemodynamic complications.

Knowing the patient's health and medication history is important. The following are complications associated with CO_2 insufflation:

- Hyperkalemia
- Pulmonary complications
- Cardiovascular and vascular complications
- Subcutaneous emphysema
- Metabolic inflammatory responses
- Gas embolism (rare)

INTRAOPERATIVE CARE

Preoperative nursing care varies little from procedure to procedure; however, intraoperative care is affected by the technologies used. Nurses assisting in robotic procedures must know how to set up, calibrate, and operate the machines. During surgery, monitoring cues and messages from the robotics' system are an important aspect of nursing care. Troubleshooting is important to promote patient safety and to avoid prolonging the procedure. Knowing emergency procedures is also important for this type or any type of surgery.

POSTOPERATIVE CARE

Postoperative care of the MIS patient is performed according to the same standards as those of traditional surgery. Care focuses on stabilizing the patient, maintaining pain control, carefully monitoring the operative site, carefully monitoring vital signs and level of consciousness, and following specific standards for the particular procedure.

Because the length of stay for these patients is generally short, keen assessment skills are important to handle issues before discharge. Teaching within the shortened timeframe may be impeded by patients and family who are not ready to learn because of postoperative pain or the effects of anesthesia. The nurse always provides verbal and written discharge instructions and, when possible, follows up with the patient and her family after discharge to ensure that complications do not arise and that patients are following instructions.

Modified from Dziedzic ME: *Mosby's Nursing Consult: clinical updates: nursing challenges in the care of patients who undergo minimally invasive surgery—are you prepared?* Available at www.nursingconsult.com/das/stat/view/146436750-2/cup?nid=198886&;sid=857030837&summaryresults=true&SEQNO=1. Accessed June 28, 2009.

PATIENT AND FAMILY EDUCATION

Gynecologic Surgery

Whenever possible, provide the patient and her caregiver with *verbal* and *written* instructions. Provide them with the phone number of the physician to call if questions arise. Use visual aids to enhance instruction. Encourage the patient to verbalize any concerns she may have regarding her condition and surgery. Misconceptions about the outcome of gynecologic surgery are common. Patients may believe that undergoing a hysterectomy will cause depression, nervousness, mental instability, weight gain, wrinkles, masculinity, and hirsutism. Provide education to correct any misconceptions, and discuss any other concerns, such as fear of death, cancer, loss of femininity and childbearing ability; pain; and changes in sexuality. Education points for common gynecologic procedures are as follows.

DILATION AND CURETTAGE OF THE UTERUS

- Take your temperature once each day for the next 2 days; if your oral temperature is more than 37.7° C (100° F), call the clinic or your physician.
- Avoid sexual intercourse, tub baths, and the use of tampons for 2 weeks to allow healing and prevent infection.
- Slight bleeding is normal. However, if bleeding is as heavy as during your normal menstrual period or if it lasts longer than 2 weeks, call your physician.
- Use a heating pad or hot water bottle to relieve abdominal cramping if it occurs.
- If procedure was performed for miscarriage, add the following:
  - Mood swings and depression are common after pregnancy loss. It can be helpful to talk to friends, family, or clergy about your loss.
  - Support groups may be helpful in the recovery period.
  - Attempts at subsequent pregnancy should be postponed until indicated by your physician.

ENDOMETRIAL ABLATION

- Spotting and vaginal drainage are normal for several days (even weeks or months) after the procedure.
- Use a heating pad or hot water bottle to relieve abdominal cramping if it occurs.
- You can return to your normal activities within 2 to 3 days.
- Avoid sexual intercourse, tub baths, and the use of tampons for 2 weeks to allow healing and prevent infection.

FIBROID EMBOLIZATION

- Eat a normal diet including fluids and fiber.
- Avoid straining during a bowel movement.
- Monitor your puncture site (groin) for any excessive swelling or redness. Slight bruising may occur, but a large area of bruising or tenderness should be reported to your physician.
- Call your physician if you have any abnormal or foul-smelling vaginal discharge.
- Do not use tampons, douche, or have vaginal intercourse for at least 4 weeks or as long as directed by your physician.

VULVECTOMY

- Avoid sexual activity for 4 to 6 weeks or as long as directed by your physician.
- Rest frequently.
- Avoid crossing your legs and sitting or standing for long periods.
- Avoid tight, constricting clothing, and wear cotton underwear.
- Keep your perineal area clean and dry. Wash perineum after each elimination, and pat dry.
- Report any swelling, redness, unusual tenderness, drainage, or foul odor of the incision site to your physician.
- Eat a well-balanced diet to promote healing.
- Elevate legs periodically to prevent pelvic congestion.

HYSTERECTOMY

- You will no longer have a period, although you may have some vaginal discharge after you go home.
- Eat foods high in protein, iron, and vitamin C to aid tissue healing; include foods with high fiber content, and drink six to eight glasses of water daily.
- Rest when tired; resume activities as comfort level permits. Avoid vigorous exercise and heavy lifting for 6 weeks. Avoid sitting for long periods. Resume driving when comfort allows or on advice from your physician.
- Avoid tub baths, intercourse, and douching until after your follow-up examination.
- When vaginal intercourse is resumed, use water-based lubricants to decrease discomfort.
- Report the following symptoms to your physician: vaginal bleeding, gastrointestinal changes, persistent postoperative symptoms (e.g., cramping, distention, change in bowel habits), and signs of wound infection (e.g., redness, swelling, heat, or pain at the incision site).
- Avoid activities that increase pelvic congestion (e.g., dancing, horseback riding, sitting for long periods) until allowed to resume by your physician.
- If your ovaries were removed you may experience symptoms of menopause, including hot flashes, night sweats, and vaginal dryness.
- Estrogen replacement therapy may be prescribed.

Modified from Canobbio MM: *Mosby's handbook of patient teaching,* ed 3, St Louis, 2006, Mosby; Lowdermilk DL: Structural disorders and neoplasms of the reproductive system. In Lowdermilk DL, Perry SE, editors: *Maternity and women's health care,* ed 9, St Louis, 2007, Mosby; Gingrich PM: Interventions for clients with gynecologic problems. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, Philadelphia, 2010, Saunders.

Surgical Interventions

VULVAR SURGERY

A variety of malignant and nonmalignant conditions may affect the vulva. Nonmalignant lesions are generally excised. The treatment of early malignant disease of the vulva is accomplished by a skinning technique, by local wide excision, or, for more multicentric or extensive lesions, by simple or radical vulvectomy. Vulvar surgery may also be indicated in the treatment of vestibulitis and vestibulodynia.

Excision of Condylomata Acuminata

Vulvar/perineal condylomata are caused by the human papillomavirus (HPV) (Figure 13-11) and may be transmitted sexually. Often these warty lesions will extend into the vaginal vault and may be aggravated by hormonal changes in pregnancy. Depending on the strain of the virus, the condition may be benign or associated with dysplasia and malignancy. Surgical treatment ranges from desiccation of the lesions with electrocoagulation to sharp excision or eradication through use of the laser. Surgical intervention is based on the type and extent of the lesions.

Simple Vulvectomy

Simple vulvectomy is removal of the labia majora and labia minora, possibly but not preferably the glans clitoris, and occasionally tissue from the perianal area. A simple vulvectomy is usually done to treat carcinoma in situ of the vulva when it is multicentric. Occasionally a vulvectomy is necessary for the treatment of either leukoplakia or intractable pruritus, especially when a skinning procedure is impractical or has failed.

Procedural Considerations. The basic vaginal instrument set is required, plus an electrosurgical unit (ESU), if desired. The nurse assists with placing the patient in the lithotomy position and performs a vaginal prep.

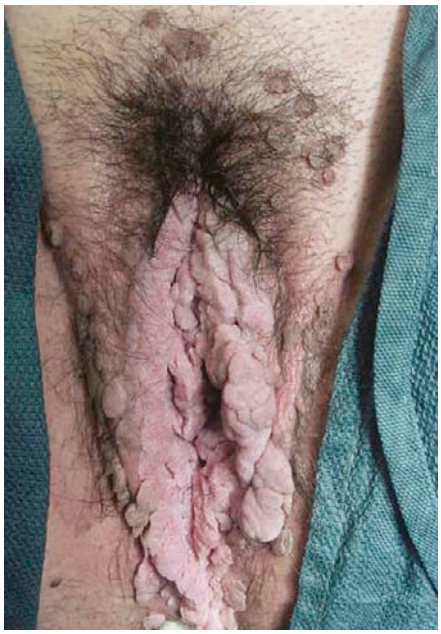


FIGURE 13-11 Condylomata acuminata.

Operative Procedure

1. The surgeon incises the affected skin, usually starting anteriorly above the clitoris. The incision is continued laterally to the labia majora, to the midline of the perineum, and around the anus, if it is involved. A knife, hemostats, gauze sponges on sponge-holding forceps, tissue forceps, and Allis forceps are needed. Bleeding vessels are clamped and electrocoagulated or ligated.
2. Periurethral and perivaginal incisions are made. Bleeding of this vascular area can be controlled by means of Kelly or Crile hemostats and the ESU. Ligation of blood vessels should be minimal. Allis-Adair forceps are used for holding diseased tissues.
3. Using curved dissecting scissors, tissue forceps, Allis forceps, and sponges on holding forceps, the surgeon undermines and mobilizes the skin and subcutaneous tissues.
4. The wound is closed, usually by simple bilateral Z-plasty. In some cases, the surgeon excises the skin around the anus to accomplish a sliding skin flap.
5. Closed-wound drainage catheters may be placed in the dependent areas, an indwelling urinary catheter is inserted, and vaginal gauze packing may be placed in the vagina. Dressings are applied.

Skinning Vulvectomy

Skinning vulvectomy is the simple removal of the external skin from the affected area, which has been previously identified with a stain such as toluidine blue. The purpose of this procedure is to preserve the underlying structures of the external genitalia. A skinning procedure may be done to treat leukoplakia, intractable pruritus, or other types of skin lesions, such as kraurosis, vitiligo, and chronic venereal granulomas.

Procedural Considerations. The instrumentation required and patient position are as described for simple vulvectomy.

Operative Procedure. The external skin is simply excised from the affected area (Figure 13-12, *A*).

Radical Vulvectomy and Groin Lymphadenectomy

Radical vulvectomy and groin lymphadenectomy are the en bloc dissection of the following structures: a large segment of skin from the abdomen and groin, the labia majora, the labia minora, the clitoris, the mons veneris, and terminal portions of the urethra, vagina, and other vulvar organs, as well as the superficial and deep inguinal nodes, portions of the round ligaments, portions of the saphenous veins, and the lesion itself. It also involves reconstruction of the vaginal walls and pelvic floor and closure of the abdominal wounds. Full-thickness pinch or split-thickness grafts may be placed if the denuded area of the vulva appears too large for normal granulation. A plastic surgeon may immediately complete skin grafts or rotation flaps to cover defects (see Chapter 21).

Radical vulvectomy and groin lymphadenectomy involve abdominoperineal dissection and groin dissection, which may be performed as a one- or two-stage operation. When performed as a one-stage operation, it is optimally done by a four-person team. The skin prep is extensive, including the abdomen and thighs; if a skin graft will be done, the donor site will also need to be prepped.

Procedural Considerations. The patient lies supine and may be placed in the Trendelenburg's and low lithotomy positions, as required for the various stages. The skin prep includes the abdomen, vulva, and thighs. An indwelling urinary catheter is often inserted to act as a urethral marker and to prevent postoperative urethral trauma. As in other radical surgery, the perioperative nurse should be prepared to measure blood loss and anticipate procedures to combat hypovolemia.

For radical vulvectomy, the basic vaginal instrument set is required, with the addition of assorted sizes of Richardson retractors, Richardson appendectomy retractors, Volkmann rake retractors, skin hooks, and closed-wound drainage systems.

For groin lymphadenectomy, the basic abdominal gynecologic instrument set is required, with the addition of Schnidt tonsil forceps, Kantrowitz thoracic clamps, ligating clips and appliers, and closed-wound drainage systems.

Operative Procedure

RADICAL VULVECTOMY

1. The skin incisions of the abdomen and thigh join with those for vulvectomy. The incisions in the vulva encircle the urethra.
2. In the vulvar dissection, the surgeon removes the terminal portions of the urethra and vagina, the mons veneris, the clitoris, the frenulum, the prepuce of the clitoris, Bartholin's and Skene's glands, and fascial coverings of the vulva with the specimen (Figure 13-12, *B*).

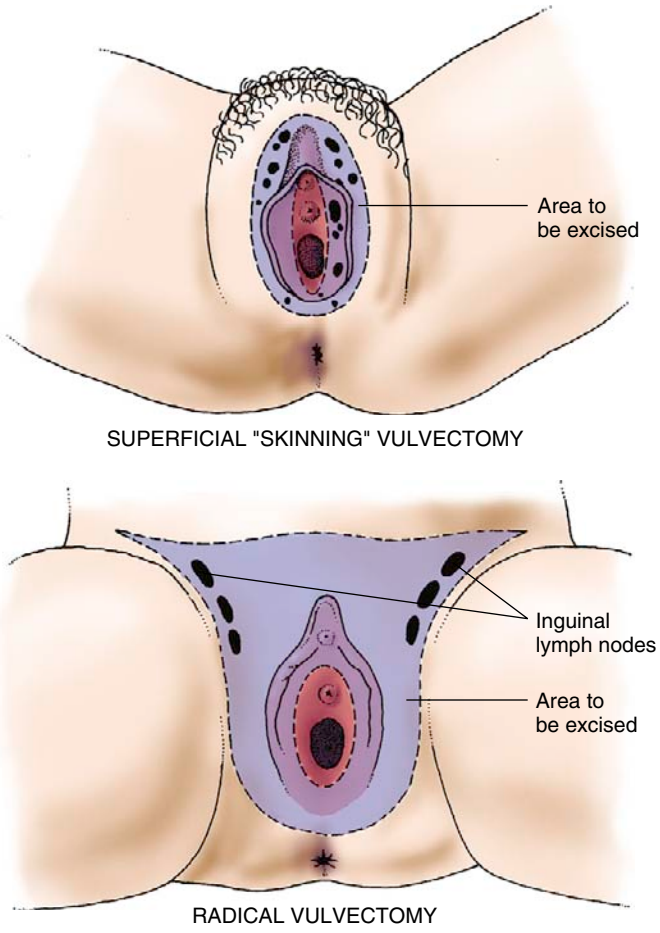


FIGURE 13-12 Outline of incisions used for (**A**) superficial skinning vulvectomy and (**B**) radical vulvectomy.

3. Reconstruction of the vaginal walls and the pelvic floor is completed.
4. An indwelling urinary catheter is inserted, closed-wound drainage catheters are placed in the denuded area, and pressure dressings are applied.

GROIN LYMPHADENECTOMY

1. The surgeon makes the first skin incision on the side opposite the primary lesion. The end of the incised skin is grasped with Allis forceps. The incision is extended to the aponeuroses of the external oblique muscle.
2. The fascia over the inguinal ligament and the fascia lata of the upper thigh are exposed, separated, and freed with retractors, knife, scissors, hemostats, and sponges.
3. Bleeding vessels, including the superficial iliac artery and vein, the epigastric artery and vein, and the superficial external pudendal artery and vein, are clamped and ligated. Smaller bleeding vessels are controlled with the ESU.
4. Using Metzenbaum scissors, tissue forceps without teeth, and long-bladed retractors the surgeon resects the fibers of the inguinal, hypogastric, and femoral nerves.
5. The lymphatic node beds may be identified with silk sutures or metal clips. Fine, long, sharp tissue dissection scissors are needed.
6. The large tissue surfaces are exposed for complete dissection by means of retractors and are protected by warm, moist laparotomy packs. High saphenous vein ligation is performed with scissors, forceps, and hemostats and then is doubly tied.
7. The surgeon cleans the femoral canal of its lymphatics; the round ligament is clamped, cut, and ligated.
8. The peritoneum is freed from the muscles; the fascia is dissected free; deep lymphatic nodes and areolar tissue are removed; and vessels and their attachments are clamped, cut, and ligated, using long curved scissors, long tissue forceps, hemostats, and ligatures.
9. The surgeon removes the lesion. In deep pelvic lymphadenectomy, the ureter may be exposed and the area drained. In some instances, ureteral stents are placed; if that is necessary, cystoscopy instrumentation is required.
10. The inguinal canal is reconstructed, the wound closed with nonabsorbable suture, and dressings applied.
11. An indwelling urethral catheter is inserted before the patient is transferred to the PACU.

Vestibulectomy and Vestibuloplasty

Vestibulodynia is defined as severe pain or burning on vestibular touch or attempted vaginal entry or tenderness localized within the vulvar vestibule. It is often associated with erythema of varying degrees (vestibulitis) (Katz, 2007). Surgical intervention is often successful in relieving the symptoms associated with the condition.

Procedural Considerations. The instrumentation required and patient position are as described for simple vulvectomy. Before the administration of the anesthetic agent, the patient identifies the painful areas of the vestibule in response to pressure from a cotton-tipped applicator. The surgeon may mark these areas with a sterile skin marker.

Operative Procedure. For vestibulectomy, the surgeon uses a #15 blade to excise the vulvar area identified by the patient,

carefully avoiding injury to the urethra. The mucosa of the hymen is removed, and the surgeon closes the mucosa and subcutaneous tissue with interrupted absorbable suture. For vestibuloplasty, the procedure is the same but closure is accomplished by advancing a vaginal flap and suturing it to the excision line.

GYNECOLOGIC SURGERY USING VAGINAL APPROACH

Plastic Reconstructive Repair of the Vagina (Anterior and Posterior Repair; Colporrhaphy)

A vaginal repair is done to correct a cystocele or a rectocele and to reestablish the support of the anterior and posterior vaginal walls, restoring the bladder and rectum to their normal positions.

A cystocele is a herniation of the bladder that causes the anterior vaginal wall to bulge downward (Figure 13-13). A defect in the anterior vaginal wall is usually caused by obstetric or surgical trauma, advanced age, or an inherent weakness. A large protrusion may cause a sensation of pressure in the vagina or present a mass at or through the introitus; it may also cause voiding difficulties.

A rectocele occurs when the anterior rectal wall (posterior vaginal wall) protrudes into the vagina. In general, the anterior rectal wall forms a bulging mass beneath the posterior vaginal mucosa (Figure 13-14). As the mass pushes downward into the lower vaginal canal, the rectum may be torn from the fascial and muscular attachments of the urogenital diaphragm and the pelvic wall. The levator ani muscles become stretched or torn. The patient may present with a mass protruding into the vagina, difficulty in evacuating the lower bowel, hemorrhoids, and a feeling of pressure.

An enterocele is a herniation of the pouch and almost always contains loops of the small intestine. An enterocele herniates into a weakened area between the anterior and posterior vaginal walls.

Procedural Considerations. The procedure is done with the patient in the lithotomy position. The basic vaginal instrument set is required. A D&C may be done in conjunction with the repair. Vaginal retractors are used for exposure. The labia may be sutured to the mons pubis if the exposure is inadequate.

Operative Procedure

CYSTOCELE REPAIR

1. The bladder may be drained, or an indwelling urinary catheter or suprapubic cystostomy catheter may be inserted (surgeon's preference). Areolar tissue between the bladder and vagina at the bladder reflection is exposed. The full thickness of the vaginal wall is separated up to the bladder neck by a knife, curved scissors, tissue forceps, Allis-Adair or Allis forceps, and gauze sponges. Bleeding vessels are clamped and tied with ligatures or electrocoagulated.
2. The surgeon mobilizes the urethra and bladder neck with a knife, gauze sponges, and curved scissors.
3. Sutures are placed adjacent to the urethra and bladder neck in such a manner that, after they have been tied, the bladder neck and the posterior urethrovesical angle are narrowed (Figure 13-15, *A*).
4. The surgeon sutures the connective tissue on the lateral aspects of the cervix into the cervix to shorten the cardinal ligaments.
5. Allis-Adair forceps are applied to the edges of the incision, and the left flap of the vaginal wall is drawn across the midline. Edges are trimmed according to the size of the cystocele. The surgeon repeats the process on the right flap of the vaginal incision.

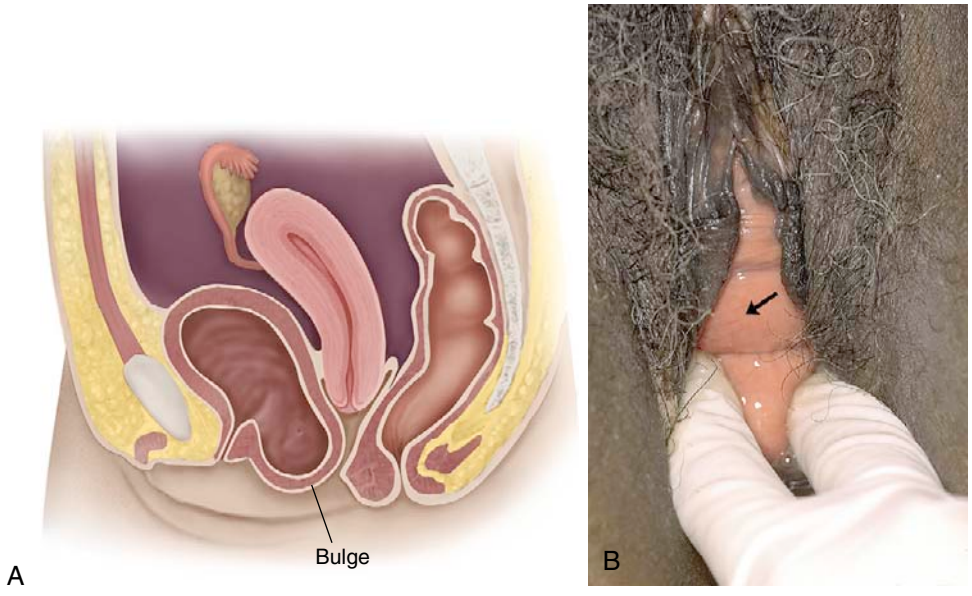


FIGURE 13-13 **A**, Cystocele resulting from unrepaired tears of muscles of pelvic floor and those under bladder, usually resulting from childbirth, surgical trauma, advanced age, or inherent weakness. **B**, Cystocele *(arrow)*.

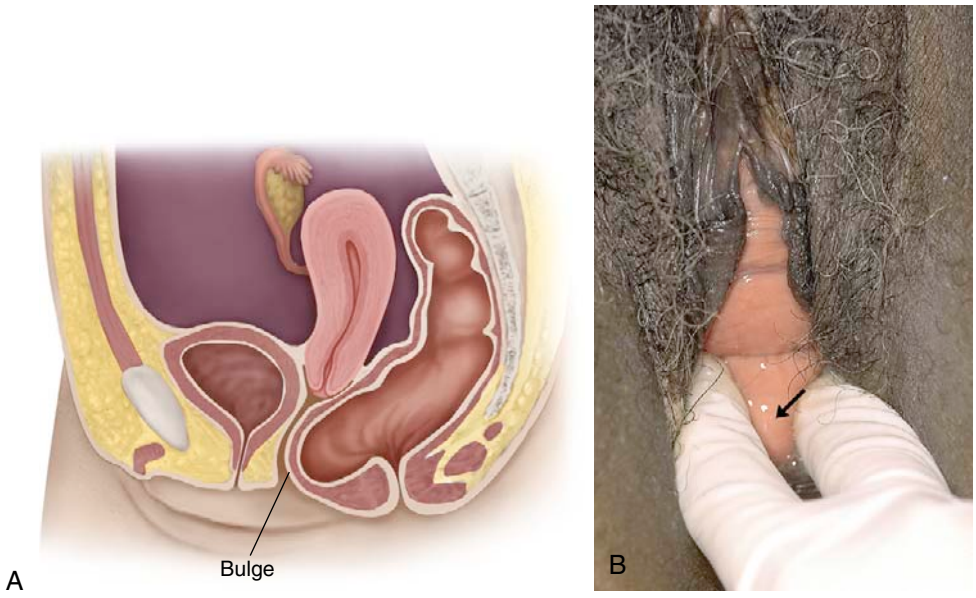


FIGURE 13-14 **A**, Rectocele resulting from unrepaired tears of muscles of pelvic floor and those under bladder, usually resulting from childbirth, surgical trauma, advanced age, or inherent weakness. **B**, Rectocele *(arrow)*.

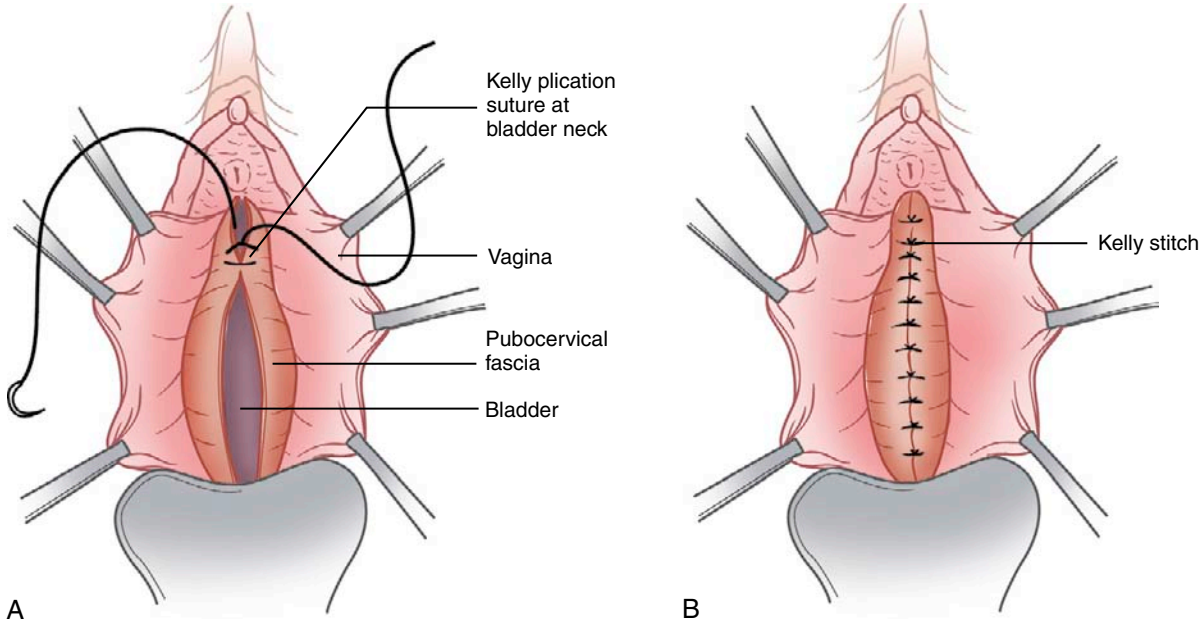


FIGURE 13-15 Cystocele repair. **A**, The placement of a Kelly stitch in the pubocervical fascia at the junction of the urethra with the bladder neck. **B**, The repair of the cystocele as the pubocervical fascia is sutured. Thus the cystocele is plicated.

6. The anterior vaginal wall is closed in a manner resulting in reconstruction of an anterior vaginal fornix (Figure 13-15, *B*). Cystoscopy instrumentation may be required to evaluate the integrity of the urethra and ureteral orifices.

RECTOCELE REPAIR

1. The surgeon places Allis forceps posteriorly at the mucocutaneous junction on each side, at the hymenal ring, and just above the anus (Figure 13-16, *A*).
2. Skin and mucosa are incised and dissected from the muscles beneath with a knife, tissue forceps, curved scissors, and gauze sponges.
3. Allis-Adair forceps are placed on the posterior vaginal wall, scar tissue (from obstetric trauma) is removed, and the surgeon continues the dissection to the posterior vaginal fornix and laterally, depending on the size of the rectocele (Figure 13-16, *A* and *B*).

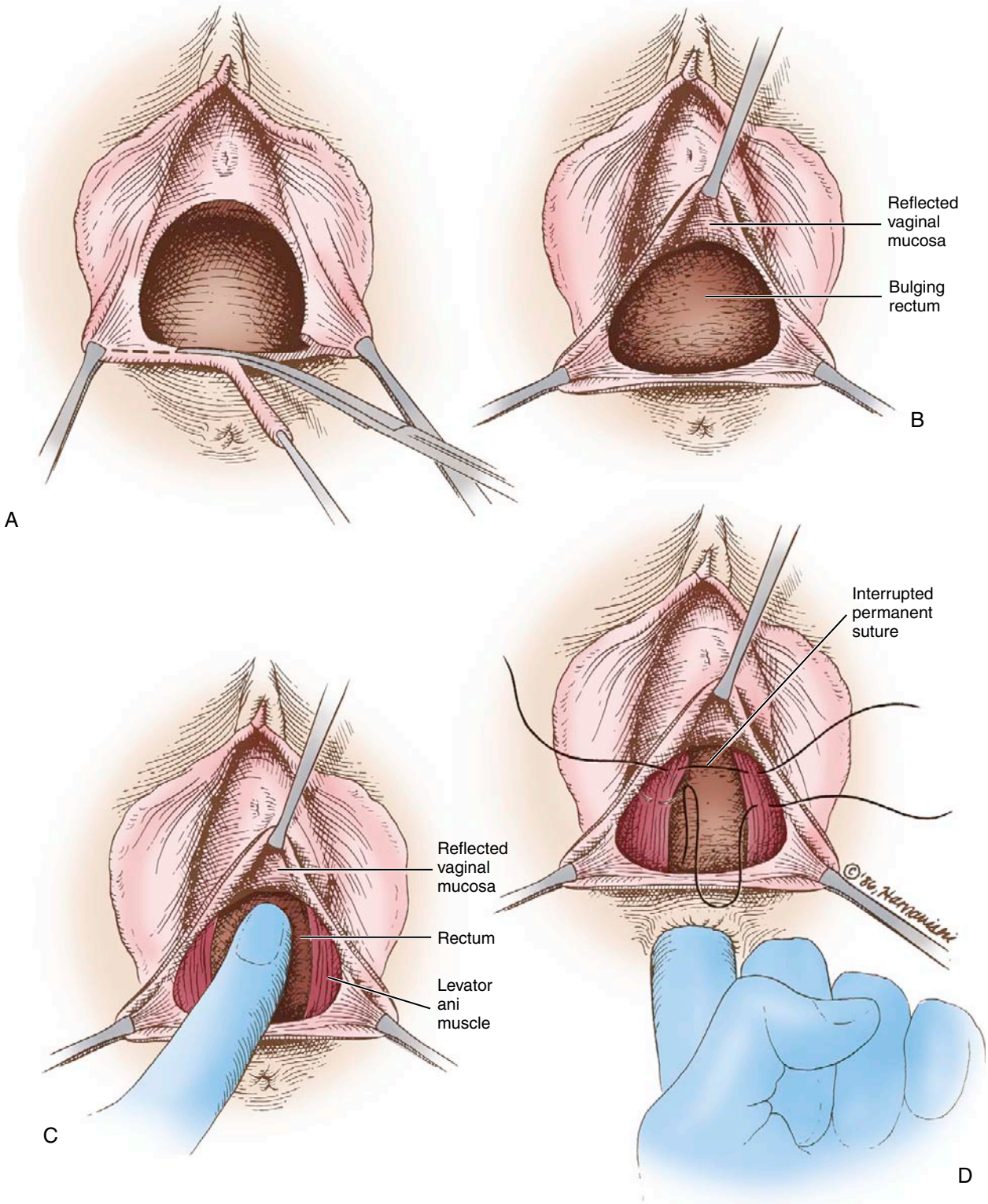


FIGURE 13-16 Rectocele repair. **A**, Placement of Allis clamps at margins of perineal incision; perineal incision is being made. **B**, Reflected vaginal mucosa with rectum bulging. **C**, Depression of rectum identifying margins of levator ani muscle. **D**, Placement of sutures in perirectal tissue and levator ani bundles.

4. The perineum is denuded by sharp dissection, and the trimming of the posterior vaginal wall is carried out with Allis forceps and curved scissors (Figure 13-16, *C*).
5. The rectal wall proximal to the puborectal muscle is strengthened by placement of sutures.
6. Bleeding is controlled, and the surgeon closes the vaginal wall from above, downward to the anterior edge of the puborectal muscle. The rectocele is repaired from the posterior fornix to the perineal body. Remains of the transverse perineal and bulbocavernosus muscles are used to augment the perineum. The anterior edge of the levator ani muscle may be approximated (Figure 13-16, *D*).
7. The mucosa and skin are trimmed, and the remaining closure is performed with interrupted sutures.
8. The vagina may be packed with 2-inch vaginal gauze packing to which antibiotic or antifungal cream may be added. An indwelling urinary catheter or suprapubic cystostomy catheter is inserted, according to the surgeon's preference.

The surgeon will require an additional pair of sterile gloves if a rectal digital exam is performed during the procedure.

ENTEROCELE REPAIR. The procedure is illustrated in Figure 13-17. The peritoneal sac must be carefully dissected from the underlying rectum, the overlying bladder, or both, so that the peritoneal tissues are completely freed from the surrounding structures. The sac is opened to establish true identification and is then closed as high as possible by permanent purse-string sutures. The portion of peritoneal tissue distal to the purse-string ties is then excised, and the area is reinforced locally by transverse suture closures using any available supportive tissues. This technique is used to prevent recurrence.

PERINEAL REPAIR. The procedure is illustrated in Figure 13-18.

VESICOVAGINAL FISTULA REPAIR. A vesicovaginal fistula (a communication between the urinary bladder and the vagina) is repaired by free dissection of the mucosal tissue of the anterior vaginal wall, closing of the fistula tract, and repair of the fascial attachments between the bladder and vagina, with establishment of urinary drainage. Fistulas vary in size from a small opening that permits only slight leakage of urine into the vagina to a large opening that permits all urine to pass into the vagina (Figure 13-19). They may result from radiation therapy, radical surgery for the management of pelvic cancer, chronic ulceration of the vaginal structures, penetrating wounds, or obstetric trauma.

Vesicovaginal Fistula Repair (Transperitoneal Approach)

Procedural Considerations. In the presence of a high vesicovaginal fistula, a suprapubic incision is used. The opening from the bladder into the vagina is closed, and the fascial attachments are repaired.

The patient is supine with a slight Trendelenburg's angle. Ureteral catheters may be inserted just before surgery (see Chapter 14). An abdominal gynecologic instrument set is required. The vagina is cleansed and may be packed with moist gauze saturated with an antibiotic or antimicrobial solution before the abdominal site is prepped.

Operative Procedure

1. The surgeon makes a midline abdominal incision, as described for laparotomy.
2. The fistulous tract is identified; the vaginal vault and the adjacent adherent bladder are separated using scissors, forceps, and sponges.
3. The vesicovaginal septum is dissected down to healthy tissue beyond the site of the fistula.
4. The fistulous tract is mobilized. The bladder site of the fistula is inverted into the interior of the bladder with two rows of inverting sutures. The muscularis and mucosa layers of the vagina are inverted into the vaginal vault by means of two rows of sutures.
5. Flaps of peritoneum are mobilized, both from the bladder and from the adjacent vaginal vault, and closed to form a new vesicovaginal reflection of peritoneum below the site of the old fistulous tract.
6. The surgeon closes the wound in layers, as for laparotomy. Abdominal dressings are applied.

URETHROVAGINAL FISTULA REPAIR (VAGINAL APPROACH). A urethrovaginal fistula (a communication between the urethra and the vagina) usually causes constant incontinence or difficulty in retaining urine. This condition occurs after damage to the anterior wall and bladder, radiation therapy, or parturition.

Procedural Considerations. The basic vaginal instrument set is required, with the addition of Kelly fistula scissors, dressing forceps, probes, skin hooks, Frazier suction tips, urethral catheters, and sterile water for irrigation. The patient is in the lithotomy position; the perioperative nurse seeks assistance during positioning to safely raise and lower the patient's legs simultaneously to prevent injury.

Operative Procedure

1. After traction sutures are placed around the fistulous tract, the surgeon grasps the tissues with Allis-Adair forceps and plain tissue forceps.
2. The surgeon excises scar tissue around the fistula, locates the cleavage between the bladder and vagina, and mobilizes the flaps using scissors, forceps, and gauze sponges.
3. The bladder mucosa is inverted toward the interior of the bladder with interrupted sutures. The sutures are passed through the muscularis of the bladder down to the mucosa.
4. A second layer of inverting sutures is placed in the bladder and tied, thereby completely inverting the bladder mucosa toward the interior.
5. The surgeon closes the vaginal wall with interrupted sutures in a direction opposite the closure of the bladder wall.
6. The bladder is distended with sterile saline to determine any leaks. An indwelling urinary catheter is inserted.

URETEROVAGINAL FISTULA. A ureterovaginal fistula (a communication between the distal ureter and the vagina) develops as a result of injury to the ureter. In some cases, reimplantation of the ureter in the bladder or ureterostomy may be done.

RECTOVAGINAL FISTULA REPAIR (VAGINAL APPROACH). Rectovaginal fistula repair by the vaginal approach includes repair of the perineum, fascia, and muscle-supporting structures between the rectum and vagina, thereby closing the fistula formed between the rectum and the vagina (Figure 13-20). In the presence of a large rectovaginal fistula, as in patients who have incurable cancer, a colostomy may be performed (see Chapter 10). The surgeon will require an additional pair of sterile gloves if a rectal digital exam is performed during the procedure.

Procedural Considerations. The basic vaginal instrument set is required for a rectovaginal fistula repair. The patient is placed in the lithotomy position.

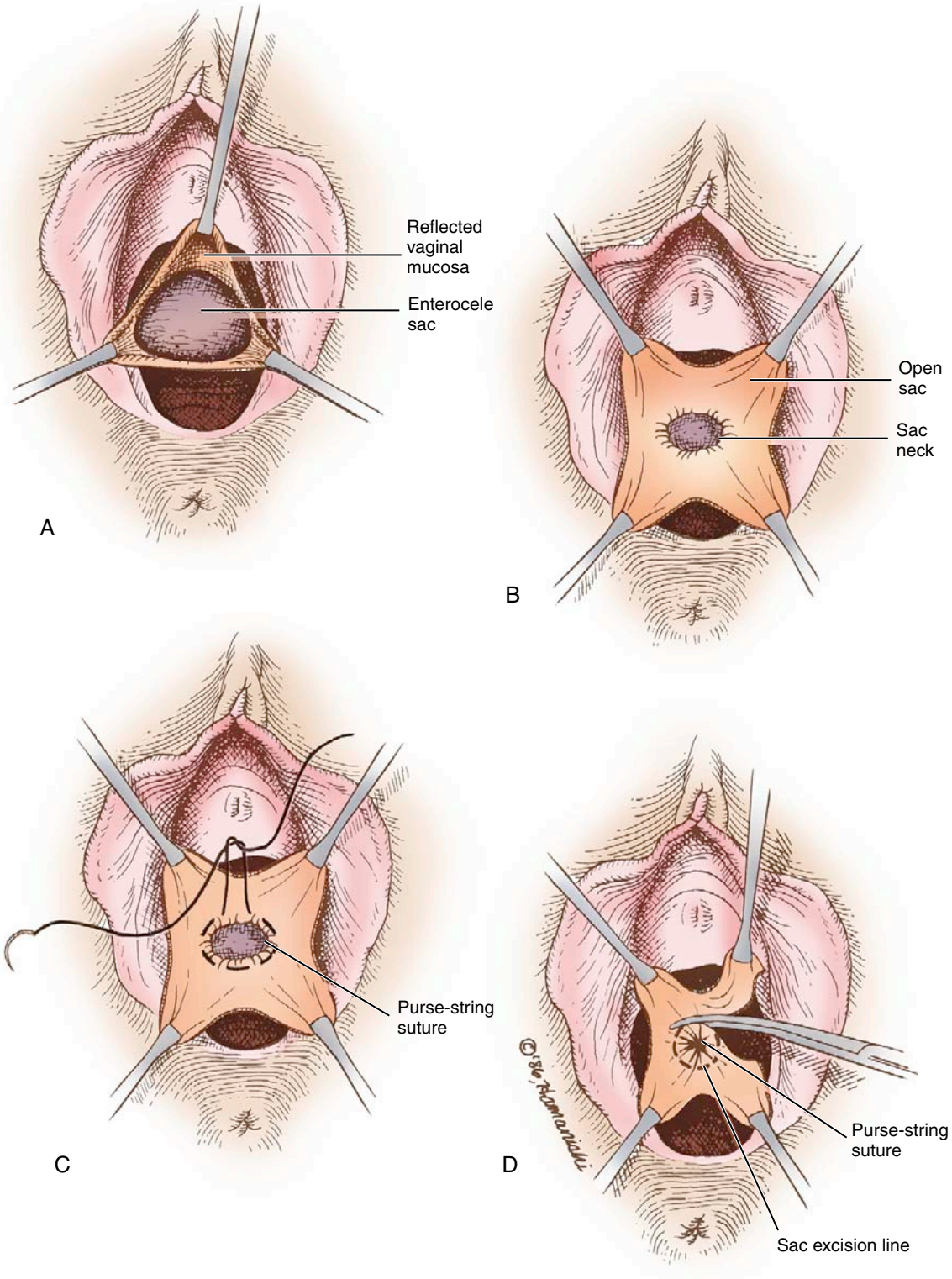


FIGURE 13-17 Enterocele repair. **A**, Appearance of enterocele sac with vaginal wall reflected. **B**, Appearance of open enterocele sac with sac neck identified. **C**, Placement of purse-string suture at neck of enterocele sac. **D**, Excision of enterocele sac.

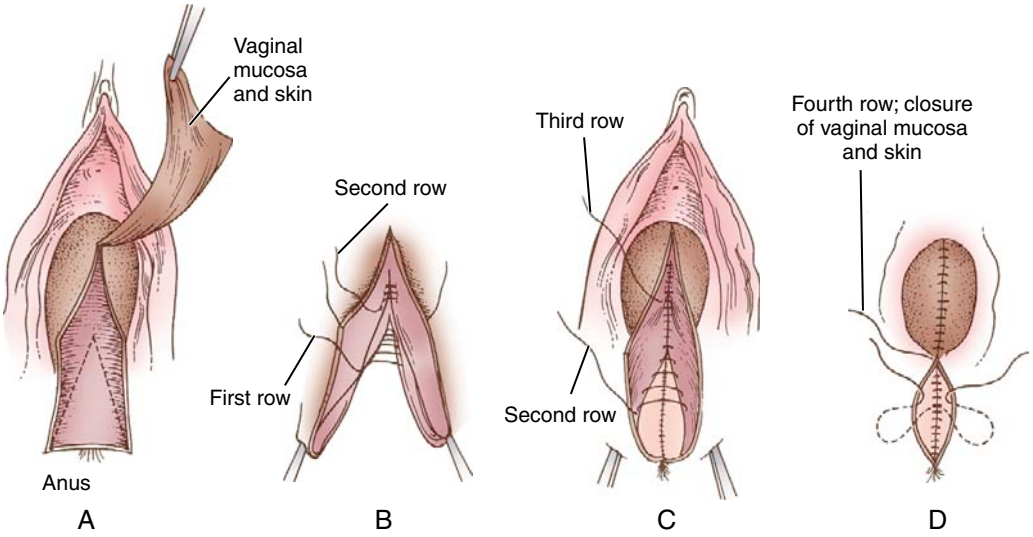


FIGURE 13-18 Repair of complete lacerations of the perineum. **A**, Lower margins of incision. **B**, Placement of first and second rows of sutures. **C**, Second and third rows of sutures. **D**, Fourth row of sutures.

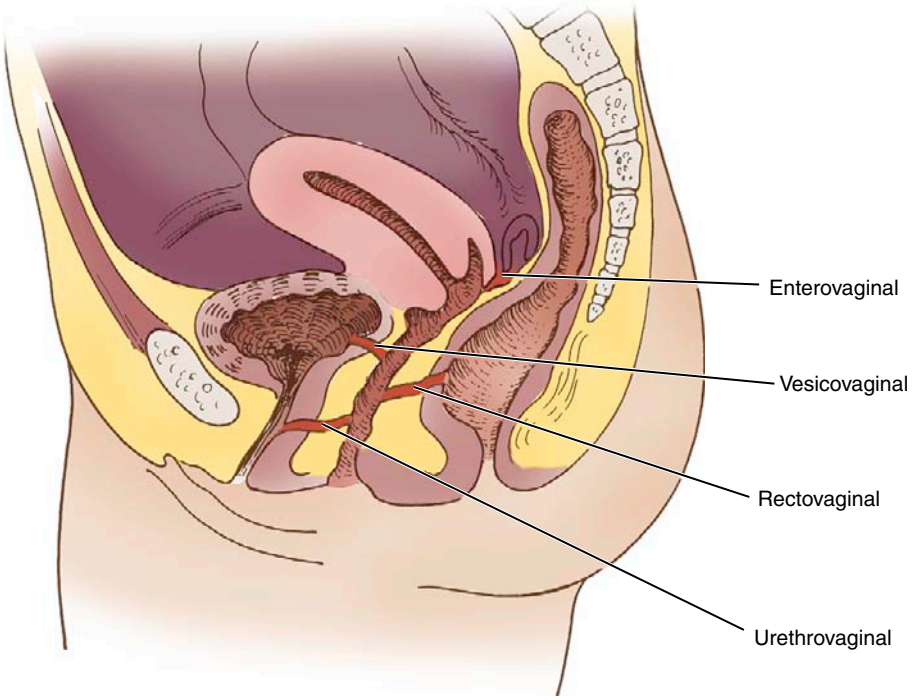


FIGURE 13-19 Genital fistulas may present as communications between the urethra, bladder, one of the ureters, or the bowel and some part of the genital tract. Two of the most common types are urethrovaginal and vesicovaginal, both of which empty into the vaginal canal.

Operative Procedure

1. The surgeon excises the scar tissue and tract between the rectum and vagina (Figure 13-21); edges of fresh tissue are approximated with absorbable sutures.
2. The rectum and vaginal walls are mobilized; the rectum is closed with inversion of the mucosa into the rectal canal.
3. The vagina is closed transversely or in a sagittal plane different from that of the rectal canal. The vaginal mucosal layer is inverted into the vaginal wall; an indwelling urinary catheter is inserted.

Operations for Urinary Stress Incontinence

Urinary incontinence describes the involuntary loss of urine. The three main types of incontinence include stress urinary incontinence (SUI), urge urinary incontinence (UUI), and mixed incontinence (MI), which describes the presence of both types of urinary incontinence simultaneously. Normal micturition depends on a finely coordinated group of voluntary and involuntary movements. As a result of volitional impulses, voiding may be inhibited or stopped by the intrinsic muscles

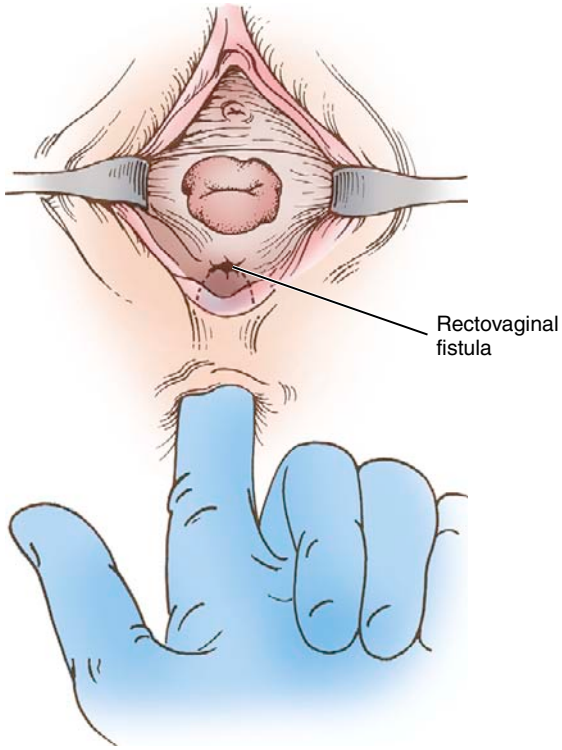


FIGURE 13-20 Rectovaginal fistula. Examiner's finger puts tension on rectovaginal septum.

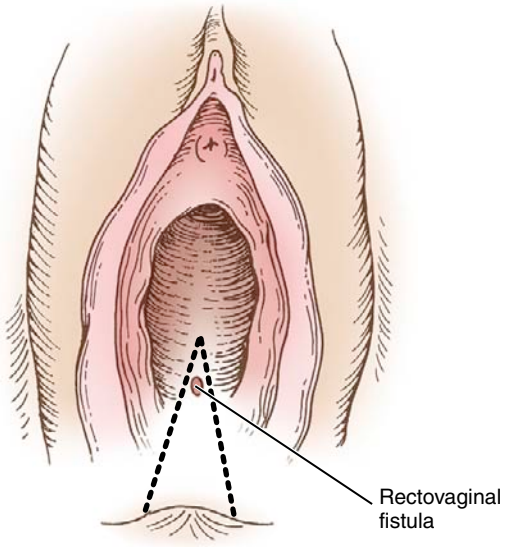


FIGURE 13-21 Repair of rectovaginal fistulas of all types is essentially the same as shown here. Portion of scar tissue to be excised is included within dotted lines; repair is as described for complete lacerations of perineum (see Figure 13-18).

of the bladder neck and proximal urethra and the puborectalis division of the levator ani muscle (see Chapter 14).

Previous pelvic procedures may have resulted in scarring and distortion, with displacement of the bladder neck. Conditions such as uterine prolapse, cystocele, urethrocele, cystourethrocele, or urogenital fistulas after radiation therapy may be associated with stress incontinence.

The type of operation selected depends on the severity of stress incontinence, the extent of the condition causing it, the patient's ability to use the anatomic mechanism for voluntary inhibition of urination, and any procedures that have previously been performed. States of stress incontinence are classified in relation to frequency and degree of incontinence, the presence of other diseases, and the function of the pubococcygeal muscle (levator ani). Surgery for urinary stress incontinence entails repair of the fascial supports and the pubococcygeal muscle surrounding the urethra and the bladder neck. This repair is performed through either a vaginal or an abdominal approach. In recent years, retropubic and transobturator suburethral tape has become important in the treatment of stress incontinence (Aschkenazi and Goldberg, 2009).

The desired outcome of any operation for urinary stress incontinence is to improve the performance of a dislodged or dysfunctional vesical neck, to restore normal urethral length, and to tighten and restore the anterior urethral vesical angle.

Operative Procedure

VAGINAL APPROACH

1. An indwelling urinary catheter or suprapubic cystostomy catheter is inserted, according to the surgeon's preference. The posterior vaginal wall is retracted, and the surgeon makes an incision through the anterior vaginal wall down to the urethra and bladder.
2. The vaginal wall is dissected from the bladder and urethra; the neck of the bladder is sutured together. The wound is closed as described for anterior vaginal wall repair.

VESICOURETHRAL SUSPENSION. The Marshall-Marchetti-Krantz procedure is fully described in Chapter 14. Basic steps of the procedure follow:

1. The surgeon enters the space of Retzius through a suprapubic abdominal incision, and frees the bladder and urethra from the underlying structures.
2. Mattress sutures are inserted through the perivaginal fascia on either side of the vesicourethral angle area and preferably at a right angle to the long axis of the urethra and bladder. These are then passed through the central portion of the undersurface of the symphysis pubis under direct vision. The application of the sutures to the perivaginal connective tissue is done with the surgeon's hand in the vagina to ensure that the suture material is not passed through the vaginal mucosa.
3. The wound is closed and may be drained if the vascularity of the area warrants. An abdominal dressing is applied.

Construction of a Vagina

Two basic approaches are used for repairing or overcoming a congenital or surgical defect of the vagina: obtaining a skin graft, which is applied to a mold and placed in the area of vaginal reconstruction; or making a simple opening in the area of vaginal reconstruction and placing a mold to permit spontaneous epithelialization of the area.

Procedural Considerations. For a skin graft, the plastic surgery instrument set (see Chapter 21) is required, with the addition of a dermatome, marking pen, and nonadherent gauze dressing. For vaginal construction, the basic vaginal instrument set is required, with the addition of iris scissors, skin hooks, a vaginal mold, Halsted mosquito hemostats, and a ruler.

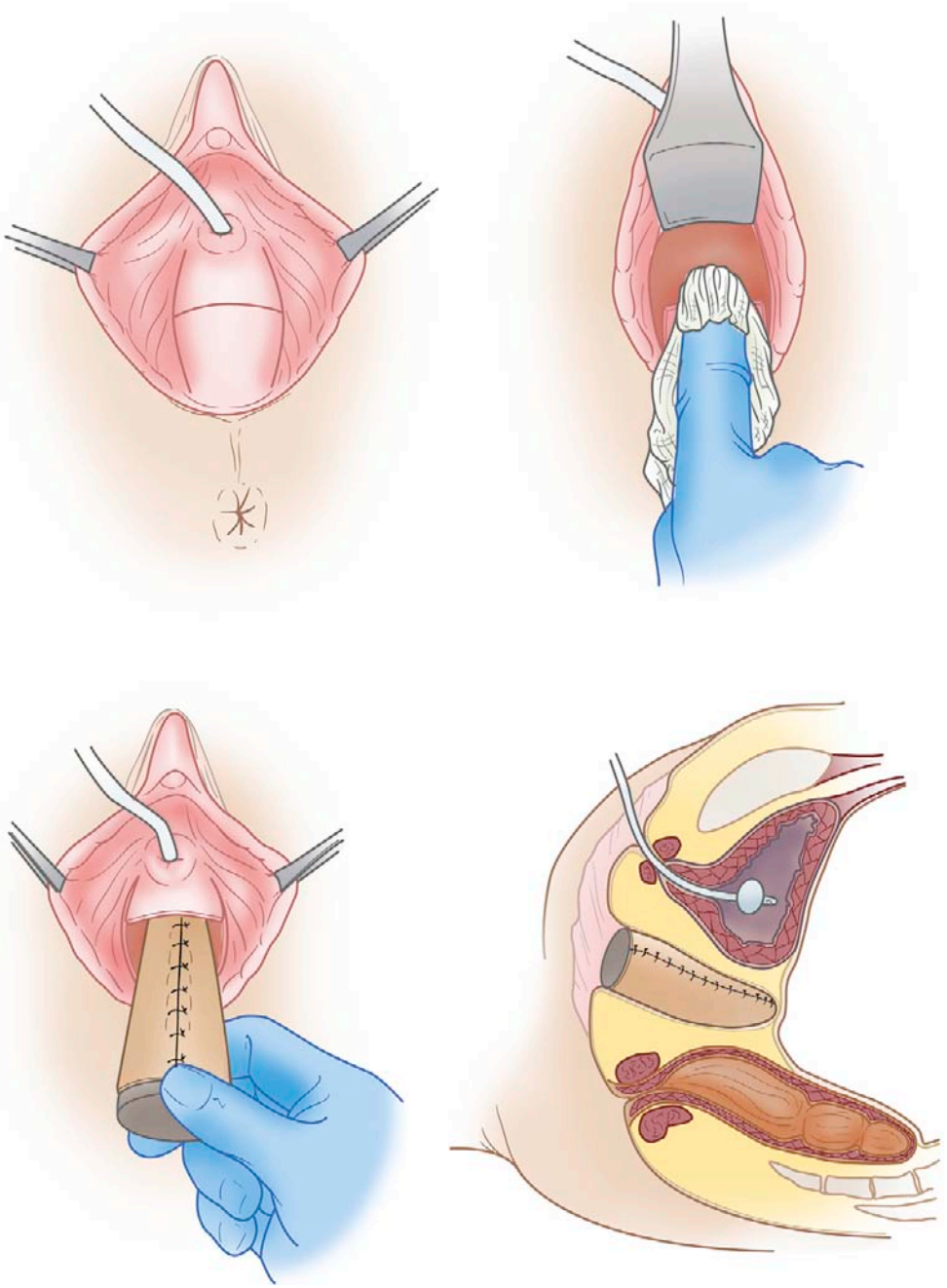


FIGURE 13-22 Vaginal reconstruction using split-thickness skin graft.

Operative Procedure

1. The skin graft is taken from the abdomen or anterior area of the thigh. The donor site is dressed in the routine manner with nonadherent gauze and a pressure dressing.
2. The skin graft is kept in a moist gauze sponge until it is ready to be used.
3. The surgeon uses sharp dissection to create a vaginal orifice, taking care to prevent damage to the rectum and bladder. A mold is used to apply the donor skin or simply to hold the dissected area open to permit spontaneous epithelialization (Figure 13-22).

Trachelorrhaphy

Trachelorrhaphy is removal of torn surfaces of the anterior and posterior cervical lips and reconstruction of the cervical canal. It is performed to treat deep lacerations of a cervix that is relatively free from infection.

Procedural Considerations. The basic vaginal instrument set is required, plus the ESU and a conization loop electrode, if desired. An indwelling urinary catheter may be inserted into the bladder, depending on the surgeon's preference. The patient is in the lithotomy position.

BOX 13-2

Supporting Patients through Miscarriage or Stillbirth

A diagnosis of pregnancy is often a joyous occasion; however, many women can experience perinatal loss, which is defined as ectopic pregnancy, miscarriage, or fetal death. Miscarriage occurs in approximately 15% of all pregnancies, and approximately 5 of every 1000 births result in stillbirth or fetal death (e.g., those occurring after 20 weeks of gestation). The primary cause of miscarriage and infant death is birth defects (127.6 per 100,000 births). Perinatal loss may occur with little or no advance warning for the mother, and unfamiliar and invasive procedures at this time can increase the woman's sense of vulnerability. The perioperative nurse can play a sensitive and supportive role when providing care for patients who present to the OR with miscarriage or cesarean section for stillbirth.

By definition, a miscarriage is a pregnancy loss that occurs before 20 weeks of gestation. In the United States, state laws often stipulate that, in addition, the weight of the fetus is less than 350 g and signs of life are absent. Abortion is the medical term used for both spontaneous and elective pregnancy termination occurring before 20 weeks of gestation. Terms used to identify the diagnosis should also be carefully chosen. Many women find the term abortion harsh and unkind when referring to spontaneous events. Some may feel insulted or misunderstood, believing that abortion refers only to an elective procedure. The term miscarriage is more neutral and should be used consistently for early loss. Products of conception are better referred to as tissue and the embryo or fetus as baby. For infant death, the nurse should use the words "dead and died" rather than "lost." The nurse should also avoid the use of clinical terminology as this may convey a lack of sincere feeling on the part of the caregiver.

When discussing perinatal loss with a woman, the nurse may want to initiate the conversation by referring to the pregnancy and listening for the patient's use of either the terms pregnancy or baby when referring to the loss. The nurse's neutrality encourages the woman to express her feelings without being encumbered by what she "should" do and what she "should" feel and eliminates the perceived expectations negatively influencing the woman. Additional tips for communicating with parents include the use of phrases and open-ended questions such as follows:

- "I am sad for you."
- "How are you coping with all of this?"
- "I am sorry for your loss."
- "I am here, and I want to listen."
- "What can I do for you?"

The following phrases should be avoided:

- "Be thankful you have another child."
- "I know how you feel."
- "You have to keep going."
- "You're young and you can have others."
- "Better for this to happen now, before you knew the baby."
- "There was something wrong with the baby anyway."

Compiled from Gilbert ES: *Manual of high risk pregnancy and delivery,* ed 4, St Louis, 2007, Mosby; Miles MS: Grieving the loss of a newborn. In Lowdermilk DL, Perry SE, editors: *Maternity and women's health care,* ed 9, St Louis, 2007, Mosby; March of Dimes: *Perinatal statistics,* available at www.marchofdimes.com/peristats/. Accessed June 28, 2009.

Operative Procedure

1. The labia may be retracted with Allis-Adair tissue forceps or sutures. The surgeon grasps the cervix with a tenaculum.
2. The tissue of the exocervix is denuded with a knife. Using sharp dissection, the surgeon undermines the flaps. Bleeding vessels are clamped and ligated. The mucosa is dissected from the cervix.
3. A small distal portion of the cervical canal is coned with a knife or a loop electrode to remove tissue. Bleeding vessels are clamped and ligated.
4. The denuded and coned areas are covered by transversely suturing the mucosal flaps of the exocervix, using interrupted sutures. Tissue forceps, hemostats, and gauze sponges are needed. The sutures are placed in such a manner that the fibromuscular tissue of the cervix is included, thereby eliminating dead space where a hematoma may form, and providing a complete reconstructed cervical canal.
5. A vaginal pack may be inserted. A perineal pad is applied.

Dilation of the Cervix and Curettage (D&C)

D&C is done either for diagnostic purposes or as a form of therapy for a variety of pelvic conditions, such as abnormal uterine bleeding, or primary dysmenorrhea. D&C may also be performed when carcinoma of the endometrium is suspected, in the study of infertility, before amputation of the cervix, or before surgery for a prolapsed uterus. A common indication for D&C is incomplete abortion (e.g., miscarriage), or therapeutic abortion. The perioperative nurse should be especially sensitive to the emotional needs of a patient experiencing a miscarriage (Box 13-2).

Procedural Considerations. In D&C, instruments are introduced through the vagina for the purpose of dilating the cervix. Dilation of the cervix can also take place by inserting laminaria tents into the cervical os before surgery; these tents are removed immediately before the procedure. The patient is in the lithotomy position for this procedure; the perioperative nurse ensures assistance is available for positioning.

Operative Procedure

1. The surgeon places a Jackson or Auvard weighted speculum in the vagina. A Sims or Deaver retractor is placed anteriorly to expose the cervix. The anterior lip of the cervix is grasped with a tenaculum (Figure 13-23).
2. The direction of the cervical canal and the depth of the uterine cavity are determined by means of a blunt probe or graduated uterine sound.
3. The surgeon dilates the cervix using graduated Hegar or Hank dilators and/or a Goodell uterine dilator.
4. Exploration for pedunculated polyps or myomas may be done with a polyp forcep.
5. Using a sharp curette the surgeon scrapes the interior of the cervical canal and uterine cavity to obtain either a fractional or a routine specimen. For specific identification of the site of specimens, the endocervix is scraped with the curette first, and the specimen is separated from the curetted matter

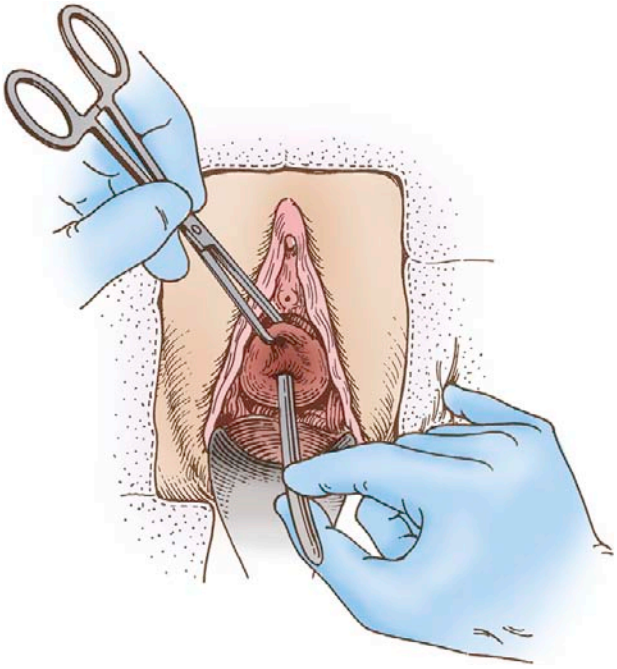


FIGURE 13-23 Dilation of cervix and curettage. Vaginal wall retracted; cervix held by tenaculum; cervix dilated with dilator. Uterine cavity curetted with sharp curettes.

of the uterine endometrium. In a routine curettage, all curetted matter is sent together for identification of tissue cells.

6. Fragments of endometrium or other dislodged tissues may be removed with warm, moist gauze sponges on sponge-holding forceps or with a teaspoon.
7. The surgeon may take multiple punch biopsies of the cervical circumference (at the 3, 6, 9, and 12 o'clock positions) with a Gaylor biopsy forceps to supplement the diagnostic studies.
8. Retractors are withdrawn; iodoform or plain gauze packing may be inserted into the uterus, using dressing forceps. The tenaculum is removed from the cervix. A vaginal pack may be inserted. A perineal pad is applied.

Suction Curettage

Suction curettage is vacuum aspiration of the uterine contents. Aspiration has proved to be a safe and effective method for early termination of pregnancy and for use in missed and incomplete spontaneous abortions. Advantages are smaller dilation of the cervix, less damage to the uterus, less blood loss, less chance of uterine perforation, and reduced danger of infection. Laminaria tents may be inserted approximately 4 to 24 hours before suction curettage to dilate the cervix; they are removed before the surgical prep begins. Suction curettage is the treatment of choice for benign gestational trophoblastic neoplasia, more commonly known as hydatidiform mole. Hydatidiform mole is a condition that arises from fertilization by the sperm in a defective egg that has no nucleus or fertilization of the egg by two sperm. This results in the synthesis of material that is termed a mole and consists of multiple fluid-filled vesicles resembling a cluster of grapes (Figure 13-24).

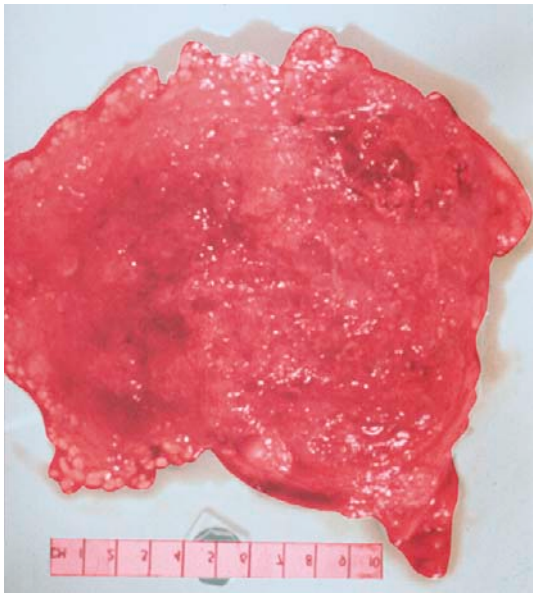


FIGURE 13-24 Hydatidiform mole. Note vesicles have appearance of grapes.

Procedural Considerations. The instrumentation required includes the D&C set, with the addition of one set of Pratt, Hawkin, or Hank uterine dilators, placenta forceps, urethral catheter, sterile cannulae, aspirator tubing, a vacuum aspirator unit, and oxytocic drugs. The patient will be in the lithotomy position.

Operative Procedure

1. The surgeon exposes the cervix with an Auvard weighted speculum and an anterior retractor, grasps it with a sharp tenaculum, and draws it toward the introitus.
2. The cervix is dilated, allowing 1 mm of cannula diameter for each week of pregnancy.
3. The appropriate-size cannula is inserted into the uterus until the sac is encountered. The suction is turned on with immediate disruption and aspiration of the contents. Continued gentle motion of the cannula removes the uterine contents (Figure 13-25). Use of uterine curettes may supplement suction in removing the entire uterine contents.
4. Retractors and tenaculum are removed.
5. A perineal pad is applied.

Removal of Pedunculated Cervical Myomas (Cervical Polyps)

Cervical polyps (small pedunculated lesions) stem from the endocervical canal and consist almost entirely of columnar epithelium with or without squamous metaplasia (Figure 13-26). They may vary in size and are soft, red, and friable. Bleeding may result from the slightest trauma. Pedunculated lesions may be removed by the snare method or by dissection from the cervical canal with a knife, cold-knife conization, or resectoscope. Usually the surgeon performs an endometrial and endocervical curettage, and a cytologic smear is taken.

Procedural Considerations. A D&C set, a tonsil snare with medium-size snare wire, glass slides, the ESU, and a blade electrode or resectoscope are required. The patient is in the lithotomy position.

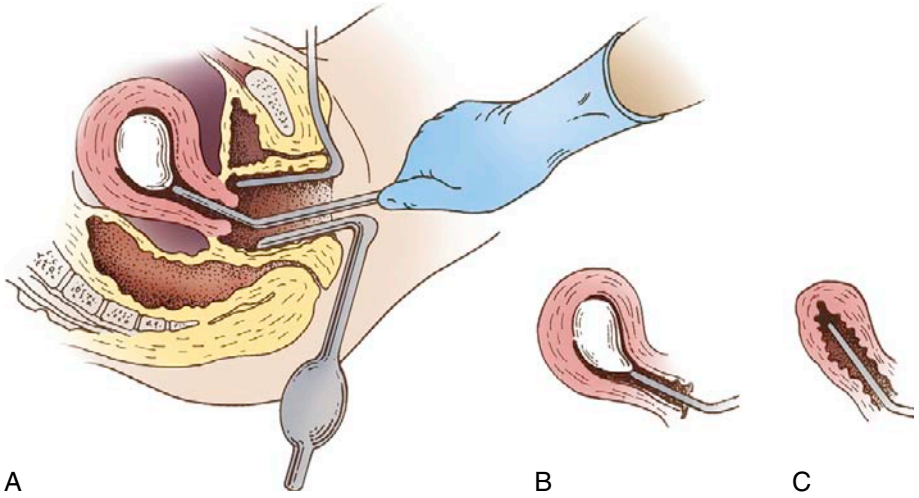


FIGURE 13-25 Suction curettage. **A**, Insertion of cannula. **B**, Gentle suction motion to aspirate contents. **C**, Uterine contents evacuated.

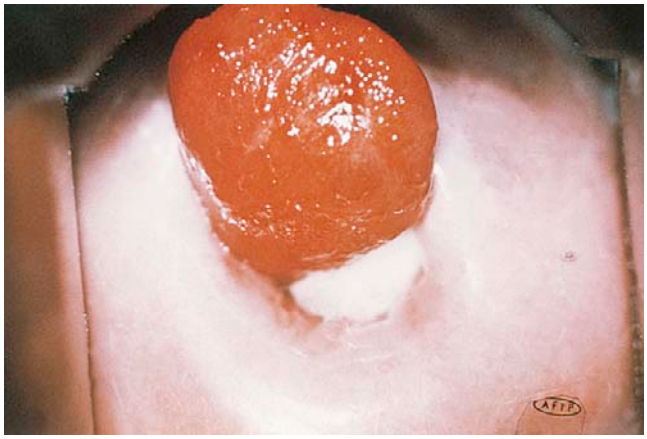


FIGURE 13-26 Cervical polyp. A large polyp protrudes from the external cervical os.

Operative Procedure

1. The surgeon grasps the anterior lip of the cervix with a Jacobs vulsellum or a tenaculum. The canal is sounded and dilated either to visualize or to palpate the base of the pedicle.
2. If the pedicle of the polyp is thin, the surgeon may place a tonsil snare over the body of the tumor, permitting the snare to crush the base of the tumor and to control bleeding. If the polyp is large, its base is dissected out with a knife. Bleeding may be controlled by the use of warm, moist gauze sponges with or without electrocoagulation. A resectoscope with the use of electrosurgery may be used to dissect the tumor.
3. Iodoform or plain gauze packing may be introduced into the cervical os. The tenaculum is removed from the cervix, and the retractors are withdrawn. A vaginal pack may be inserted for hemostasis. A perineal pad is applied.

Conization and Biopsy of the Cervix

Conization and biopsy of the cervix are generally performed for the diagnosis or treatment of cervical dysplasia. The procedure may be initiated with colposcopy and punch biopsy, followed by electrocoagulation, cryosurgery, cold-knife cone biopsy, loop electrosurgical excision cone (LEEC), or laser excisional cone.

Procedural Considerations. The instruments required include a D&C set along with an ESU or laser, conization electrical loop, and ball-tipped electrode, depending on the procedure. The patient is in the lithotomy position.

Operative Procedure

1. The surgeon retracts the posterior vaginal wall with a speculum and the anterior vaginal wall with lateral retractors. The outer portions of the cervix are grasped with a tenaculum, and the cervix is drawn toward the introitus. Cystic areas of the cervix may be treated with a needle electrode or laser. Endometrial biopsy may be done (Figure 13-27, *A*). Bleeding points are coagulated or lased.
2. The electrode is passed into the cervical canal, and the diseased tissue is treated. Ferric subsulfate (Monsel's solution) may be used for hemostasis.
3. The surgeon uses the electrical loop (Figure 13-27, *B* and *C*) or the laser to remove the diseased tissue and obtain a histologic specimen for pathologic diagnosis.
4. If a wide conization is performed, the cervix may be sutured and vaginal packing may be used. An indwelling urinary catheter may be inserted. A perineal pad is applied.

Cesium Applicator Insertion for Cervical and Endometrial Malignancy

Cesium has generally replaced radium insertions for treatment of malignancy of the cervix and endometrium.

Procedural Considerations. The patient is in the lithotomy position. The bladder is drained with an indwelling urinary catheter. The catheter balloon is inflated with a radiopaque medium for radiographic visualization after insertion of the cesium. An indwelling rectal marker is also placed by the surgeon for radiographic visualization. Various types of cesium applicators may be used according to the surgeon's preference and the area of malignancy (Figure 13-28). The cesium is

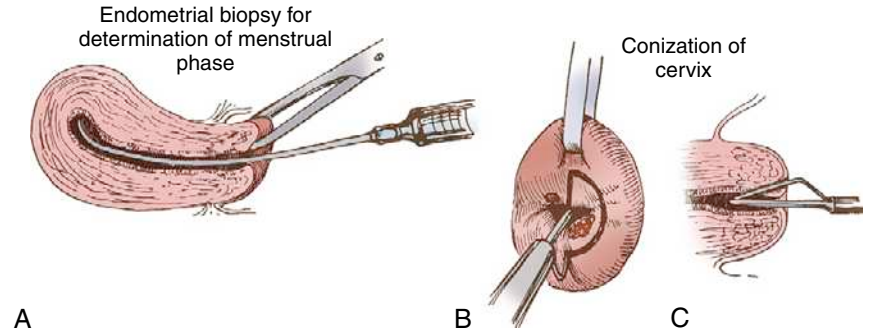


FIGURE 13-27 A, Endometrial biopsy technique. B and C, Conization loop used to treat cervical conditions or obtaining specimens for diagnostic tests.

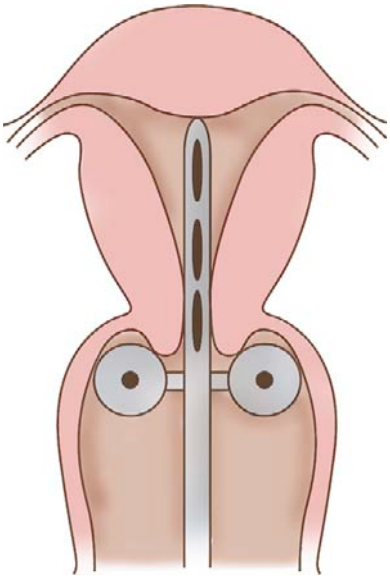


FIGURE 13-28 Intracavitary implant. Applicator in place in uterus.

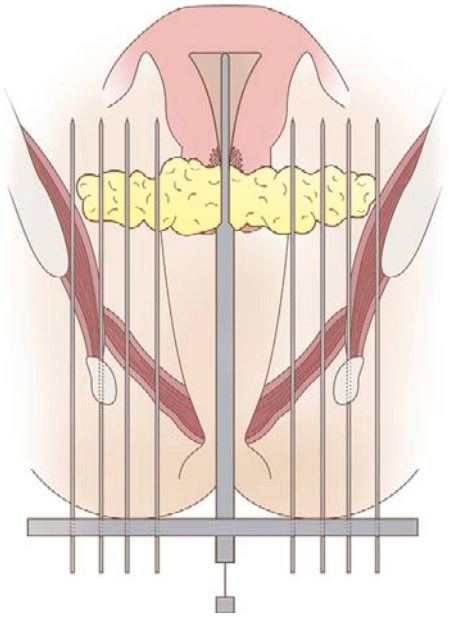


FIGURE 13-29 Interstitial intracavitary implant.

loaded into the applicators later in the radiation department or in the patient's room under controlled conditions, in which all personnel are monitored by use of a dosimeter.

Interstitial Therapy. Cesium needles are available in various lengths with small diameters for insertion into the tissue surrounding the cervix (Figure 13-29). They are inserted vaginally with a needle applicator and are used as a supplement to intravaginal or intrauterine sources. To facilitate removal, the needles have wires or threads attached to their distal ends.

Marsupialization of Bartholin Duct Cyst or Abscess

A cyst in a Bartholin gland usually follows acute infection and is treated by marsupialization. Such cysts result from retention of glandular secretions caused by blockage in the duct system (Figure 13-30). Marsupialization of a Bartholin duct cyst or abscess entails removal or incision of the cyst through the vaginal outlet and drainage of the area. In true marsupialization the cyst is surgically exteriorized by resecting the anterior wall and suturing the cut edges of the remaining cyst to the adjacent edges of the skin.

Procedural Considerations. The basic vaginal instrument set is required, with the addition of a 15-gauge needle, syringe, culture tubes (aerobic and anaerobic), iodoform or plain gauze packing, and a drain, if desired by the surgeon.

Operative Procedure

1. The labia minora may be sutured to the perineal skin on each side to expose the vaginal introitus.
2. A stellate incision is then made into the mucosa, which is distended over the cyst.
3. The surgeon dissects the cyst wall and, if indicated, removes the gland with blunt-pointed scissors. The tissue may be everted with sutures and left open. A drain or packing may be inserted, and a perineal pad is applied.

Vaginal Hysterectomy

Vaginal hysterectomy is removal of the uterus through an incision made in the vaginal wall and the pelvic cavity (History box). Contraindications to a vaginal approach are (1) a large uterine tumor, (2) a pelvic malignancy, and (3) the possibility of overlooked metastatic disease that might be present if malignancy is suspected.

HISTORY

A Historical Look at Vaginal Hysterectomy

Women undergoing vaginal hysterectomy in the 1900s did so without the benefit of technology available today. The woman was admitted to the hospital several days in advance of the planned surgical procedure. Vigorous bowel preparation and thrice-daily douches with caustic solutions were a routine preoperative preparation, as was the removal of all hair from the abdomen and genitalia.

On the day of surgery, the perioperative nurse was responsible for administering a douche before transporting the patient into the OR. After positioning the patient for the procedure, the nurse used green soap to cleanse the vulva and vaginal canal, followed by a rinse of saline and a douche of 10% creolin. The creolin was followed by an additional douche of corrosive sublimate in a 1:2000 concentration in sterile water. Using a glass catheter, the nurse ensured the patient's bladder was empty before the start of the procedure.

During the vaginal hysterectomy, the surgeon controlled the patient's bleeding with clamps or ligatures. After the uterus was removed, as many as six clamps, which were equipped with detachable handles, were left in place for hemostasis. The clamps were surrounded with a roll of iodoform gauze extending up into the vagina. A retention catheter was placed in the bladder at the end of the procedure. The catheter would be used in the postoperative period for bladder irrigations.

Before the patient returned to consciousness, the nurse tied the patient's legs together with a broad towel to prevent strain on the clamps and any ligatures that had been placed. The towel was not removed until the patient regained consciousness and was able to cooperate.

The patient was transported back to her room, with the clamps in place, experiencing considerable pain. Two days after the procedure, the perioperative nurse accompanied the surgeon to the patient's room to assist with the removal and retrieval of the clamps. The previously placed gauze packing was removed. The surgeon reattached the handles to the clamps and began removal, using a rocking motion, starting with the uppermost clamp. As the clamps were released, pieces of tissue would adhere, causing great discomfort for the patient. The nurse assisted the surgeon with repacking the patient's vagina with gauze and then returned the clamps, which were coated with rust, tissue, and secretions, to the instrument room.

The patient was allowed to sit up in bed 2 days after the clamps were removed; she was lifted to a chair on the fourth day, and began to ambulate on the fifth or sixth day.

Modified from Fowler R: *The operating room and the patient,* ed 3, St Louis, 1913, Mosby; Haubold HA: *Preparatory and after treatment in operative cases,* New York, 1910, D Appleton & Co.

FIGURE 13-30 Bartholin abscess.

Procedural Considerations. The instrumentation includes the basic vaginal instrument set with the addition of two 22-gauge needles and two 10-ml syringes. An abdominal gynecologic instrument set should be available in case laparotomy is indicated. To facilitate dissection and decrease bleeding, the vaginal walls may be infiltrated with normal saline or a local anesthetic (vasoconstrictors are optional). The patient is in the lithotomy position.

Operative Procedure

1. The labia may be retracted with sutures. The surgeon places a weighted vaginal retractor to retract the vaginal wall.
2. A Jacobs vulsellum, tenaculum, or suture ligature is placed through the cervical lips to permit traction on the cervix.
3. The surgeon incises the anterior vaginal wall with a knife through the full thickness of the wall (Figure 13-31, *A*). A circumferential saline with epinephrine injection of the submucosa may be done at this point in the procedure. The bladder is then freed from the anterior surface of the cervix by sharp and blunt dissection. The bladder is then elevated to expose the peritoneum of the anterior cul-de-sac, which is entered by sharp dissection (Figure 13-31, *B*).
4. The peritoneum of the posterior cul-de-sac is identified and incised.
5. The surgeon clamps, cuts, and ligates the uterosacral ligaments (Figure 13-31, *C* and *D*). The ends of the ligatures are left long and are tagged with a clamp.
6. The uterus is drawn downward, and the bladder is held aside with retractors and moist, small laparotomy packs.
7. The surgeon clamps, cuts, and ligates the cardinal ligaments on each side. The uterine arteries are doubly clamped, cut, and ligated.
8. The fundus is delivered with the aid of a uterine tenaculum.
9. When the ovaries are not removed, the surgeon clamps and cuts the round ligament, the utero-ovarian ligament, and the fallopian tube on each side (Figure 13-31, *E*) and removes the uterus. These pedicles are then ligated.
10. The surgeon reapproximates the peritoneum between the rectum and vagina with a continuous suture. The retroperitoneal obliteration of the cul-de-sac is accomplished by

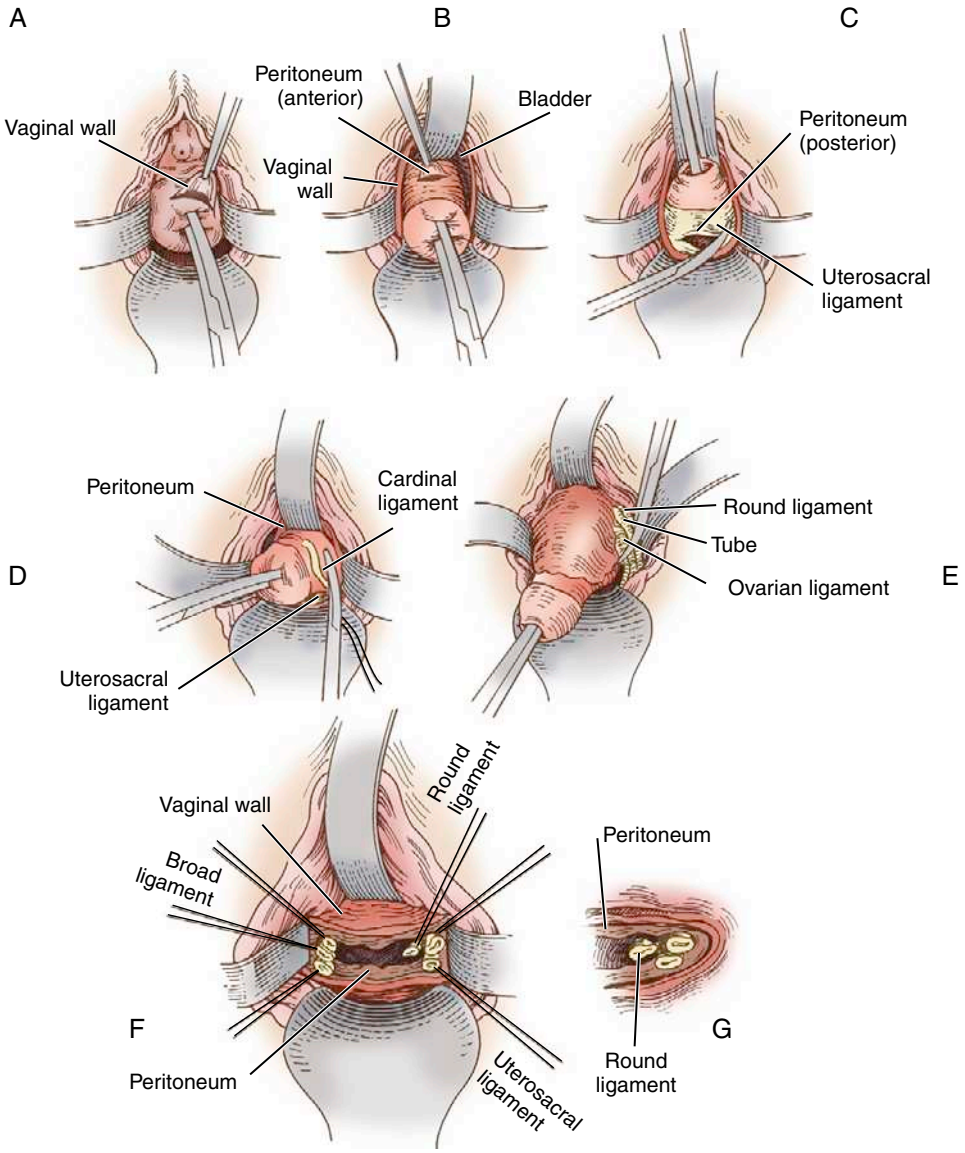


FIGURE 13-31 Vaginal hysterectomy. **A**, Incision of vaginal wall around cervix. Anterior vaginal wall slightly elevated. **B**, Deaver retractor on each side; one Deaver retractor under bladder. Peritoneum opened. **C**, Posterior cul-de-sac opened. Heaney clamp applied to left uterosacral ligament. **D**, Left uterosacral ligament cut and tied. Clamp applied to left cardinal ligament. **E**, Clamp applied to ovarian ligament, round ligament, and fallopian tube. **F**, Uterosacral ligament, broad ligament, and round ligament shown in their respective normal positions. **G**, Peritoneum closed and cardinal ligament, broad ligament, and uterosacral ligament reattached to angle of vagina. Left uterosacral and broad ligaments anchored.

passing sutures from the vaginal wall through the infundibulopelvic ligament and round ligament, through the cardinal ligament, and out the vaginal wall. The sutures are tied on the vaginal aspect of the new vault (Figure 13-31, *F* and *G*). The round, cardinal, and uterosacral ligaments may be individually approximated for additional support.

11. Any existing cystocele and rectocele and the perineum are repaired. In the presence of prolapse, reconstruction of the pelvic floor may be required.
12. An indwelling urethral or suprapubic catheter is usually inserted. The vagina may be packed, and a drain may be inserted. A perineal pad is applied.

GYNECOLOGIC SURGERY USING MINIMALLY INVASIVE TECHNIQUES

Hysteroscopy

Hysteroscopy is the endoscopic visualization of the uterine cavity and tubal orifices. The common indications for hysteroscopy include evaluation of abnormal uterine bleeding (with possible endometrial ablation), location and removal of "lost" intrauterine devices (IUDs), evaluation of infertility, diagnosis and surgical treatment of intrauterine adhesions, verification of submucous leiomyomas or endometrial polyps, resection of uterine septa or submucous leiomyomas, and tubal sterilization.

Laparoscopy may be done in association with hysteroscopy to assess the external contour of the uterus. Contraindications to either diagnostic or operative hysteroscopy include pelvic infection, cervical malignancy, and, in some instances, heavy bleeding.

A significant potential complication related to hysteroscopy is the intravasation of the fluid used to distend the uterine cavity. Intravasation can lead to hyponatremia. Signs and symptoms of hyponatremia may include bradycardia, hypertension followed by hypotension, nausea, vomiting, headache, visual disturbances, agitation, confusion, and lethargy. The perioperative nurse is responsible for accurately monitoring fluid intake and output during hysteroscopy. Monitoring may be manual (i.e., calculating the difference between inflow and outflow) or may be automatically calculated on commercially available hysteroscopy pumps, which decrease the chance of human error. Discrepancies of 500 ml or more must be communicated to the surgeon and the anesthesia provider (Cheong and Ledger, 2007).

Procedural Considerations. The instrumentation required includes a D&C set, with the addition of a hysteroscopy set, 50-ml syringes, polyethylene tubing, fiberoptic light source, the ESU or laser, hysteroscopic insufflator, pressure-infusion pump, and a video camera and monitor. The patient will be in the lithotomy position.

Operative Procedure

1. The surgeon places an Auvard weighted speculum and an anterior retractor to expose the cervix; the anterior lip of the cervix is grasped with a tenaculum and is drawn toward the introitus.
2. The direction of the cervical canal and the depth of the uterine cavity are determined by means of a graduated uterine sound.
3. The surgeon dilates the endocervical canal with graduated Hegar or Hank uterine dilators to 6, 7, or 8 mm, depending on the size of the hysteroscope.
4. A self-retaining vacuum cannula with obturator may be placed into contact with the cervix. The cannula is firmly applied to the cervix by vacuum created with a negative pressure.
5. The surgeon withdraws the obturator and introduces the hysteroscope to the level of the internal cervical os.
6. To achieve satisfactory visualization and sustained intrauterine pressure, the uterine cavity must be distended with one of the following media: 32% dextran 70 in dextrose (Hyskon), dextrose 5% in water (D_5W), sorbitol, mannitol, saline (normal saline solution [NSS]), sterile water, or by CO_2 gas insufflation. Because air or gas used for uterine insufflation may result in air or gas embolism, CO_2 pressures must be monitored closely. Injection of liquid media may be under continuous pressure from a 50-ml syringe or delivered by means of a pressure-controlled fluid-infusion (hysteroscopic) pump into the irrigating channel of the hysteroscope. When the syringe is used, care must be taken to prevent air bubbles, which distort the view or could lead to air embolism. Uterine distention with D_5W may be achieved by inserting a 500-ml plastic bag containing the medium into an intravenous pressure infusor or the infusion pump. The fluid runs freely within polyethylene tubing through the channel of the hysteroscope.
7. Exploration of the uterine cavity is begun. A video camera monitor may be used to enhance visibility for the OR team, and the procedure may be videotaped for record keeping and reevaluation.
8. The surgeon may introduce ancillary instruments, such as rigid and flexible biopsy forceps, scissors, grasping forceps, insulated coagulation electrodes, resectoscope with "rollerball" electrode, laser fiber tips, and tubal occlusive devices, for intrauterine manipulation or surgical intervention through the operating channel of the hysteroscope.
9. On completion of the procedure, the hysteroscope is withdrawn and the self-retaining vacuum cannula is removed.

If Hyskon is used for uterine distention, the instruments must be rinsed immediately and cleaned in hot water, because dextran has a tendency to harden and is difficult to remove if permitted to dry.

Endometrial Ablation

Endometrial ablation is performed to treat abnormal uterine bleeding. The overall goal of endometrial ablation is to create amenorrhea or to reduce menstrual bleeding to a normal, tolerable flow for the patient. It may be an alternative to hysterectomy in some patients with chronic menorrhagia. The procedure is performed through the hysteroscope with the use of either the laser, ESU, or microwave energy.

The Nd:YAG laser destroys the endometrium and results in scarring of the uterine lining. It is often the laser of choice for this procedure because of its ability to penetrate deep into the tissue, resulting in greater tissue destruction. The Nd:YAG, argon, and potassium titanyl phosphate (KTP) 532 lasers may be used hysteroscopically.

The two endometrial ablation techniques used with the Nd:YAG laser are *blanching* and *dragging*. In the blanching technique, the tip of the laser fiber is held away from tissue. In the dragging technique, the laser fiber tip is in direct contact with the endometrium. The endometrial lining is treated from the fundus to approximately 4 cm above the external cervical os. Air or gas is not used in cooling the laser fiber because of the risk of air or gas embolism. Because of the systemic effects of fluid absorption through open capillaries, Hyskon is not generally used as an irrigant for endometrial laser ablation.

A specially designed diode laser may also be used for endometrial ablation. The diode laser utilizes a disposable handset that emits laser beams through three separate parallel panels. The handset conforms to the shape of the uterus and delivers energy in all directions to destroy the tissue in the fundus and cornua, away from the cervical opening. A hysteroscopy may be performed at the conclusion of the therapy to evaluate the results.

Electrical energy delivered through an adapted urologic resectoscope, using continuous-flow irrigation, either coagulates or resects the endometrium. Endometrial ablation with the use of a resectoscope, with a rollerball electrode attached, is not an option for a patient who desires to remain fertile. When using the resectoscope, often Hyskon is chosen as the distending medium because it is electrolyte-free and compatible with electrosurgery.

Reported complications associated with endometrial ablation using the Nd:YAG laser and electrosurgery include hemorrhage, fluid overload, uterine perforation, recurrent bleeding, injury to bowel and bladder, cervical lacerations, and rupture of a fallopian tube.

A general anesthetic is usually administered, although endometrial ablation can be performed using a local anesthetic. If the Nd:YAG laser is to be used, the perioperative nurse ensures that all laser safety precautions for the patient and the OR team are followed (see Chapter 7). The length of the procedure is typically less than that for a hysterectomy. Therefore the patient requires less anesthetic and may be discharged the same day, provided that her condition remains stable.

Balloon Endometrial Ablation. Endometrial ablation may also be accomplished using balloon therapy. The action of balloon therapy is thermal. The uterine balloon catheter conforms to the internal uterine contour and contains a heating element. The surgeon performs suction curettage before the therapy to provide maximal balloon contact with the uterine lining. The cervix is dilated to 5 mm, and the balloon catheter is inserted in the uterus until the tip touches the fundus. The surgeon inflates the balloon with sterile D_5W to a pressure of 160 to 180 mm Hg. The solution is heated to a temperature of 86.6° C (188° F) and maintained for 8 to 10 minutes. The procedure may be performed as an ambulatory surgical procedure and does not require hysteroscopy (Practice Committee, 2008).

Laparoscopy

Laparoscopy is the endoscopic visualization of the peritoneal cavity through the anterior abdominal wall after the establishment of a pneumoperitoneum. It is used to investigate and diagnose the causes of abdominal and pelvic pain and infertility and to evaluate pelvic masses. Ancillary procedures such as adhesiolysis, fulguration of endometriotic implants (Figure 13-32), aspiration of cysts, biopsy of tissue, aspiration of peritoneal fluid for cytologic study, ovarian biopsy, ovarian cystectomy, oophorectomy, removal of ectopic pregnancy, tuboplasty, and tubal sterilization may be performed. Laparoscopy also can be used for oocyte retrieval for IVF procedures. Lasers and electrosurgery may be used with the laparoscope.

Procedural Considerations. Although laparoscopy can be performed with a local anesthetic, more often the anesthesia provider administers a general anesthetic. The nurse assists with placing the patient in the lithotomy position. The abdomen, perineum, and vagina are prepped. The abdomen and perineum are then draped for a combined procedure. Specially designed drapes with openings for the umbilical and perineal areas may be used. The bladder should be emptied with an in-and-out catheterization or through insertion of a Foley catheter.

The surgeon may perform a D&C in conjunction with laparoscopic procedures when indicated. After the cervix is exposed and the position and depth of the uterus are confirmed, the surgeon will introduce a uterine manipulator or dilator into the cervix to manipulate the uterus during the laparoscopy for better visibility. If chromotubation (e.g., injection of a dilute solution of methylene blue through the cervix to determine

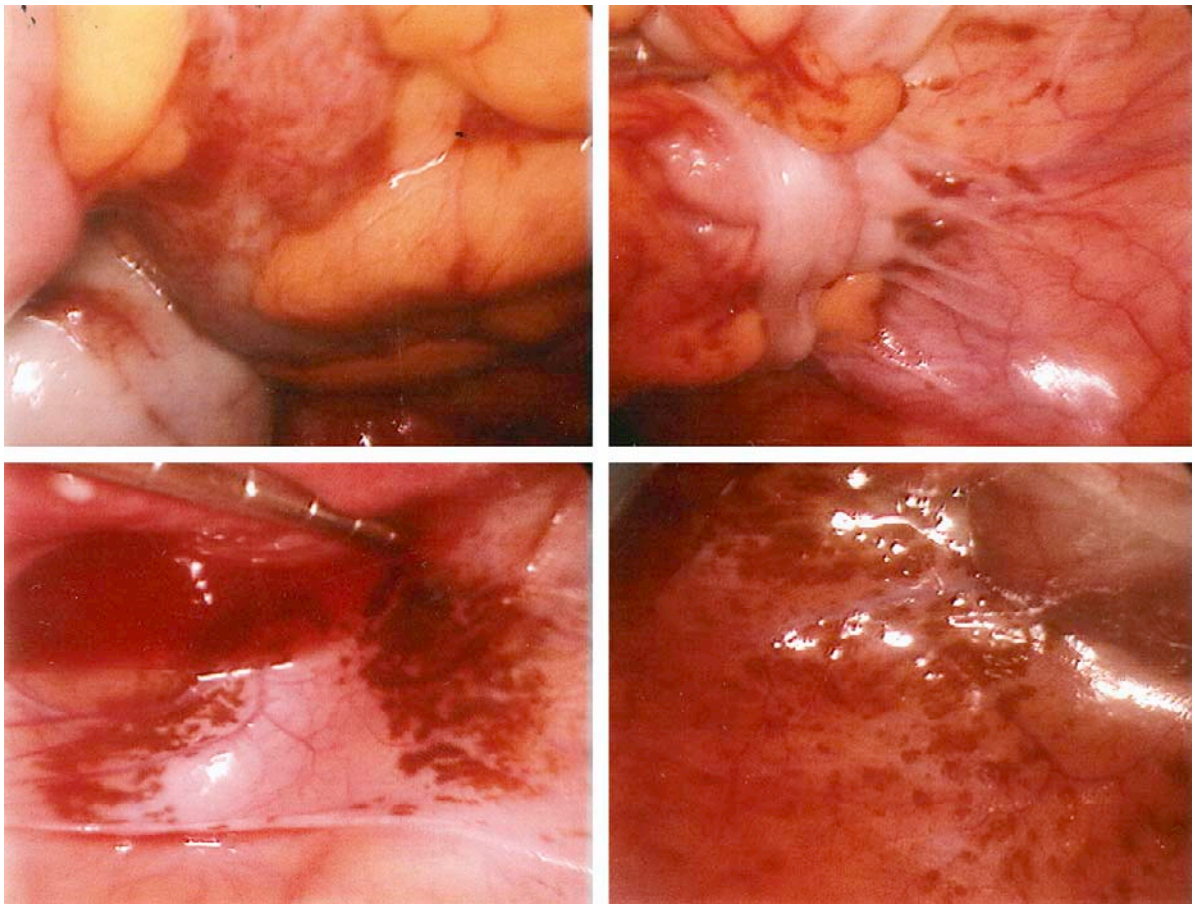


FIGURE 13-32 Laparoscopic view of endometriosis in the cul-de-sac.

fallopian tube patency) will be performed during the laparoscopy, the surgeon places an intrauterine cannula in the cervical canal at the time of D&C.

The usual instrumentation for the vaginal portion of the procedure includes a D&C set, with the addition of a uterine manipulator, intrauterine cannula, diluted methylene blue or indigo carmine solution, and a syringe.

An abdominal gynecologic instrument set should be readily available in the event that a laparotomy is indicated.

Operative Procedure

1. The surgeon makes a small incision (0.7 to 1.2 cm) at the inferior margin of the umbilicus.
2. Elevating the skin with a towel clamp on either side of the umbilicus or grasping below the umbilicus with a gauze sponge for traction, the surgeon inserts a Veress needle through the layers of the abdominal wall into the peritoneal cavity.
3. Once the Veress needle is inserted into the peritoneal cavity, a 10-ml syringe partially filled with sterile saline is attached to the needle for aspiration. If the needle has entered a blood vessel, blood is aspirated. If a loop of intestine or the stomach has been entered, bowel contents or malodorous gas is aspirated. If the needle is free in the peritoneal cavity, nothing is aspirated.
4. The surgeon attaches a plastic or Silastic tubing to the Veress needle and the gas insufflator. Approximately 2 to 3 liters of CO_2 or nitrous oxide gas is then delivered into the peritoneal cavity to achieve pneumoperitoneum. CO_2 is commonly used as the insufflation medium because it is nontoxic, highly soluble in blood, and rapidly absorbed from the peritoneal cavity. The intraabdominal pressure must be closely monitored to prevent overdistention of the abdomen and to ensure free passage of gas into the peritoneal cavity.
5. After insufflation is completed, the Veress needle is withdrawn.
6. The surgeon inserts the trocar, covered by the trocar sleeve, through the abdominal wall and into the peritoneal cavity. The angle taken by the trocar is approximately 45 degrees toward the concavity of the pelvis. The plastic or Silastic tubing is attached to the trocar sleeve, and insufflation is resumed. Some surgeons prefer a direct trocar insertion technique or the open laparoscopy technique of Hasson to establish the pneumoperitoneum through the valve of the trocar sleeve rather than through a Veress needle (see Chapter 11).
7. With the trocar sleeve in place, the surgeon withdraws the trocar and introduces the laparoscope.
8. Visualization of the pelvis and lower abdomen and the visceral contents is begun. If the lens of the laparoscope becomes foggy, application of a commercially available defogger solution may control the problem. Alternatively, the surgeon may touch the lens to a loop of intestine to clear it. Before use, warming the tip of the scope in warm saline or towels may prevent fogging of the distal lens.
9. The anesthesia provider places the patient in the Trendelenburg's position.
10. The video camera is attached to the scope to aid in the OR team's visualization, and the procedure may be recorded for future reference. If an ancillary instrument such as biopsy forceps or bipolar forceps is needed, the surgeon inserts a second trocar with sleeve under direct laparoscopic visualization through a suprapubic incision.
11. To test for tubal patency, the surgeon injects diluted methylene blue or indigo carmine solution through the intrauterine cannula into the cervical canal (i.e., chromotubation). If the fallopian tubes are patent, dye can be seen at the fimbriated ends.
12. On completion of the intraabdominal procedure, the surgeon withdraws the laparoscope and the insufflated gas is allowed to escape from the trocar sleeve or by suction. The trocar sleeve is removed and trocar sites closed.
13. Application of staples or subcuticular closure of the primary skin incision is followed by placement of a small bandage or wound closure strip.
14. The surgeon removes the uterine manipulator and checks the cervix for bleeding. If bleeding is present, pressure may be applied with a sponge stick or a suture ligature may be passed through the bleeding portion.
15. The perioperative nurse applies a perineal pad.

Salpingostomy for Ectopic Tubal Pregnancy

Ectopic pregnancy is defined as any gestation developing outside of the endometrial cavity. Risk factors for developing an ectopic pregnancy include use of intrauterine devices (IUDs) for contraception, pelvic inflammatory disease, tubal ligation, tubal dysfunction (as with endometriosis), in vitro fertilization, and previous ectopic pregnancy. Although the fallopian tube is the most common site for ectopic pregnancies (occurring in up to 95% of all cases), they can develop in the cervix or broad ligament; in a previous cesarean section scar (myotomy), they can develop in the ovary and the peritoneal cavity (Genovese, 2007). Women who experience ectopic pregnancy generally present with abdominal pain, abnormal vaginal bleeding, and a palpable adnexal mass. Diagnosis is confirmed through measurement of human chorionic gonadotropin (hCG) levels and use of ultrasound to determine the absence of a gestational sac. A serious complication of ectopic pregnancy is tubal rupture and hemorrhage (Figure 13-33). The ultrasound is also useful in identifying free fluid in the peritoneal cavity. Ruptured ectopic pregnancy is considered a surgical emergency and is associated with severe abdominal pain, tachycardia, and hypotension. The woman with a ruptured ectopic pregnancy may also experience shoulder pain because of irritation of the phrenic nerve from the hemoperitoneum. Ectopic pregnancy may be treated medically with methotrexate or surgically through salpingostomy, segmental resection, fimbrial expression, and salpingectomy

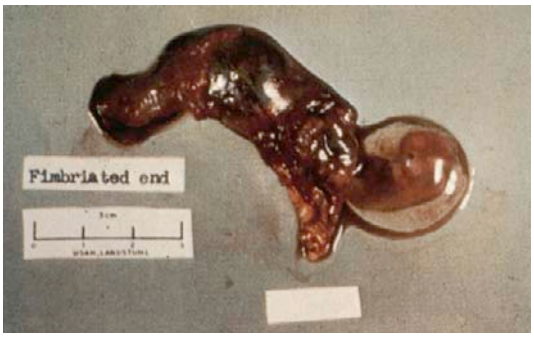


FIGURE 13-33 Ruptured ectopic pregnancy with fetus in sac.

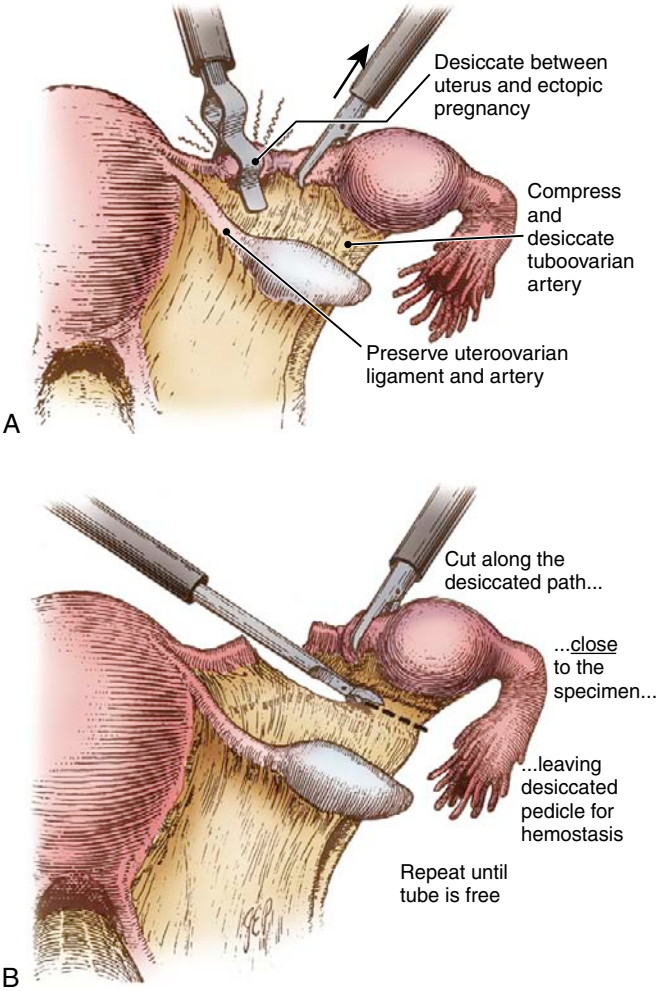


FIGURE 13-34 **A**, Electrodesiccation of the proximal fallopian tube during salpingectomy. **B**, Excision of the fallopian tube.

(Figure 13-34). Methotrexate destroys rapidly dividing cells and is often administered in conjunction with the surgical procedure to destroy any residual trophoblastic cells that might remain (Research Highlight) (Genovese, 2007). Laparoscopic and/or ultrasound-guided application of methotrexate to the extrauterine gestational sac may also be used as an alternative therapy (Lobo, 2007).

Procedural Considerations. Procedural considerations for laparoscopic salpingostomy are identical to those for any laparoscopic procedure with the addition of methotrexate.

Operative Procedure

1. The surgeon establishes a pneumoperitoneum, inserts the telescope, and mobilizes the distal end of the fallopian tube to perform an adhesiolysis. Grasping forceps are placed on either side of the fallopian tube, and gentle traction is applied.
2. Before making an incision, coagulation of the serial vessels on both sides of the anticipated incision may be performed. A dilute solution of vasopressin may also be injected into the mesenteric margin to avoid excessive bleeding (Figure 13-35).

RESEARCH HIGHLIGHT

Medical Management of Ectopic Pregnancy

Ectopic pregnancy is a devastating complication that affects up to 2% of all pregnancies. Although perioperative nurses are most familiar with the surgical treatment of ectopic pregnancy, the more cost-effective medical treatment for ectopic pregnancy is considered a front-line therapy in many major medical centers.

In this prospective study, researchers evaluated 100 women diagnosed with ectopic pregnancy who elected to have medical therapy for acceptability of the treatment and resolution of the pregnancy without surgical intervention. Participants received an intramuscular injection of methotrexate on days 0 and 4 and received additional doses on days 7 and/or 11 if their hCG levels did not decrease by 15% in the follow-up period. A total of 88 women were treated successfully with the methotrexate protocol; the others required surgery. Over half of the women (53%) treated with the protocol reported adverse effects related to the treatment, most commonly gastrointestinal complaints.

To assess satisfaction with the medical protocol, researchers mailed a questionnaire with a 5-point scale to collect data on the side effects of the treatment, missed work/school days, and the feasibility of choosing the medical protocol over surgery in the future, if necessary. A total of 64 women returned the questionnaire; 58 reported they were "satisfied" or "very satisfied" with their treatment and would also undergo the same treatment if they experienced another ectopic pregnancy in the future.

Modified from Barnhart K et al: Use of "2-dose" regimen of methotrexate to treat ectopic pregnancy, *Fertil Steril* 87(2):250-256, 2007.

3. A single incision is made with scissors from the mesenteric to the antimesenteric side of the fallopian tube, where the products of conception are exposed.
4. The tissue is removed gently with forceps while constant irrigation is maintained with an isotonic solution (Figure 13-36). Vigorous evacuation is avoided so that the highly vascular underlying interstitial layer is not disturbed.
5. Small bleeding vessels can be ligated with a fine, nonreactive suture. Simple traumatic compression of bleeding margins will also promote hemostasis. Mesosalpingeal vessel ligation may be performed.
6. The tubal incision may be allowed to close by secondary intention or, as in the instance of salpingotomy, the incision may be closed in one or two layers, with 6-0 interrupted sutures. On completion, the endoscope and instrumentation are removed. The insufflated gas is permitted to escape from the trocar sleeves. Trocar sleeves are then removed. Subcuticular closure of the primary skin incisions is followed by placement of wound closure strips or small dressings.

Ovarian Cystectomy

Ovarian cystectomy is frequently performed via the laparoscopic approach.

Operative Procedure

1. After successful laparoscopic entry, adhesiolysis is achieved.
2. On entry, peritoneal washings for cell block are obtained, if indicated.

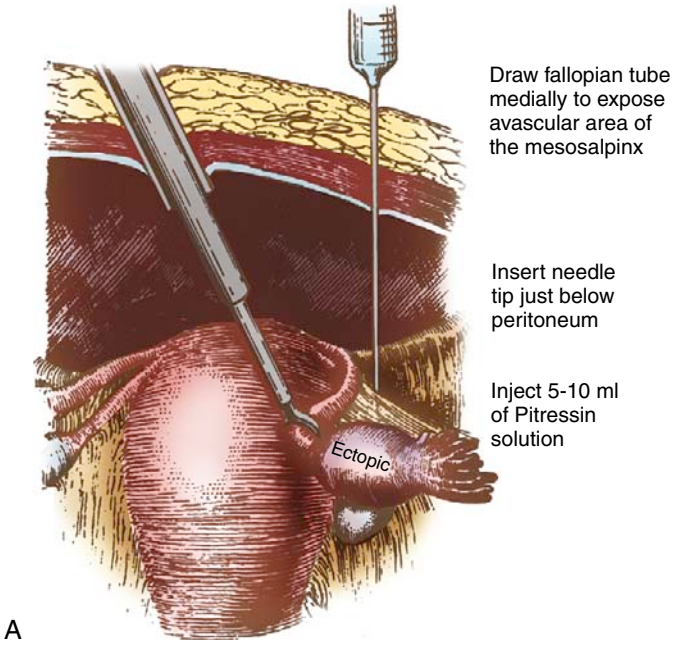


FIGURE 13-35 Salpingostomy. **A**, Injection of vasopressin into mesosalpinx. **B**, Incision made into fallopian tube.

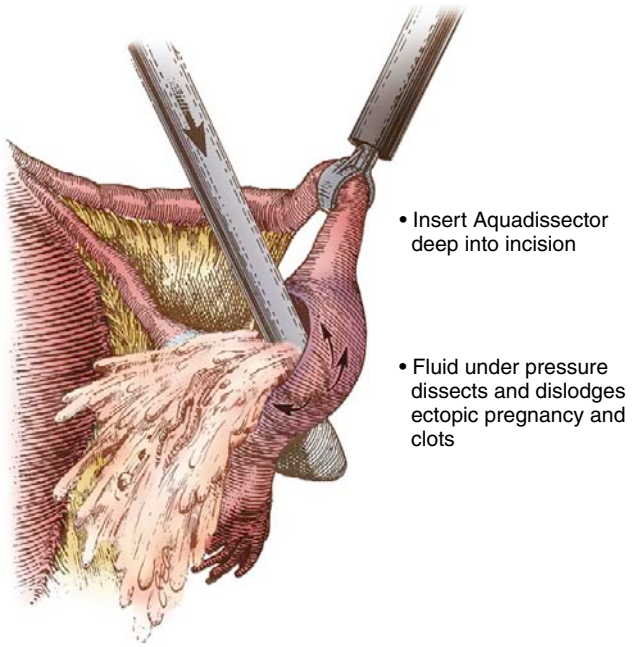


FIGURE 13-36 Hydrodissection used to separate ectopic pregnancy from fallopian tube during salpingostomy.

3. The ovarian cyst is mobilized, and the cortex is grasped with a biopsy instrument.
4. The surgeon incises the cortex with scissors or the laser, exposing the cyst wall.
5. The incision is then enlarged with scissors, and pressurized hydrodissection is used to separate the cyst from the ovarian stroma.
6. The cyst is dissected and may be removed intact by a culdotomy incision, or the cyst may be opened, evacuated, thoroughly cleaned by lavage with the hydrodissector, and then removed.
7. If the cyst is opened intraperitoneally, the patient should be placed in the supine, not Trendelenburg's, position while the fluid is removed and the pelvis is cleaned by lavage.
8. Arterial bleeders are identified and desiccated.
9. The ovary usually does not require suturing; however, if the edges gape widely, the surgeon may loosely approximate the edges with interrupted 4-0 synthetic absorbable suture.
10. On completion, the endoscope and accessory instrumentation are removed. The insufflated gas is permitted to escape from the trocar sleeves. Trocar sleeves are then removed.
11. Closure of the primary skin incisions (fascia, if necessary, followed by a subcuticular stitch) is followed by placement of wound closure strips or small dressings.

Laparoscopic-Assisted Vaginal Hysterectomy

Laparoscopic-assisted vaginal hysterectomy (LAVH) offers an alternative to total abdominal hysterectomy (TAH) and vaginal hysterectomy (VH). The patient does not have the large abdominal incision, extended hospital stay, and long recovery period that occur with a TAH. LAVH may be associated with less pain than VH or TAH. Patients who are not candidates for traditional VH may be candidates for LAVH. Although not described here, in laparoscopic-assisted supracervical hysterectomy (LASH), the body of the uterus is removed and the cervix is left intact (Goeser and Hasiak 2008).

The surgeon uses laparoscopy to visualize the pelvis and thereby determine whether disease is present. This is not possible with traditional vaginal hysterectomy. Conditions leading to LAVH include postmenopausal bleeding, pelvic pain, uterine leiomyomas, and adnexal masses. Indications for LAVH may be absence of genital prolapse, required adnexectomy, history of abdominopelvic surgery, salpingitis or endometriosis, lymphadenectomy, and endometrial cancer.

Procedural Considerations. Procedural considerations and accessory instrumentation and approach are similar to those used in other laparoscopic surgical procedures. The patient is placed in the low lithotomy position with attention to positioning interventions to protect the patient from injury.

Operative Procedure. The operative procedure may include the following:

1. Hydrodissection of the broad ligament
2. Desiccation of the round and infundibulopelvic ligaments with bipolar coagulation
3. Dissection of the broad ligaments
4. Freeing of the urinary bladder from the lower uterine segment
5. Opening of the vaginal vault with endoscopic scissors or monopolar electrode and removal of the uterus vaginally

Robotically-Assisted Procedures

Robotic-assisted surgery represents the newest available technology for minimally invasive gynecologic procedures. The robotic system has the following three components: (1) a surgeon console with a stereoscopic viewer, hand manipulators, and foot controls; (2) the vision system that provides a three-dimensional image through an endoscope equipped with stereoscopic cameras and dual optics; and (3) an ancillary cart with telerobotic arms (Reynolds, 2006). Robotic technology has been used for myomectomies, sacrocolpopexies, hysterectomies, oophorectomies, and lymphadenectomies (Fanning et al, 2008) (Research Highlight). Advantages to robotic procedures include smaller incisions (often 1 to 2 cm in length), reduced blood loss, shorter hospital stays, and greater patient satisfaction.

Procedural Considerations. General anesthesia is used for robotic procedures. Procedural considerations applicable to laparoscopic surgery are appropriate for robotic surgery including prepping and draping practices. The perioperative nurse must be familiar with the specialized equipment used for robotic surgery to minimize operative time and facilitate a smooth experience for the patient and surgical team. Instrumentation to convert the robotic procedure to an open procedure should be available.

Operative Procedure—Robotic-Assisted Hysterectomy

1. The surgeon places a uterine manipulator into the cervix and a vaginal balloon occluder into the vagina.
2. A Veress needle is placed and the surgeon establishes an adequate pneumoperitoneum. Alternately, the open Hasson technique (see Chapter 11) may be used.
3. The surgeon incises the skin at the umbilicus and places the endoscope port. Additional incisions are created and supplementary ports are inserted for instrumentation and suction.
4. The anesthesia provider positions the patient in steep Trendelenburg's position, and the perioperative nurse positions the surgical cart with the robotic arms between the patient's legs while observing the integrity of the sterile field.
5. Following the manufacturer's directions, the surgical technologist and surgical assistant dock the robotic system.
6. The surgeon moves to the console for the remainder of the procedure.
7. Using the hand and foot controls of the console, the surgeon surveys the operative field and opens the peritoneum using the ESU.

RESEARCH HIGHLIGHT

Robotic Hysterectomy for Benign and Malignant Disease

Minimally invasive approaches to gynecologic surgery have recently expanded to include robotic-assisted procedures. Robotic-assisted surgery offers several advantages over standard laparoscopy including decreased tissue trauma, enhanced precision, and stereoscopic visualization.

To evaluate the use of robotic surgery in a minimally invasive approach to hysterectomy for benign uterine disease, a group of researchers performed a retrospective chart review to examine the operative and perioperative characteristics and trends for 200 patients before and after implementation of a robotic program in a community hospital. The researchers reviewed 100 charts of patients who underwent laparoscopic hysterectomy before the implementation of the robotic program to the charts of the first 100 patients to undergo robotic hysterectomy. Indications for surgery included myomas, endometriosis, ovarian cysts, dysmenorrhea, and dyspareunia. Both groups were similar in demographics and body mass index. Their review concluded that a twofold decrease in blood loss was realized in robotic hysterectomies compared to laparoscopic hysterectomies (e.g., 61 ml in the robotic group, 113 ml in the laparoscopic group), and hospital stays were decreased in the robotic group. They also reported that the rate of conversion to an open procedure was zero for the robotic group, but 11% in the laparoscopic group.

Robotic surgery may also have a place in the treatment of malignant gynecologic conditions. Researchers in Boston sought to determine if robotic hysterectomy would improve short-term outcomes in women being treated with open radical hysterectomy for cervical cancer. Using a retrospective chart review they compared 48 radical hysterectomies. Of the 48 cases reviewed, 16 were robotic radical hysterectomies and 32 were open radical hysterectomies. All patients were similar in body mass, age, and stage of cancer. They determined that operative time for the robotic hysterectomy was significantly longer than that for the open procedures; however, mean blood loss was significantly less in robotic hysterectomy patients (e.g., 81.9 ml for the robotic group vs 665 ml for the open group). Postoperative complications were less in the robotic group, and the mean length of stay was 1.7 days in the robotic group compared to 4.9 days in the open group.

As techniques for this relatively new technology evolve, research is needed to quantify the benefits and to determine future applications in the treatment of both benign and malignant uterine conditions.

Modified from Payne TN, Dauterive FR: A comparison of total laparoscopic hysterectomy to robotically assisted hysterectomy: surgical outcomes in a community practice, *J Minim Invasive Gynecol* 15(3):286-291, 2008; Ko EM et al: Robotic versus open radical hysterectomy: a comparative study at a single institution, *Gynecol Oncol* 111:425-430, 2008.

8. The surgeon skeletonizes and ligates the uterine artery pedicles and infundibulopelvic ligament with polyglactin suture or free ties.
9. Additional dissection is performed to divide the cardinal and uterosacral ligament complex on both sides.
10. The surgical assistant provides traction on the uterus while the surgeon performs an anterior and posterior colpotomy.
11. The uterus and cervix are detached and delivered into the patient's vagina; they remain in the vagina while the surgeon closes the vaginal cuff using interrupted polyglactin suture. When the cuff is closed and hemostasis is achieved, the specimen is removed from the vagina.
12. The surgical assistant disengages the robotic arms and removes the trocars.
13. Using polyglactin suture the surgeon or surgical assistant closes the fascia. Wound closure strips are used to close the skin incisions, and small dressings and a perineal pad are applied.

Uterine Artery Embolization

Uterine artery embolization (UAE, also referred to as "uterine fibroid embolization [UFE]") is an alternate treatment for fibroids that blocks the blood vessels supplying nutrients and oxygen to the tumors. The blockage causes the fibroid muscle cells to degenerate and form scar tissue, which causes the fibroids to shrink. The greatest period of shrinkage occurs in the first 6 months following the procedure with an additional 42% to 82% shrinkage over the next 6 months (Andrews et al, 2009). This procedure appeals to many women because of its minimally invasive nature and ability to be performed in the outpatient setting. The main complication associated with the procedure is postembolization syndrome, occurring in 2% to 10% of patients. Postembolization syndrome is characterized by pelvic pain, low-grade fever, vomiting, loss of appetite, and malaise in the first 48 hours after UAE (Parker, 2007). Occasionally, the procedure is complicated by inadvertent occlusion of the ovarian blood supply. Pregnancy is not recommended following UAE.

Procedural Considerations. A hysteroscope, light source, camera, and viewing tower are required along with uterine distention system, appropriate distention fluids, and energy sources (Dooley, 2007). The patient is placed in lithotomy position with appropriate positioning safety measures (see Chapter 5). An EUA is usually performed before the start of the procedure. A perineal pad will be used at the procedure conclusion.

Operative Procedure. The procedure is performed under fluoroscopic guidance using spinal anesthesia or local anesthesia supplemented with moderate sedation. A femoral artery sheath is inserted, and arteriography of the pelvic vasculature is performed by injecting radiologic contrast through a 5-French catheter as it passes through the femoral artery to the iliac artery to the uterine artery. An embolic agent is injected through the catheter until no more proximal arterial flow or reflux of contrast material is noted. Commonly used embolic agents are gelatin sponges, nonspheric polyvinyl alcohol (PVA) particles, and trisacryl gelatin microspheres. Gelfoam pledgets are cut into strips, rolled, and loaded into a nozzle of a syringe for injection. Nonspheric PVA particles are mixed with equal parts of saline and contrast and injected through the catheter until the vessel is occluded. The PVA particle size ranges from 350 to 700 micrometers, which is comparable in size to a grain of sand. Trisacryl microspheres range in size from 700 to 900 micrometers (Scheurig et al, 2008). Collateral circulation maintains the blood supply to the myometrium. The particles remain inert in the vessel.

GYNECOLOGIC SURGERY USING ABDOMINAL APPROACH

Total Abdominal Hysterectomy (TAH)

TAH is removal of the entire uterus, including the corpus and the cervix. When TAH is combined with bilateral salpingo-oophorectomy, the procedure is commonly termed *panhysterectomy* or *complete hysterectomy.* TAH may be performed for symptomatic pelvic relaxation or prolapse, pain associated with pelvic congestion, pelvic inflammatory disease, endometriosis, recurrent ovarian cysts, fibroids (myomas), bleeding with no apparent cause in postmenopausal women, adenomyosis, or dysfunctional uterine bleeding (Evidence for Practice). TAH, usually with bilateral salpingo-oophorectomy, is also indicated in malignancy, premalignant states, and conditions of high risk for development or recurrence of malignancy. The procedure can also be used to accomplish sterilization. Approximately 516,025 hysterectomies are performed each year in the United States (HCUPnet, 2007).

Procedural Considerations. Before the abdominal skin prep, the perioperative nurse performs an internal vaginal prep using a separate prep tray, ensuring contact of the prep solution with the cervix. An indwelling urinary drainage catheter is inserted to provide constant bladder drainage during the operation. The supine position, modified during the procedure with the Trendelenburg's position, is used. Instrumentation includes the abdominal gynecologic set. Provisions are made to remove those instruments used in separating the cervix from the vagina from the surgical field, thereby avoiding vaginal contamination of the pelvis.

Operative Procedure

1. In an obese patient or for exploration of the upper abdominal cavity, a left rectus or midline incision may be made. For simple hysterectomy, a Pfannenstiel incision may be used. The surgeon opens the abdominal layers and the peritoneum as described for laparotomy (see Chapter 10).
2. As the peritoneal cavity is opened, the anesthesia provider usually places the patient in the Trendelenburg's position to provide better visualization of the pelvic organs.
3. Vasopressin may be injected into the uterus. The round ligament is grasped with forceps, clamped, and ligated with sutures on long needle holders. The surgeon cuts the pedicles with a knife or Metzenbaum scissors; sutures are tagged with a hemostat to be used as traction later. This procedure is done on both sides (Figure 13-37, *A*).
4. Using blunt dissection the surgeon separates the layer of the broad ligament close to the uterus on each side. Bleeding vessels are clamped and ligated, and a moist laparotomy pack is inserted behind the flap. The fallopian tube and the utero-ovarian ligaments are doubly clamped together, incised, and doubly tied with suture ligatures (Figure 13-37, *B*).

EVIDENCE FOR PRACTICE

Alternatives to Hysterectomy

Hysterectomy is the most common non–pregnancy-related major surgery performed on women in the United States. It is widely accepted as appropriate treatment for cancer and various noncancerous conditions, such as pain, discomfort, uterine bleeding, emotional distress, and related symptoms. Although hysterectomy can alleviate uterine problems, less-invasive treatments are available. Alternatives to hysterectomy recommended by the Agency for Healthcare Research and Quality (AHRQ) are noted in the following table.

		Pharmacologic Therapies		
Condition	**Conservative Surgery**	**Hormonal**	**Nonhormonal**	**Other Strategies**
Fibroids	Myomectomy	GnRH agonists with add-back therapy	NSAIDs	Watchful waiting
	Endometrial ablation	Oral contraceptives RU-486 (experimental) Gestrinone (experimental)		
Endometriosis	Adhesiolysis	GnRH agonists with add-back therapy	NSAIDs	Watchful waiting
	Excision or endometrial ablation	Danazol	Analgesics	Biofeedback
	Resection or cul-de-sac obliteration	Progestins	Anxiolytics	Hypnosis
	Nerve blocks	Oral contraceptives		Acupuncture
	Uterosacral nerve ablation	Tamoxifen (experimental) RU-486 (experimental)		Lifestyle modifications (nutrition/exercise)
Prolapse	Colporrhaphy Laparoscopic or vaginal suspension techniques	Estrogen		Watchful waiting Kegel exercises Pessaries Electrical stimulation Urethral beads Periurethral injections (e.g., of fat, silicone)
Dysfunctional bleeding	Dilation and curettage Endometrial ablation	Progestins Estrogens Oral contraceptives Danazol Prostaglandin inhibitors GnRH agonists Antifibrinolytic agents Luteinizing hormone agonists		Watchful waiting Antidepressants
Chronic pelvic pain	Adhesiolysis Nerve blocks Denervation procedure Uterosacral nerve ablation	Danazol GnRh agonists with add-back therapy Oral contraceptives Medroxyprogesterone acetate	NSAIDs Analgesics Nerve blocks Narcotics	Watchful waiting Counseling Biofeedback Relaxation techniques Trigger-point injections Acupuncture Psychotropics Antidepressants Physical therapy

GnRH, gonadotropin-releasing hormone; *NSAID,* nonsteroidal antiinflammatory drug.
Modified from *Common uterine conditions: options for treatment,* AHCPR Pub No. 98-0003, Rockville, Md, Dec 1997, Agency for Health Care Policy and Research, available at www.ahrq.gov/consumer/uterine1.htm. Accessed June 26, 2009.

5. The surgeon pulls the uterus forward to expose the posterior sheath of the broad ligament, and incises the ligament with a knife or Metzenbaum scissors. Ureters are identified. The uterine vessels and uterosacral ligaments are doubly clamped, divided by sharp dissection at the level of the internal os, and ligated with suture ligatures (Figure 13-37, *C*).
6. The severed uterine vessels are bluntly dissected away from the cervix on each side with the aid of sponges on sponge-holding forceps, scissors, and tissue forceps.
7. The bladder is separated from the cervix and upper vagina with sharp and blunt dissection assisted by sponges on sponge-holding forceps. The bladder may be retracted with a moist laparotomy pack and a retractor with an angular

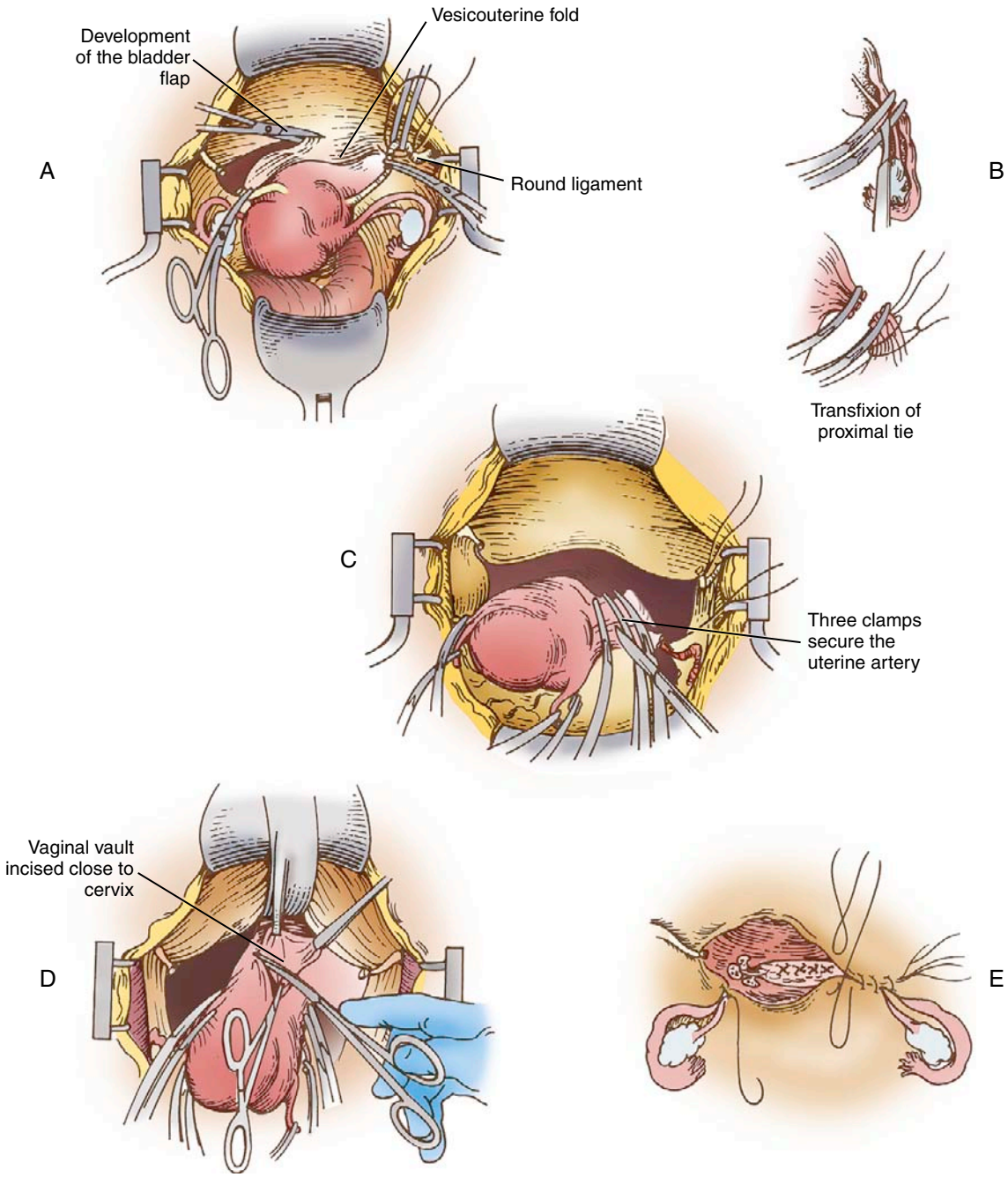


FIGURE 13-37 Abdominal hysterectomy for single fibroid uterus. **A**, Peritoneum retracted with self-retaining retractors, and organs protected with laparotomy packs saturated in warm normal saline solution. Transverse incision made through uterine peritoneum and extended to each side of uterine attachments of round ligaments. Bleeding vessels clamped and ligated. Round ligament grasped, ligated, and cut. **B**, Tube and ovarian ligaments clamped, cut, and sutured. **C**, Uterus pulled forward, posterior sheath of broad ligaments divided, and uterine artery and veins secured by three heavy curved clamps. Pedicle divided, leaving two hemostats on proximal pedicle. **D**, Bladder separated from cervix and upper vagina. Vaginal vault opened and grasped with Allis forceps. Allis forceps placed on anterior lip of cervix, and dissection of cervix carried out to complete its amputation from vagina. **E**, Three connective tissue thickenings anchored to vaginal vault, vaginal mucosa approximated, and vault closed. As shown, peritoneum closed with continuous suture.

blade. The vaginal vault is incised close to the cervix with a knife or scissors (Figure 13-37, *D*).

8. The surgeon grasps the anterior lip of the cervix with an Allis, Kocher, or tenaculum forceps. Using scissors, the surgeon dissects the cervix and amputates it from the vagina. The uterus is removed. The surgical technologist places any potentially contaminated instruments used on the cervix and vagina into a discard basin and passes them from the field (including sponge-holding forceps and suction). Bleeding is controlled with hemostats and sutures.
9. The vaginal vault is reconstructed with interrupted sutures. Angle sutures anchor all three connective tissue ligaments to the vaginal vault. The pedicles, fallopian tubes, and ovarian ligaments are left free of the vault.
10. The vaginal mucosa is approximated with a continuous suture on a long needle holder. The muscular coat of the vagina may be closed with figure-of-eight sutures to make the vault of the vagina firm and provide resistance against prolapse. A drain may be placed in the vagina.
11. The surgeon closes the peritoneum over the bladder, vaginal vault, and rectum (Figure 13-37, *E*). The laparotomy packs are removed, and the omentum is drawn over the bowel.
12. The abdominal wound is closed as described for laparotomy closure (see Chapter 10).
13. Abdominal dressings and a perineal pad are applied.

Abdominal Myomectomy

Uterine fibroids are benign tumors that arise from the muscular wall of the uterus (Figure 13-38). They may also be located in the submucosal area or the subserosal surface of the uterus. On occasion, they may become pedunculated and extend into the cervical canal. Rarely, a subserosal fibroid may pedunculate and migrate to become a parasitic fibroid attached to the omentum or mesentery. Another term for uterine fibroids is *uterine leiomyomas*. Abdominal myomectomy is removal of fibromyomas, or fibroid tumors, by carefully separating each fibroid from the uterine wall and its blood supply. Myomectomy is usually done in young women who have symptoms that indicate the presence of tumors and who wish to preserve their potential fertility. Uterine fibroids may cause pelvic pain and pressure or dysfunctional uterine bleeding, and they are a leading cause of infertility. Fibroids are more common in African-American women and become more common during the later reproductive years (Katz, 2007). Myomectomy may be performed as a prophylactic measure with other abdominopelvic surgery. Preoperative preparation may include injections of Lupron, a synthetic version of the naturally occurring gonadotropin-releasing hormone (GnRH), to reduce blood supply to the fibroid. This intervention mimics the postmenopausal state for women who receive it, as it reduces the amount of estrogen that the body synthesizes.

Procedural Considerations. The basic abdominal gynecologic instrument set and ESU are required. A laser may also be used. The patient is prepped as described for abdominal hysterectomy.

Operative Procedure

1. A midline or Pfannenstiel incision is used, and the uterus is exposed.
2. To contract the musculature of the uterine wall, a suitable drug may be injected into the fundus.
3. The surgeon grasps the fibroid tumor with a tenaculum. The broad ligament may be opened with curved hemostats and Metzenbaum scissors to determine the course of the ureter or to free the bladder.
4. Each tumor is shelled out of its bed, using blunt and sharp instruments, or the laser. Bleeding vessels are clamped and ligated or electrocoagulated.
5. The uterus is reconstructed with interrupted or continuous sutures.
6. The perimetrium is closed over the operative site, and the abdominal wound is closed.

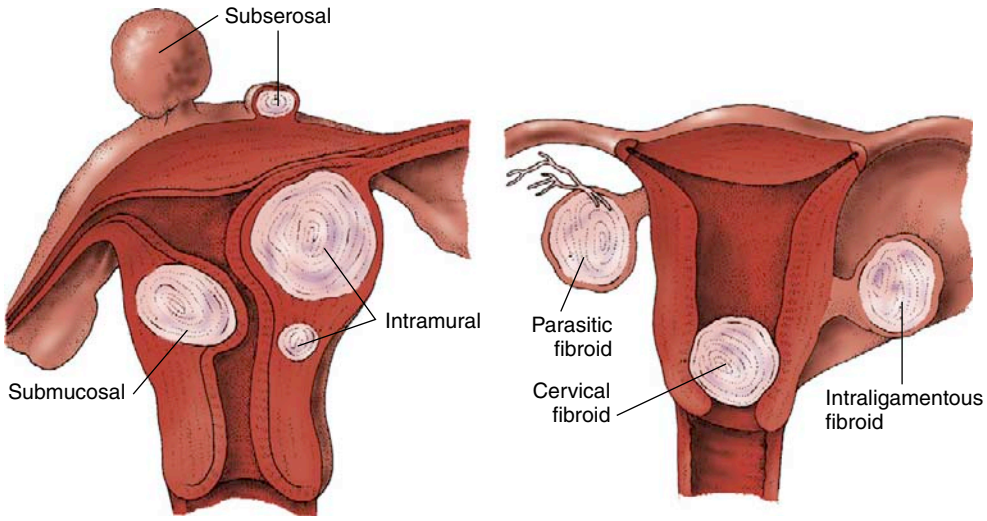


FIGURE 13-38 Classification of uterine leiomyomas.

Radical Hysterectomy (Wertheim)

Radical hysterectomy is en bloc dissection and wide removal of the uterus, tubes, ovaries, supporting ligaments, and upper vagina, together with careful removal of all recognizable lymph nodes in the pelvis (Figure 13-39). Extensive dissection of the ureters and of the bladder is also involved.

Radical hysterectomy is performed for gynecologic malignancy. Abdominal exploration determines lymph node involvement. With no lymph node involvement, a wide-cuff hysterectomy is performed. The uterus, tubes, and ovaries, together with most of the parametrial tissues and the upper portion of the vagina, are dissected en bloc. Dissection of the ureters from the paracervical structures takes place so that the ligaments supporting the uterus and vagina can be removed.

Procedural Considerations. Careful estimation of blood loss and calculation of urinary output are needed throughout the operative procedure. The patient is prepped as described for TAH. An indwelling urinary catheter is inserted. The basic abdominal gynecologic instrument set is required, with the addition of long and deep instruments and a self-retaining retractor.

Operative Procedure

1. The skin is incised, and the abdominal layers are opened, as described for laparotomy.
2. The surgeon cuts the peritoneum at its reflection on the anterior surface of the uterus between the round ligaments (Figure 13-40, *A*). Using blunt dissection, the surgeon frees the bladder surface from the cervix and vagina.
3. The right round and infundibulopelvic ligaments are clamped, cut with a knife or Metzenbaum scissors, and ligated with sutures to expose the external iliac artery. The ureter is identified and retracted with a vein retractor (Figure 13-40, *B*).
4. The lymph and areolar tissues are dissected from the iliac artery, obturator fossa, and ureter with Lahey forceps, Kitner sponges, and Metzenbaum scissors. A complete lymph gland dissection removes the tissue from the Cloquet node to the bifurcation of the iliac arteries bilaterally. The uterine artery and vein are clamped, cut, and doubly ligated.
5. The surgeon elevates the uterus and opens the cul-de-sac (Figure 13-40, *C*); the uterosacral and cardinal ligaments are clamped, cut with scissors, and doubly ligated with suture ligatures. The pararectal and paravesical areolar tissues are dissected free to skeletonize the upper vagina, and the paraurethral tissues are removed as near to the pelvic walls as possible.
6. The upper third of the vagina is cross-clamped with Heaney forceps (Figure 13-40, *D*) and divided using a long knife handle and #20 blade. The uterus and surrounding tissues are removed. Electrocoagulation is used to minimize venous oozing from small venules and capillaries. Lowering the head of the OR bed 15 degrees is also helpful in reducing the oozing of blood and serum.
7. The surgeon sutures the vagina with a running locked stitch, and inserts closed wound drains from above (Figure 13-40, *E*). The pelvis is peritonealized with a continuous suture.
8. The abdominal wound is closed (retention sutures may be used) and dressed in the usual manner. Vaginal packing and drains may be used. A suprapubic indwelling catheter may be placed to assist in preventing postoperative bladder spasm and for bladder drainage if the patient is unable to void after removal of the urethral catheter.
9. A perineal pad is applied.

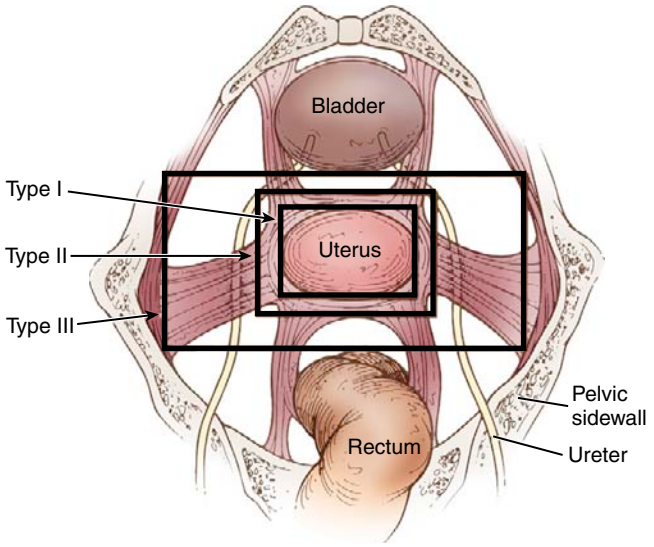


FIGURE 13-39 Different types of hysterectomy: type I—simple hysterectomy; type II—modified radical hysterectomy; type III—radical hysterectomy.

Pelvic Exenteration

Pelvic exenteration is the en bloc removal of the rectum, the distal sigmoid colon, the urinary bladder and the distal ureters, the internal iliac vessels and their lateral branches, all pelvic reproductive organs and lymph nodes, and the entire pelvic floor with the accompanying pelvic peritoneum, levator muscles, and perineum. A partial exenteration, either anterior or posterior, may be performed, depending on the origin of the carcinoma and the extent of local tissue invasion (Figure 13-41).

Pelvic exenteration is the preferred treatment for recurrent or persistent carcinoma of the cervix after radiation therapy. Advanced or recurrent vaginal, vulvar, or occasionally endometrial and rectal carcinomas are often amenable to exenteration (Jhingran and Levenback, 2007). Exenteration is considered only after a thorough investigation of the patient and disease status to determine if there is a reasonable chance of cure and of return to a productive life.

The need to create urinary and bowel diversions must also be considered, together with the patient's ability to cope with these diversions postoperatively. Plastic surgery may be required for creation of a neovagina. Psychologic preparation and support of the patient and family by the perioperative nurse and physician are prime requisites.

Procedural Considerations. Utmost care must be taken in positioning the patient because of the duration of surgery. The perioperative nurse pays strict attention to the patient's knees, hips, and lower back to prevent vascular and nerve damage. The patient is in the supine position with legs abducted in the ski position (i.e., lower extremities resting on a well-padded plantar surface rather than on the heel or popliteal area) or elevated in

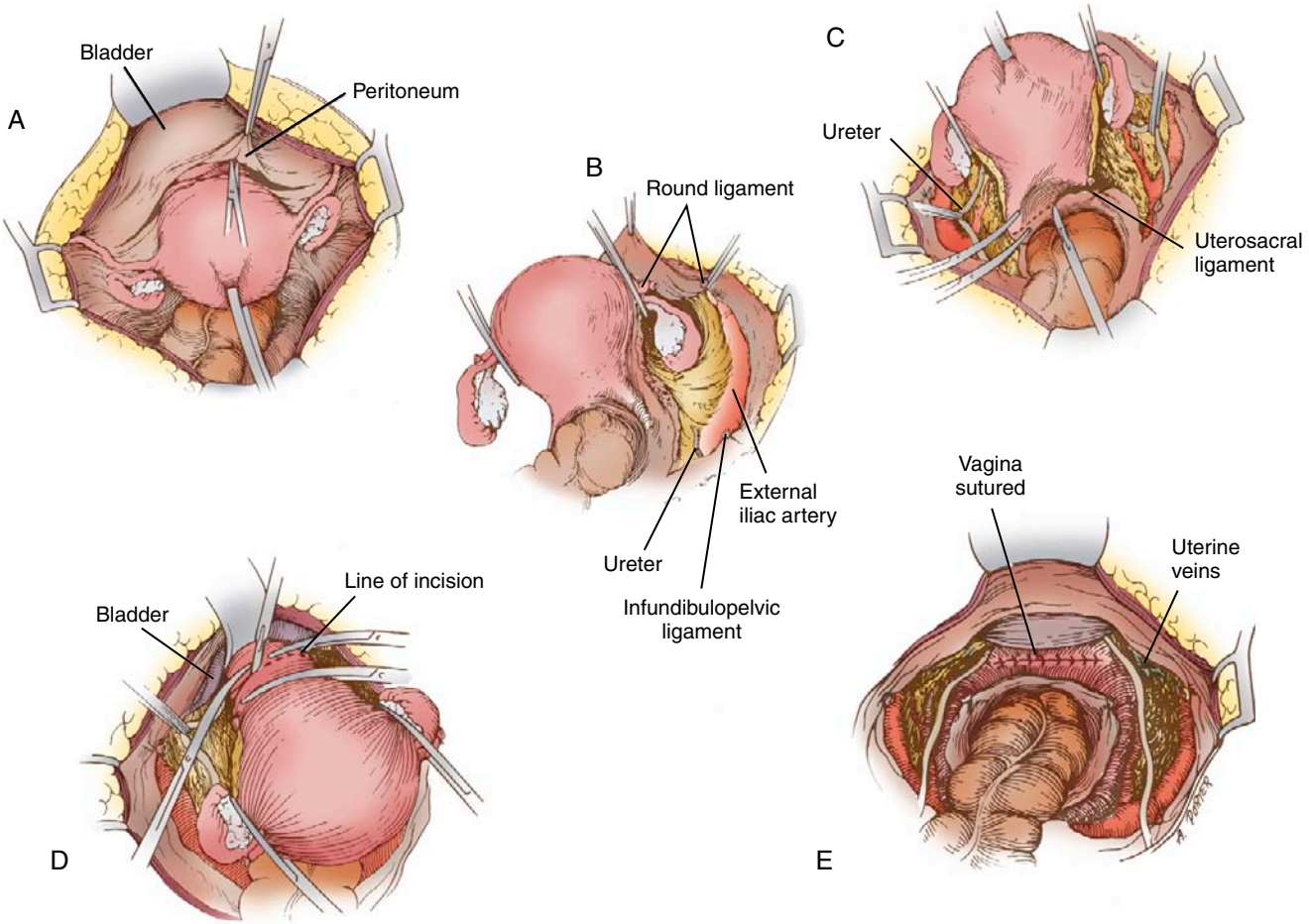


FIGURE 13-40 Wertheim radical hysterectomy. **A**, With upward traction applied on uterus, peritoneum is incised from round ligament to round ligament. **B**, Right round and infundibulopelvic ligaments are ligated and cut, thus exposing right external iliac artery. **C**, Uterus is held upward and forward, exposing cul-de-sac, which is incised as shown by dotted line. **D**, After dissection is completed, vagina is doubly clamped preparatory to transection, after which entire specimen is lifted out en bloc. **E**, Vagina is closed. Peritoneum remains to be reperitonealized.

a modified lithotomy position to allow access to the perineum without disruptive position changes. Skin prepping includes the abdomen, thighs, perineum, and internal vaginal vault.

The perioperative nurse and surgical technologist must be alert to fluid and blood loss. Irrigation solutions must be accurately measured, laparotomy packs must be weighed to assess blood volume loss, and the anesthesia provider and surgical team must be apprised of the measurements.

When the colon is transected or ureteral drainage is diverted into a segment of the ileum the gastrointestinal technique (i.e., bowel technique) as described in Chapter 10 should be followed.

Separate instrument setups are required for the abdominal and perineal approaches. Extra drapes, gowns, and gloves should be available.

For the abdominal approach, the basic abdominal gynecologic instrument set and instrumentation for abdominoperineal resection (see Chapter 10) are required.

For the perineal approach, the basic vaginal instrument set is required. To prevent contamination, the anus may be closed with a purse-string suture.

Operative Procedure

1. A long midline incision from the symphysis pubis to the umbilicus is made, and the abdomen is opened in the usual manner. A second incision within the perineum encircling the vestibule and anus is also made.
2. The surgeon explores the peritoneal cavity for metastasis to the liver, the nodes of the celiac axis, the superior mesenteric artery, and the para-aortic tissues.
3. The pelvis is explored, and the peritoneum along the brim of the pelvis is examined for lymph node involvement. Frozen sections may be indicated. The obturator fossa and the region of the uterosacral ligaments are explored. When findings at exploration are negative, retractors are placed and the small bowel is isolated with moist laparotomy packs (Figure 13-42).
4. The surgeon frees the sigmoid mesocolon and sections it by means of intestinal clamps and a scalpel or a stapling device. The proximal end is exteriorized through an opening in the left side of the abdomen; an intestinal clamp is left across the lumen until later, when the permanent colostomy will be secured to the skin.

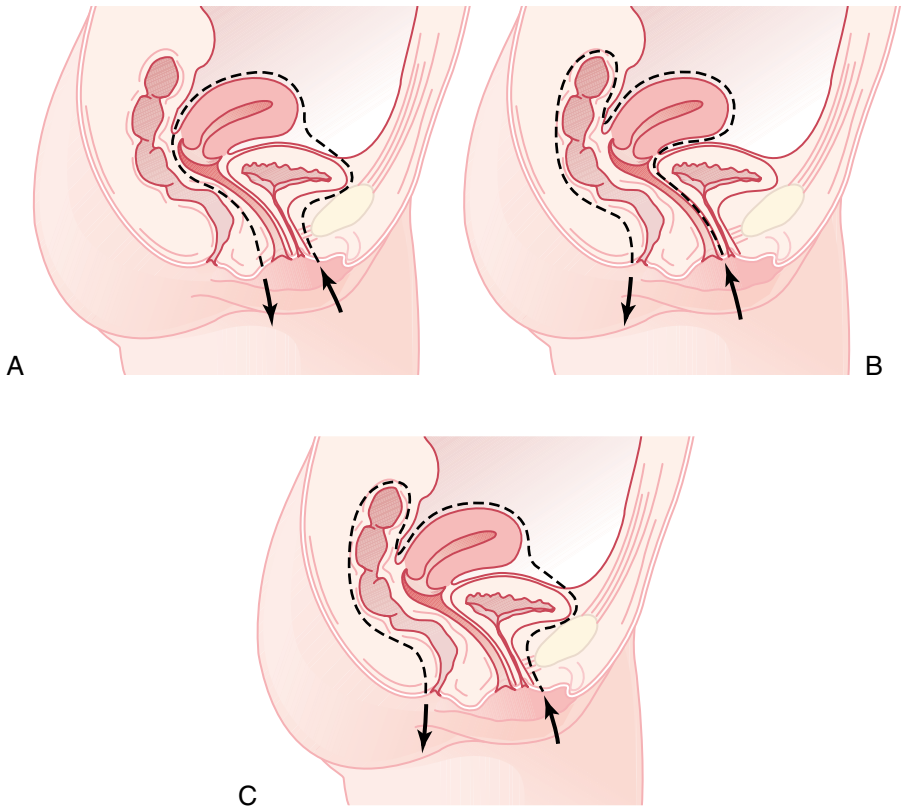


FIGURE 13-41 Organs removed in pelvic exenteration. **A**, Anterior exenteration. **B**, Posterior exenteration. **C**, Total pelvic exenteration.

5. The remaining sigmoid mesentery is clamped with Rochester-Péan forceps, cut, and ligated down to and including the superior hemorrhoidal vessels. Long instruments and sutures are used to reach the deep pelvic structures.
6. The distal sigmoid colon is closed with an inverting suture. The sigmoid colon and rectum are freed from the sacrococcygeal area by blunt and sharp dissection.
7. The lateral pelvic peritoneum is cut along the iliac vessels; the ovarian vessels and round ligaments on each side are clamped with Rochester-Péan forceps, cut, and doubly ligated.
8. The surgeon incises the peritoneum over the dome of the bladder with a long knife and Metzenbaum scissors, and separates the bladder from the symphysis pubis down to the urethra.
9. The ureters are identified and divided 2 to 3 cm below the brim of the pelvis. The proximal end is left open to allow urinary drainage, whereas the distal end is ligated.
10. The hypogastric artery, the internal iliac vein, and the superior and inferior gluteal vessels are exposed, clamped with hemostats, doubly ligated, and cut. The external iliac vein is retracted to allow evacuation of the contents of the obturator fossa, leaving the obturator nerve intact. Care must be taken in dissection not to damage the sacral plexus and sciatic nerve.
11. The surgeon isolates the internal pudendal vessels, ligates them with transfixion sutures, and cuts them. The remaining soft-tissue attachments of the pelvis are clamped and cut. Steps 10 and 11 are then performed on the opposite side.
12. The perineum is incised by an elliptic incision that includes the clitoris and anus. The ischiorectal fat is incised up to the area of the levator muscle.
13. The coccygeal attachment of the rectum is severed. The levator muscles are severed at their lateral attachments by using a long knife handle with #20 blade; hemostasis is maintained by pressure and traction.
14. The paravesical and paravaginal tissues are resected from the periosteum of the symphysis pubis and superior pubic rami by means of a knife. The specimen is completely freed and removed from the pelvis (Figure 13-43).
15. After residual bleeding vessels are identified and controlled by transfixing ligatures, the surgeon closes the subcutaneous tissue with interrupted sutures. A drain is placed in the wound, and the skin is closed.
16. Further residual bleeding vessels are controlled in the abdomen. Packs may be left in the pelvis, to be removed through the perineum after 48 hours.
17. The ileal segment is then fashioned, and the ureters are anastomosed to it. The external stoma is placed on the right side of the abdomen.
18. A jejunostomy catheter is inserted into the proximal jejunum to aid in postoperative bowel decompression. It is connected to the bowel with a purse-string suture and exteriorized to the skin, where it is sutured in place.
19. A gastrostomy tube is placed into the stomach in the same manner.
20. Hemostasis is checked. The small intestine is carefully repositioned into the pelvis. Packs and retractors are removed.

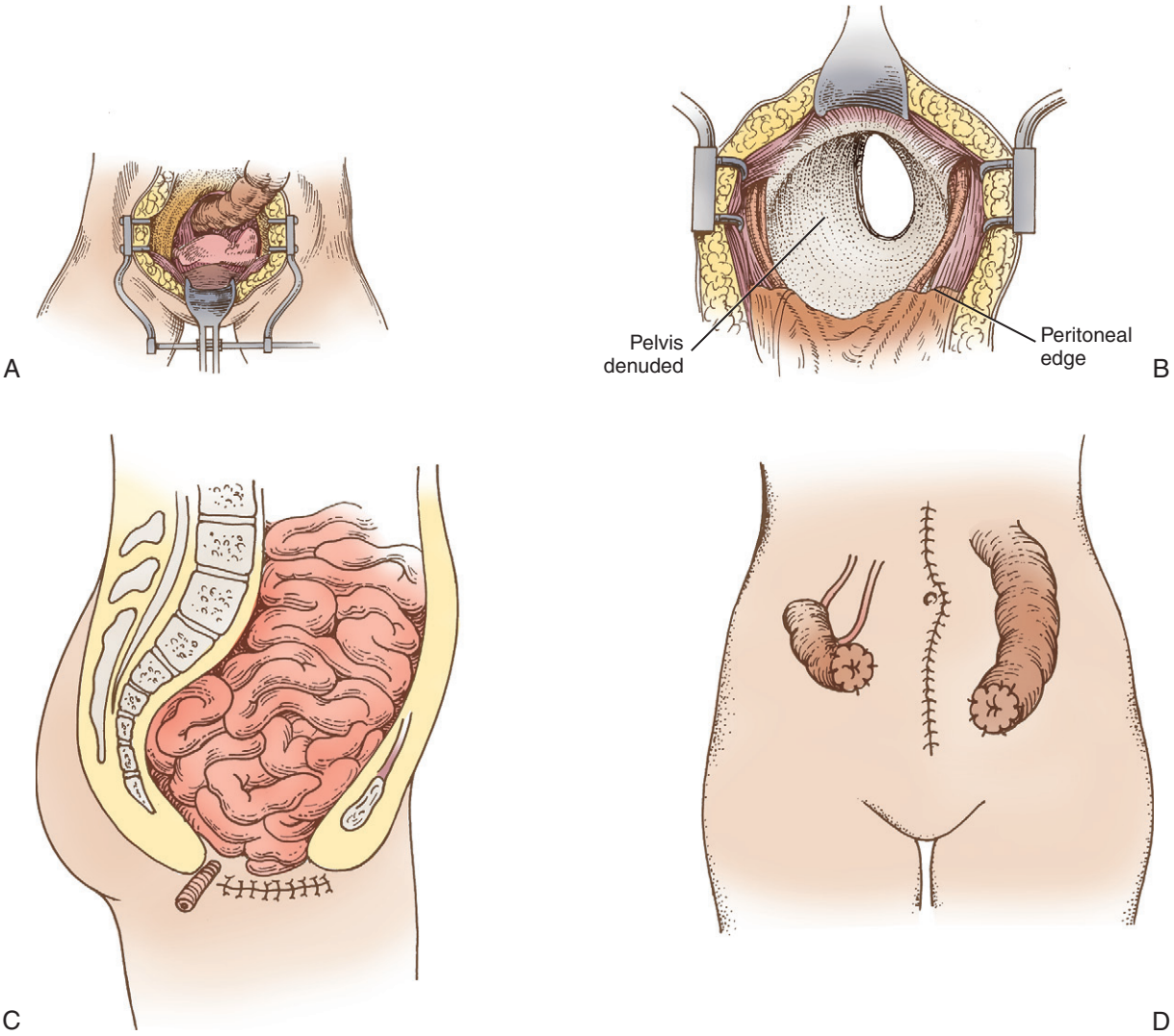


FIGURE 13-42 Pelvic exenteration. **A**, Pelvic viscera in situ as viewed from operating surgeon's vantage point after retractors are placed and small bowel is isolated with moist laparotomy packs. **B**, Empty pelvis after dissection of paravesical and paravaginal tissues and removal of specimen en bloc. **C**, Sagittal view of small bowel above pelvic defect. Perineal packing or drain may be used. **D**, After closure of abdominal wall, colostomy and urostomy stomas are sutured to skin edges.

21. The peritoneum, rectus muscles, and fascial sheaths are closed with interrupted figure-of-eight sutures. The skin is closed with interrupted sutures.
22. The colostomy stoma is prepared by removing the intestinal clamp from the sigmoid colon, opening the colon, and suturing the stoma to the skin edges.

The abdominal wound and tube sites are dressed in the usual manner. Drainage devices are applied to the colostomy and urostomy stomas.

SURGERY FOR CONDITIONS THAT AFFECT FERTILITY

Oophorectomy and Oophorocystectomy

Oophorectomy is removal of an ovary. Oophorocystectomy is removal of an ovarian cyst. Functional cysts constitute the majority of ovarian enlargements, with follicular cysts being the most common. Functional cysts develop in the corpus luteum. Benign cystic teratomas, also known as dermoid cysts, are very common and are composed of ectodermal tissues (sweat glands, hair follicles, and teeth) (Figure 13-44). Other tissues found in dermoid cysts include adult brain, bronchus, thyroid, cartilage, bone, and intestinal cells (Katz, 2007). Ovarian epithelial tumors, serous cystadenomas, and pseudomucinous cystadenomas are prone to malignant change.

The choice of operation depends on the patient's age and symptoms, findings during physical examination, and direct examination of the adnexa during exploration. If the ovarian tumor is recognized as benign, only the visibly diseased portions of the adnexa are removed. In the presence of dermoid, follicular, and corpus luteum cysts, the cyst is usually enucleated and most of the ovarian parenchyma is preserved. In tubal pregnancy, the ectopic pregnancy may be removed from the tube or the pregnant fallopian tube may be removed concomitant with, in some instances, the ovary.

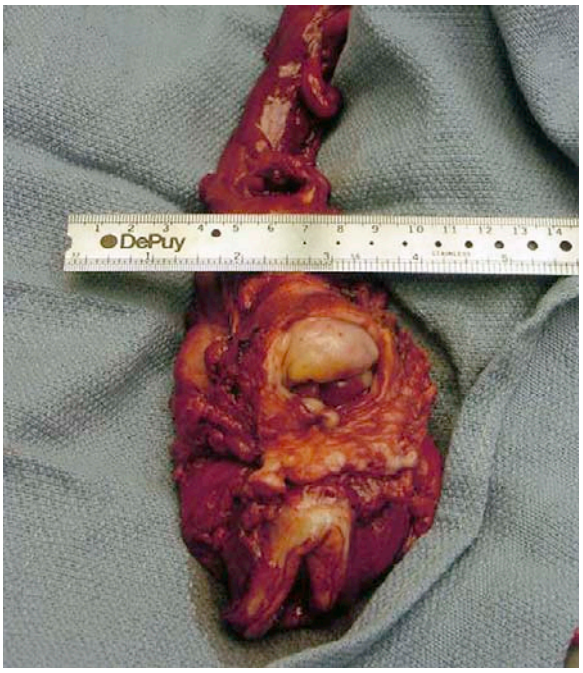


FIGURE 13-43 Pelvic exenteration specimen.

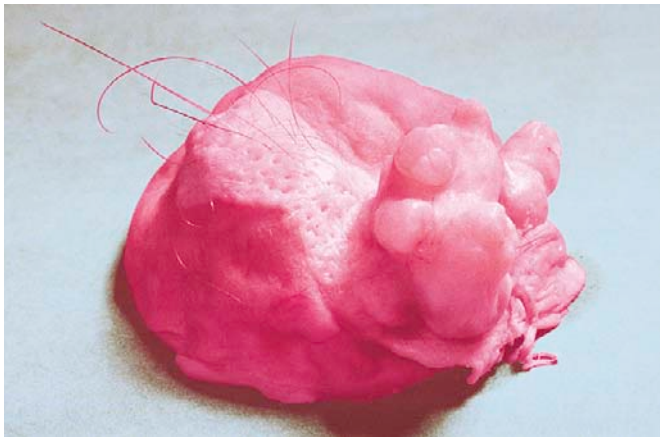


FIGURE 13-44 Dermoid cyst.

Procedural Considerations. The basic abdominal gynecologic instrument set is required, with the addition of a trocar and cannula, suction tubing, 10-ml syringe, and 21-gauge needle.

Operative Procedure

1. The surgeon opens the abdominal cavity as described for laparotomy.
2. After the abdominal cavity is opened, the surgeon has several options.
   a. For removal of a large ovarian cyst, a purse-string suture may be placed into the cyst wall and a trocar introduced in its center; the suture is tightened around the trocar as the fluid is aspirated. The trocar is removed, and the purse-string suture is tied. All normal ovarian tissue is preserved.
   b. For removal of a smaller ovarian cyst, a clamp is placed at the base of the cyst and the cyst is excised. The wound in the ovary is closed with absorbable suture (Figure 13-45).
   c. For removal of a dermoid cyst, the field is protected with laparotomy packs because the cystic contents produce irritation if they are spilled into the peritoneal cavity. An incision is made along the base of the cyst between the wall and normal ovarian tissue. The cystic wall is dissected away. The ovary is closed with interrupted or continuous sutures.
   d. For decortication of the enlarged ovary and wedge resection, a large segment of the ovarian cortex opposite the hilum is removed. The cysts are punctured with a needle point and collapsed. A wedge of ovarian stroma, extending deep into the hilum, is resected with a small knife; the cortex of the ovary is closed with interrupted or continuous sutures.
3. To prevent prolapse of the tube into the cul-de-sac, the tube may be sutured to the posterior sheath of the broad ligament.
4. The abdominal wound is closed as described for laparotomy, and dressings are applied.

Salpingo-oophorectomy

Salpingo-oophorectomy is removal of a fallopian tube and all or part of the associated ovary. Unilateral salpingo-oophorectomy may be done to cure chronic salpingo-oophoritis, for ectopic tubal gestation, or for certain disease conditions of the adnexa or large adnexal cysts. If both tubes and ovaries are diseased, they are removed with total hysterectomy.

Procedural Considerations. The basic abdominal gynecologic instrument set is required.

Operative Procedure

1. The surgeon opens the abdominal cavity as described for laparotomy.
2. The affected tube is grasped with Allis or Babcock forceps. The infundibulopelvic ligament is clamped with hemostats, cut, and ligated.
3. The mesosalpinx is grasped with hemostats and divided with the suspensory ligament of the ovary.
4. The cornual attachment of the tube is excised with a knife or curved scissors. Bleeding vessels are clamped and ligated.
5. The edges of the broad ligament are peritonealized from the uterine horn to the infundibulopelvic ligament as described for total hysterectomy.
6. The wound is closed as described for laparotomy, and dressings are applied.

Microscopic Reconstructive Surgery of the Fallopian Tube

The obstructed portion of a fallopian tube may be removed and the tube reconstructed to create patency of the remaining portion of the tube, promoting the possibility of fertilization. Reconstructive surgery of the tube, broadly called *tuboplasty,* includes reanastomosis, salpingoneostomy, fimbrioplasty, and lysis of adhesions.

The development of microsurgical techniques has advanced surgical reconstruction of fallopian tubes. Microsurgical techniques may be used with mini-laparotomy or laparoscopy, or both. Microsurgical tubal anastomosis permits atraumatic,

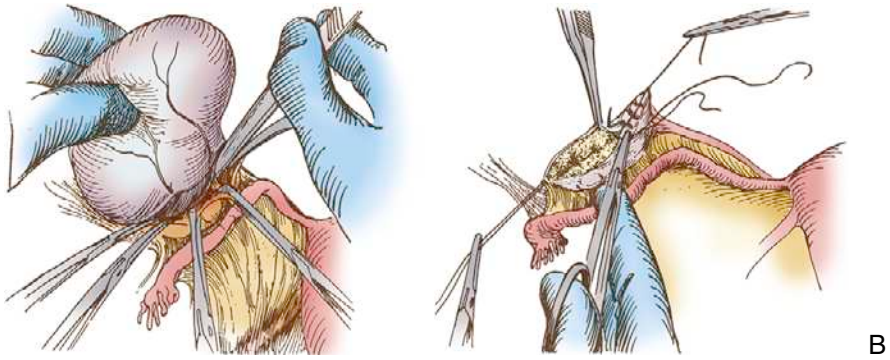


FIGURE 13-45 Resection of small cyst from ovary. **A**, Incision made around ovary near junction of cyst wall and normal ovarian tissue. Knife handle is convenient instrument for removal of cyst contents. **B**, Wound in ovary closed.

accurate alignment of fallopian tube segments. After surgery the fallopian tubes are shorter in length yet remain normal in other aspects. The laser may be adapted to the operating microscope, or the freehand approach may be used in tubal reconstructive surgery.

Procedural Considerations. The patient is in the supine position. The surgeon may place a Kahn, Calvin, Rubin, Hui, or Humi cannula or a pediatric Foley catheter into the uterine cavity for intraoperative chromotubation with diluted methylene blue or indigo carmine solution. Intraoperative chromotubation can also be achieved by applying a Buxton uterine clamp around the lower segment of the uterus and inserting an Angiocath catheter through the fundus into the cavity. A vaginal pack may be inserted to help elevate the uterus.

The basic abdominal gynecologic instrument set is required, with the addition of iris scissors (one curved and one straight), Adson forceps without teeth, Halsted mosquito hemostats, a set of Bowman lacrimal probes, Webster needle holders, Frazier suction tip, Kirschner retractor (if desired), and a Buxton uterine clamp (if desired).

Basic microsurgical instruments include microscissors (one curved and one straight), bayonet microscissors, jeweler's forceps, microforceps, fallopian tube forceps, petit-point mosquito hemostats, micro–needle holders (one curved and one straight), ball-tipped nerve hook, and glass or Teflon rods.

Accessory items include micro–needle electrodes, electrosurgical pencil, bipolar forceps with cord, irrigator, syringes and blunt needles for irrigation of the tissues, plastic or silastic tubing and connectors, diluted methylene blue or indigo carmine solution, diluted heparinized lactated Ringer's solution, microscope drape, microscope or operative loupes, ESU with monopolar and bipolar capabilities, and a video monitoring system (if desired).

Operative Procedure. Operative procedures for correction of postsurgical tubal occlusion are usually performed under the operating microscope. Other reconstructive procedures vary according to the nature of the pathologic condition of the tube and may be performed under the operating microscope or by use of operative loupes.

In microsurgery the surgeon must make sure that virtually no instruments are used in contact with the fallopian tube except those necessary to carry out the surgical technique. Microsurgery for infertility requires the use of specialized and delicate instruments. Each of these instruments is designed to permit gentle, atraumatic handling of tissues and prevent abrasions, lacerations, and vascular damage.

The tissues must be continually irrigated to prevent drying of the serosal surfaces. Lactated Ringer's solution alone or with heparin added may be used as the irrigating solution. Meticulous hemostasis is required in microsurgery. Irrigation is used to identify bleeding vessels or tissues. Hemostasis can be achieved by electrocoagulation with a micro–needle electrode or very fine bipolar forceps. When a CO_2 laser beam is used, the smoke from laser vaporization should be evacuated to prevent carbon deposits on the tissue.

Tubal Ligation

Tubal ligation is interruption of fallopian tube continuity, resulting in sterilization of the patient. In general, the indication for sterilization depends entirely on the desire of the patient. Certain medical indications and concern for the psychosocial needs of the patient are factors, and occasionally an obstetric indication exists, such as inherited fetal deformity. However, at least in the United States, sterilization is entirely a voluntary procedure. Depending on state law, a sterilization permit may have to be signed by the husband. Thorough presurgical counseling is needed for the patient and her husband or significant other because this procedure is not predictably reversible. Patients may elect to have the procedure performed on an ambulatory surgery basis at a time that is convenient for them.

Tubal ligation may be performed during or soon after delivery. This timing usually does not delay the normal discharge time for the patient. An objection to this practice is that the danger of hemorrhage still exists soon after delivery. With a vaginal delivery, tubal ligation is done on the first or second postpartum day. If a cesarean delivery is done, the tubes may be ligated at that time.

Operative Procedure. Many surgical methods and techniques are available for tubal ligation. The objective of each method is to achieve complete closure of the fallopian tube so that conception is prevented. When a segment of each fallopian tube is excised, it is preserved for pathologic examination. General surgical considerations are directed to excising a section of

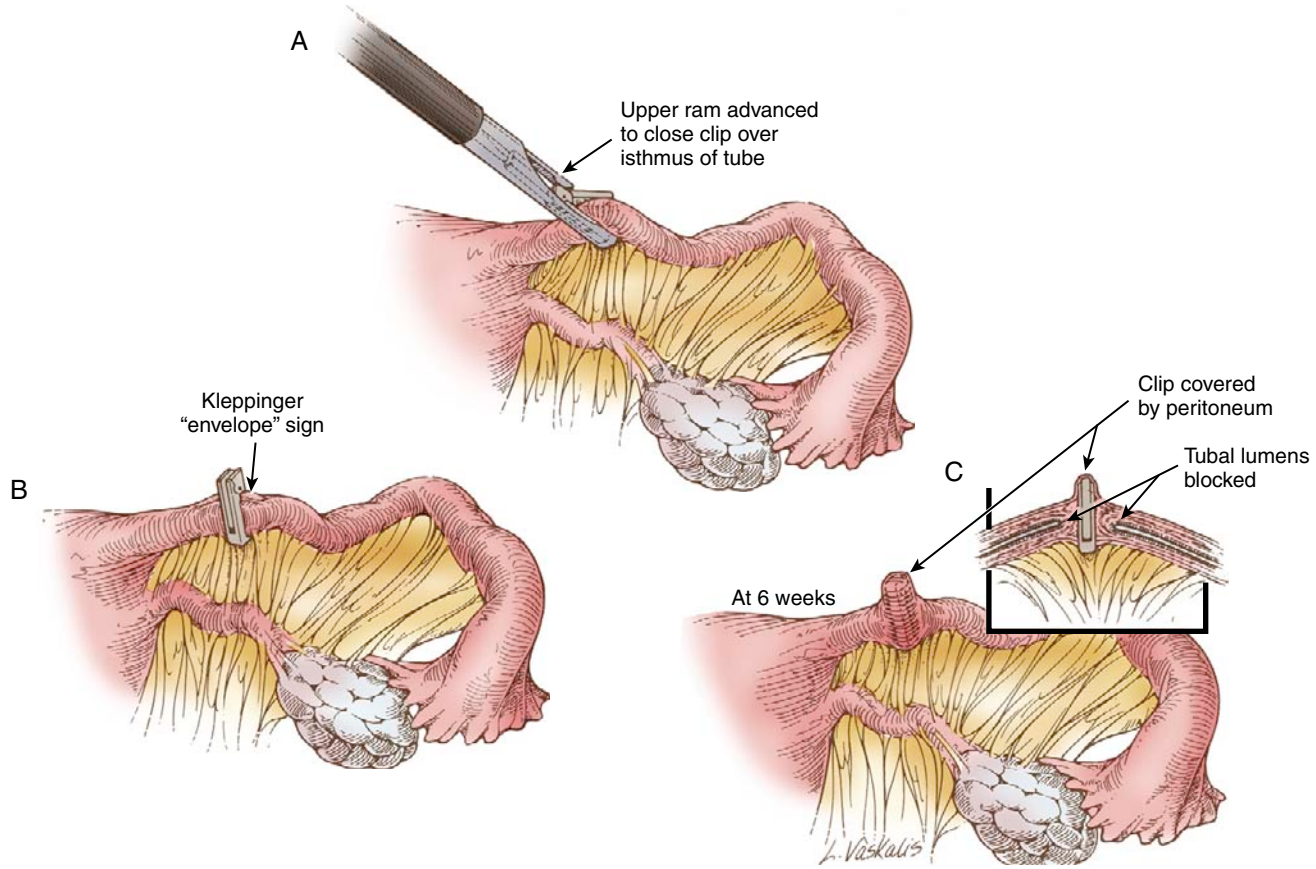


FIGURE 13-46 Spring clip. **A**, Isthmic portion (first 2 to 3 cm of tube) is maneuvered into the open jaws of the clip until it is snug against the hinge. **B**, Closing the clip will create the Kleppinger envelope sign—a fold of tubal peritoneum in the hinge of the clip. **C**, Failure to get the clip completely across the isthmus may result in pregnancy. Some surgeons routinely use two clips close together on each tube.

each fallopian tube, ligating the severed ends, achieving hemostasis, and incorporating the proximal stump within layers of the mesosalpinx. Another approach, involving insertion of an expandable spring coil into the fallopian tube to mechanically block it, is accomplished hysteroscopically via the transcervical route. The device is made from titanium, stainless steel, nickel, and Dacron fibers. Ultimately the device provides an inflammatory response and fibrosis of the intramural tubal lumen over a 3-month period (Hastings-Tolsma et al, 2006).

LAPAROSCOPIC TUBAL OCCLUSION

1. The operative approach is the same as that for laparoscopy.
2. An accessory suprapubic incision may be made for the occluding instrument.
3. Sterilization may take place by thermal coagulation or by placement of a spring clip or silastic band after the tube has been identified and isolated in the grasping forceps.
   a. Bipolar coagulation occurs when electrical current passes only through the tube from prong to prong. At least 3 cm of the tube is destroyed, which therefore prevents spontaneous recanalization. It has been recommended that the tube be grasped at least 2 to 3 cm away from the uterocornual junction at the time of this procedure so that a stump of isthmus remains to absorb the intrauterine fluid under pressure and minimize fistula formation, which could result in an ectopic pregnancy for the patient in the future.
   b. The *spring clip* occludes the isthmus of the tube by two plastic jaws (Figure 13-46, *A* and *B*). The tube is compressed by a stainless-steel spring that presses the jaws together. Spring clip application requires careful surgical technique to ensure that the clip is completely across the isthmus of the tube (Figure 13-46, *C*). Some surgeons apply two spring clips positioned close together on each tube when using this approach.
   c. With a *silastic band,* the tube is drawn 1.5 cm into a 0.5-cm diameter metal cylinder, which destroys approximately 3 cm of the tube (Figure 13-47, *A*). A silastic ring stretched on the outside of the cylinder is released to form an occlusion (Figure 13-47, *B*). Over time, about 3 cm of the constricted tube undergoes necrosis and the tubes separate (Figure 13-47, *C*).

MINI-LAPAROTOMY APPROACH

1. The surgeon creates a 2-cm transverse incision above the pubic hairline.
2. A large bivalved speculum may be placed through the incision and into the peritoneal cavity. The large Graves bivalve speculum serves as a small abdominal retractor and permits easy access to the tubes.
3. Spring clips or silastic bands can be applied, or the original Pomeroy method of ligation can be carried out. The Pomeroy technique provides a tissue specimen of each tube.

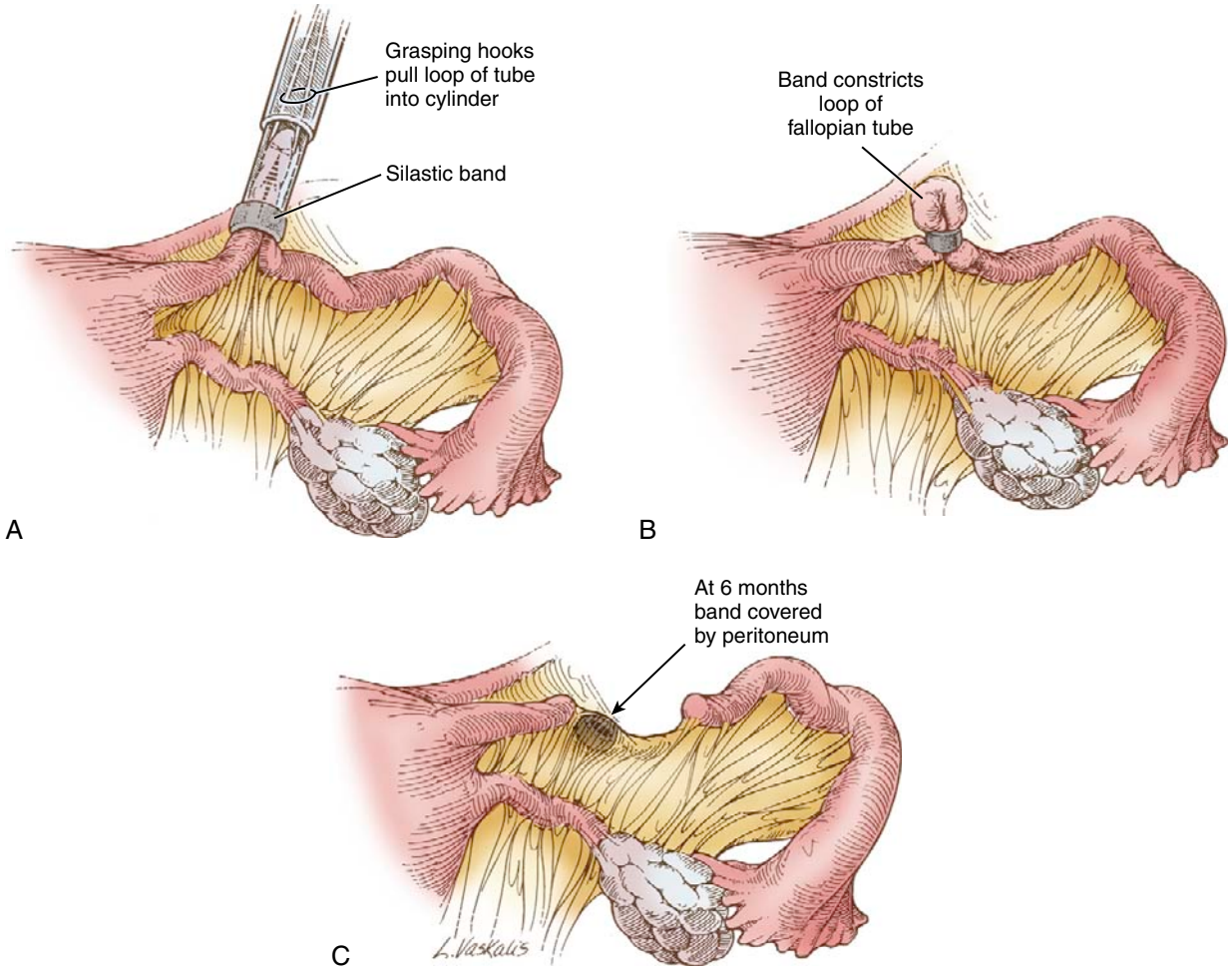


FIGURE 13-47 Silastic band. **A**, About 3 cm of tube is drawn into a 5-mm cylinder over which a silastic band has been stretched. **B**, Releasing the band constricts the knuckle of tube with eventual necrosis. **C**, As with the Pomeroy technique, 6 months later the stumps are about 3 cm apart.

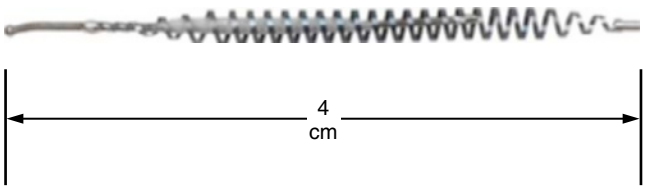


FIGURE 13-48 Essure implant.

Suture material is tied around each tube, and a section of tube is removed. Over time, the tubes separate, destroying the passage between the ovary and the uterus.

TRANSCERVICAL APPROACH (ESSURE)

1. The operative approach is the same as that for hysteroscopy.
2. The uterus is distended, and the ostia are visualized.
3. The spring device (Figure 13-48) is placed on the tip of the plastic carrier provided in the kit and inserted through the hysteroscope's channel.
4. The device is guided to the tubal ostium, and the handle for the carrying device is stabilized.
5. The device is released from the plastic carrier, and the coil is deployed as the handle is retracted (Figure 13-49).
6. The surgeon counts the number of coils trailing into the uterine cavity. There should be three to eight visible coils (Figure 13-50).
7. The sequence is repeated for the remaining fallopian tube.

ASSISTED REPRODUCTIVE THERAPIES FOR INFERTILITY

Infertility is a condition that affects approximately 10% of reproductive-age couples. Infertility implies subfertility—a prolonged time to conceive—as opposed to sterility, which means inability to conceive (Lowdermilk, 2007b). Infertility is referred to as primary when it occurs without a prior pregnancy and secondary if it occurs after a successful conception. Facing infertility is an emotionally stressful process for both partners. Treatment of infertility is multidimensional and may involve medical as well as surgical interventions. Often by the time a woman presents in the perioperative setting for a procedure related to infertility, she and her partner have undergone many months or years of testing and medical interventions. Individuals with infertility use various coping strategies, and the perioperative nurse needs to be aware of these in providing supportive care.

Eighty percent of couples that do not have fertility issues achieve conception within 1 year. A couple is considered infertile if they have not conceived after attempting for 1 year, although this landmark may be modified because of select clinical circumstances. Both partners undergo extensive testing to identify possible organic or functional causes for their infertility. Identifiable conditions contributing to infertility are attributed to the female partner in 50% of couples, the male partner in 18.5% of couples, and both partners in 18.4% of couples (Robins and Carson, 2008).

The term *assisted reproductive therapies (ARTs)* refers to the multiple options couples may select to assist them in the reproduction process. ARTs are described briefly in Table 13-3. Techniques for ART have evolved over time, with the majority of interventions conducted in the physician's office. The use of ARTs has made it possible for women to successfully conceive and have children when they are older than 40.

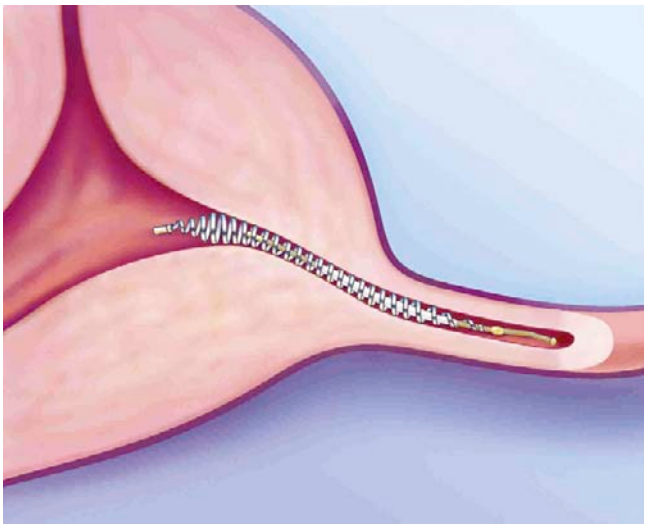


FIGURE 13-49 Essure device placed in fallopian tube.

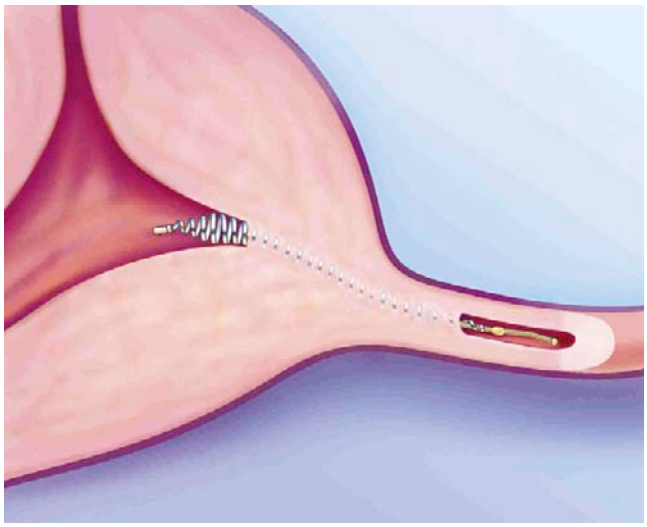


FIGURE 13-50 Essure device after carrier detached. Note coils in uterine cavity.

OBSTETRIC SURGERY

Providing safe nursing care for the perioperative patient is the goal of every registered nurse. The interventions necessary to reach that goal intensify in the pregnant woman who presents for surgery. The team is now faced with the challenge of caring for at least two patients, the mother and her child (Risk Reduction Strategies).

RISK REDUCTION STRATEGIES

Preparation for Cardiac Arrest in the Pregnant Patient

Although rare, cardiopulmonary arrest does occur in the pregnant patient. Nurses can reduce risk to the patient and her infant through familiarity with resuscitation techniques for pregnant patients. Guidelines for cardiac arrest during pregnancy include the following:

AIRWAY

- Determine unresponsiveness.
- Activate the code team and obtain the automated cardiac defibrillator.
- Position the woman supine on a firm surface with a roll or wedge placed under the right hip to displace the uterus laterally off the great vessels; or position her laterally.
- Open the airway with the head tilt-chin lift maneuver.

BREATHING

- Determine breathlessness (look, listen, and feel).
- If the woman is not breathing, give two breaths, 1 second apart.

CIRCULATION

- Determine pulselessness by checking the carotid pulse.
- If there is no pulse, begin chest compressions at a rate of 100 per minute. Chest compressions may be performed slightly higher on the sternum if the uterus is enlarged enough to displace the diaphragm into a higher position. Check the pulse after 2 minutes; if the pulse is not present, continue CPR.

DEFIBRILLATION

- If defibrillation is necessary, the nurse should ensure the paddles are placed one rib space higher than usual because the heart is displaced slightly by the uterus.

If possible the fetus should be monitored during the cardiac arrest. If the fetus is delivered within 5 minutes of the arrest, intact neurologic survival (in fetuses of viable gestational age) is likely; beyond 15 minutes, impairment or death is likely.

Successful resuscitation may be associated with complications for the woman, including laceration of the liver, rupture of the spleen or uterus, hemothorax, hemoperitoneum, or fracture of the ribs or sternum. Fetal complications may include cardiac dysrhythmia or asystole associated with maternal defibrillation and medications, CNS depression related to antidysrhythmic medications and inadequate placental perfusion, possible hypoxemia, and acidosis.

If the resuscitation is successful, ongoing intensive monitoring, including fetal surveillance, is necessary as the woman is at increased risk for recurrent cardiac arrest and dysrhythmia. Fetal status and gestational age should be considered and used in decision-making regarding delivery or continuation of the pregnancy.

Modified from McAteer J: Medical-surgical problems in pregnancy. In Lowdermilk DL, Perry SE, editors: *Maternity and women's health care,* ed 9, St Louis, 2007, Mosby.

TABLE 13-3

Assisted Reproductive Therapies

Technology	Description	Use
Assisted hatching (AH)	The zona pellucida is micromanipulated chemically or mechanically to allow the embryo to hatch and attach to the uterine wall.	Recurrent miscarriage, failed IVF, advanced maternal age
In vitro fertilization embryo transfer (IVF-ET)	Follows in vitro fertilization. The fertilized ovum is implanted in the woman's uterus. Typically three embryos are transferred.	Tubal disease or blockage, endometriosis, unexplained infertility, cervical factors, immunity issues
Donor oocyte	Eggs are donated by an IVF procedure and the donated eggs are inseminated. Embryos are transferred into the recipient's uterus, which is hormonally prepared with estrogen/progesterone.	Early menopause, surgical removal of ovaries or congenitally absent ovaries, autosomal or sex-linked disorders, lack of fertilization in repeated IVF attempts because of subtle oocyte abnormalities or defects in oocyte-spermatozoa interaction
Donor embryo	A donated embryo is transferred to the uterus of an infertile woman.	Infertility not resolved by less aggressive forms of therapy; absence of ovaries; male partner azoospermic or severely compromised
Therapeutic donor insemination (TDI)	Donor sperm are used to inseminate the female partner.	Male partner azoospermic or has very low sperm count; couple has genetic defect; male partner has antisperm antibodies
Gamete intrafallopian transfer (GIFT)	Oocytes are retrieved from the ovary and mixed in a catheter with sperm. The solution is transferred into the fimbriated end of the tube for in situ fertilization.	Unexplained infertility with normal, patent fallopian tubes
Intracervical insemination (ICI)	Performed during a natural cycle or stimulated cycle. Sperm are placed inside the neck of the cervix by means of a catheter and syringe.	Immunity issues, desire or need to use donor sperm in otherwise fertile woman, male infertility, unexplained infertility
Intracytoplasmic sperm injection (ICSI)	Selection of single sperm injected directly into the egg to achieve fertilization.	Failed IVF, oligospermia, asthenospermia, obstructive azoospermia, immunity issues, failed vasectomy reversal
Intrauterine insemination (IUI)	Similar to ICI; performed during a natural cycle or stimulated cycle. Sperm are placed inside uterus by means of a catheter and syringe.	Immunity issues, desire or need to use donor sperm in otherwise fertile woman, male infertility, unexplained infertility; failure of ICI
In vitro fertilization (IVF)	Oocytes are retrieved from the ovary and fertilized with sperm in the laboratory and allowed to develop into embryos. Embryos are then transferred to the woman using a variety of techniques.	Tubal disease or blockage, severe male infertility, endometriosis, immunity issues, unexplained infertility, cervical factors
Zygote intrafallopian transfer (ZIFT)	In vitro fertilization is accomplished and embryo is placed in the fallopian tube during the zygote stage.	Unexplained infertility with normal, patent fallopian tubes

Modified from Lowdermilk DL: Infertility. In Lowdermilk DL, Perry SE, editors: *Maternity and women's health care,* ed 9, St Louis, 2007, Mosby.

Maternal changes in pregnancy increase as the gestation progresses and include hormonal fluctuations, mechanical changes to the viscera related to the enlarging uterus, increased metabolic and oxygen demands, and hemodynamic changes. The fetus also has unique metabolic and hemodynamic needs that must be considered. Hazards of performing surgery on the pregnant patient include fetal loss, fetal asphyxia, premature labor, premature rupture of the membranes, and thromboembolic events. Many medications used in the perioperative setting cross into the placental circulation on administration to the mother (Birnbach and Browne, 2005).

Special considerations for the obstetric surgical patient include continuous monitoring of the fetal heart rate, rapid induction for general anesthesia, and preparation for the possible use of tocolytics (e.g., medications to decrease uterine activity) to prevent labor (Surgical Pharmacology). Ready access to neonatal resuscitative drugs and equipment should be established when performing surgery on pregnant women in the second trimester and beyond. If permitted by the surgical approach, the pregnant woman should be positioned with a lateral tilt or with a wedge or pillow under her right hip to provide uterine displacement and relieve pressure on the maternal vena cava. This position promotes blood flow to the placenta.

Cervical Cerclage

Incompetence of the cervix is a condition characterized by habitual midtrimester spontaneous miscarriages. The condition is characterized by shortening of the length of the cervix (observed on ultrasound) and occasional funneling of the cervix. Surgical intervention is designed to prevent cervical dilation that results in the release of uterine contents. Introduced by Shirodkar in 1951, the cervical cerclage provides a mechanical closure to the cervix. Cerclage is most commonly

SURGICAL PHARMACOLOGY

Medications Used in Gynecology and Obstetrics

Part of safe perioperative patient care focuses on safe medication practices. Strategies for safe medication administration include standardizing medication labeling both on and off the surgical field, separating sound-alike and look-alike medications, and minimizing distractions.

In addition to practicing the "seven rights" (right patient, right drug, right time, right route, right dose, right documentation and right technique) for the medications he or she administers, the perioperative nurse must be familiar with medications administered to the patient by others (e.g., anesthesia providers, surgeons). Many of the medications used in gynecologic and obstetric surgery are unique to the specialty or have unique uses within the specialty. To be able to constantly modify the patient's plan of care as needed throughout the perioperative period, the perioperative nurse must be familiar with how these medications work, dosage ranges, adverse reactions, and nursing implications.

OXYTOCICS

Medications that increase motor activity within the uterus by hormonal stimulation or direct stimulation on the smooth muscles, usually resulting in uterine contractions. Used intraoperatively and postoperatively.

Medication	Perioperative Uses	Actions	Dosage/ Administration	Adverse Reactions	Nursing Considerations
Oxytocin (Pitocin)	Postabortion bleeding, postpartum bleeding, improvement of uterine contractility after cesarean delivery	Acts on uterine myofibril activity	Given IV only, 10-40 units per liter of fluid	Hypertonicity with tearing of the uterus	Monitor BP; assess for continued bleeding; monitor fundal response to drug.
Methylergonovine maleate (Methergine)	Postabortion bleeding, postpartum bleeding	Ergot alkaline that causes vasospasm of the coronary arteries and directly stimulates uterine muscle	May be given PO, IM, or IV; most frequent route in OR is IM; IM/IV dose is 0.2 mg; may be repeated q2-4hr for no more than a total of five doses	Nausea; cramping; vomiting; dizziness; diaphoresis; bradycardia; chest pain; tachycardia; pale, cool, and blotchy skin; facial swelling; increased uterine pain	Monitor BP; assess for continued bleeding; monitor fundal response to drug. Use cautiously in patients with heart disease, hepatitis, or renal insufficiency because of vasoconstrictive effect. Assess extremities for color, warmth, movement, and pain.
Dinoprostone (Cervidil)	Postabortion bleeding, postpartum bleeding	Prostaglandin that directly acts on the myometrium, causing softening of the cervix; causes myometrial contractions in the gravid uterus	May be administered as an endocervical gel, vaginal insert, or vaginal suppository	Vomiting, nausea, bradycardia, chills/shivering, diarrhea	Keep frozen and bring to room temperature just before use. Use caution when handling to prevent skin contact. Have the patient remain supine for 15-30 min after administration. Be prepared to treat nausea. Monitor BP; assess for continued bleeding; monitor fundal response to drug.

Continued

SURGICAL PHARMACOLOGY

Medications Used in Gynecology and Obstetrics—cont'd

TOCOLYTICS

Medications that decrease uterine contractility. Most commonly used in the perioperative setting during fetal surgery or in surgical procedures on pregnant females. May also be used in the postanesthesia care unit.

Medication	Perioperative Uses	Actions	Dosage/ Administration	Adverse Reactions	Nursing Considerations
Ritodrine (Yutopar)	Prevention of preterm labor	β-Adrenergic that inhibits uterine activity by relaxing smooth uterine muscle tissue	May be given PO or IV; IV dose is 0.05-0.1 mg/min	Shortness of breath, tachypnea, tachycardia, palpitations, chest pain, fluid retention, hypotension, nausea, vomiting	Monitor vital signs closely; be prepared to treat nausea. Have propranolol available to reverse cardiovascular effects.
Terbutaline (Brethine)	Prevention of preterm labor	Adrenergic agonist that stimulates β-adrenergic receptors, resulting in relaxation of uterine smooth muscle	May be given PO, Sub-Q, or IV; usual IV dose is 2.5-10 mcg/min; may increase gradually q15-20 min up to 17.5-30 mcg/min; PO dose is 2.5-10 mg q4-6hr	Tremors, anxiety, nervousness, drowsiness, headache, nausea, heartburn, dizziness; flushing and weakness	May decrease serum potassium levels. Assess baseline maternal heart rate and fetal heart rate. Provide emotional support to help ease anxiety.
Magnesium sulfate	Prevention of preterm labor, prevention/ treatment of convulsions caused by pregnancy-induced hypertension (preeclampsia/ eclampsia)	Relaxes smooth muscle of the uterus; blocks neuromuscular transmission to produce seizure control	Loading dose of 4-6 g diluted in 100 ml of IV fluid, given over 30-60 min; maintenance dose 2-4 g/hr	Reduced respiratory rate, decreased reflexes, decreased heart rate, hypotension, sedation	Test patellar reflexes before giving drug to determine baseline. Suppressed patellar reflexes may be sign of impending respiratory arrest. Monitor vital signs. Maintain accurate I&O. Ensure calcium gluconate is available to reverse magnesium sulfate toxicity.
ANTIMETABOLITES					
Medications that interrupt cell division. May be given intraoperatively or postoperatively.					
Methotrexate	Used in ectopic pregnancy and hydatidiform mole surgery to eradicate any remaining trophoblastic cells	Inhibits RNA, DNA, and protein synthesis in rapidly dividing cells	PO, IM, IV Most commonly given IM in perioperative setting (15-30 mg)	Nausea, vomiting, stomatitis, dizziness, blurred vision, photophobia, hepatotoxicity, nephrotoxicity	Encourage patient to maintain scrupulous oral hygiene; be prepared to treat nausea and vomiting. Review good handwashing practices with patient. Discuss need for weekly repeated lab studies to monitor hCG levels 2-8 wk after procedure.

SURGICAL PHARMACOLOGY

Medications Used in Gynecology and Obstetrics—cont'd

MISCELLANEOUS AGENTS

Medication	Perioperative Uses	Actions	Dosage/ Administration	Adverse Reactions	Nursing Considerations
Misoprostol (Cytotec)	Used for cervical ripening; may be used instead of dilation and evacuation (D&E) for missed or incomplete abortion (off-label use)	Synthetic prostaglandin that acts directly on uterine muscle	Oral, rectal, or intravaginal; available in 100 and 200 mcg tablets; oral dose for missed abortion: 600 mcg; cervical ripening: intravaginal, 25 mcg (¼ of 100-mcg tablet) 2-3 hr before procedure	Diarrhea, abdominal pain; headache, nausea, uterine rupture	May increase effect of oxytocin. Do not confuse with similarly named drugs Cytoxan and metoprolol. Not approved by FDA for use in cervical ripening or missed/ incomplete abortion but endorsed by ACOG. Should not be used in patients with prior cesarean delivery.
Estradiol cream (Estrace cream)	Lubricant for vaginal packing	Increased synthesis of RNA, DNA, protein in tissues; reduces release of gonadotropin hormone from the hypothalamus; reduces FSH and LH from the pituitary gland	Topical cream, 0.1 mg/g, intravaginally	Local irritation, vaginal discharge	Assess preoperatively for any sensitivity to topical estrogens. Do not use excessive amount of cream. Cream will liquefy from patient's body heat and may soil bedding.
Miconazole nitrate cream (Monistat)	Lubricant for vaginal packing, treatment of vulvovaginal candidiasis	Inhibits synthesis of ergosterol (an important component of fungal cell formation)	2% topical cream intravaginally	Local irritation, vaginal discharge	Assess preoperatively for any sensitivity to antifungals. Do not use excessive amount of cream. Cream will liquefy from patient's body heat and may soil bedding.
Sulfathiazole/ sulfacetamide/ sulfabenzamide cream (Triple Sulfa)	Lubricant for vaginal packing, treatment of *Gardnerella* vaginitis	Exerts bacteriostatic action by competitive antagonism of PABA (a component of folic acid synthesis)	Topical cream used intravaginally; concentration: sulfathiazole 3.42%, sulfacetamide 2.86%, and sulfabenzamide 3.7%	Local irritation, vaginal discharge, Stevens-Johnson syndrome	Assess preoperatively for any sensitivity to sulfa medications or derivatives. Do not use excessive amount of cream. Cream will liquefy from patient's body heat and may soil bedding.
Vasopressin (Pitressin)	Injected directly into uterus to decrease bleeding during hysterectomy	Causes vasoconstriction through direct stimulation of smooth muscle; pituitary hormone	20 units/ml to be diluted in injectable saline as directed by surgeon	Diaphoresis, circumoral pallor, wheezing, allergic reactions	Potential for confusion related to name. Do not confuse Pitressin with Pitocin! Monitor vital signs. Verify dilution with surgeon.
Methylene blue	Indicator dye: intraoperative hysterosal-pingogram; used to test patency of ureters	Converts ferrous iron to methemoglobin	0.1-0.2% ml/kg given IV push, slowly	Hypertension, dizziness, staining of skin, discoloration of urine or stool	Warn patient about urine and stool discoloration. Methylene blue stains can be removed with mild bleach solution.

ACOG, American College of Obstetricians and Gynecologists; *BP,* blood pressure; *DNA,* deoxyribonucleic acid; *FDA,* Food and Drug Administration; *FSH,* follicle-stimulating hormone; *hCG,* human chorionic gonadotropin; *I&O,* intake and output; *IM,* intramuscular; *IV,* intravascular; *LH,* luteinizing hormone; *PABA, para*-aminobenzoic acid; *PO,* by mouth; *RNA,* ribonucleic acid; *Sub-Q,* subcutaneous.

Modified from Hodgson BB, Kizior RJ: *Saunders nursing drug handbook 2010,* St Louis, 2010, Saunders; Skidmore-Roth L: *Mosby's drug guide for nurses with 2010 update,* ed 8, St Louis, 2010, Mosby; Wanzer LJ: Perioperative initiatives for medication safety, *AORN J* 82(4):663-666, 2005; Zhang J et al: A comparison of medical management with misoprostol and surgical management for early pregnancy failure, *N Engl J Med* 353:761-769, 2005.

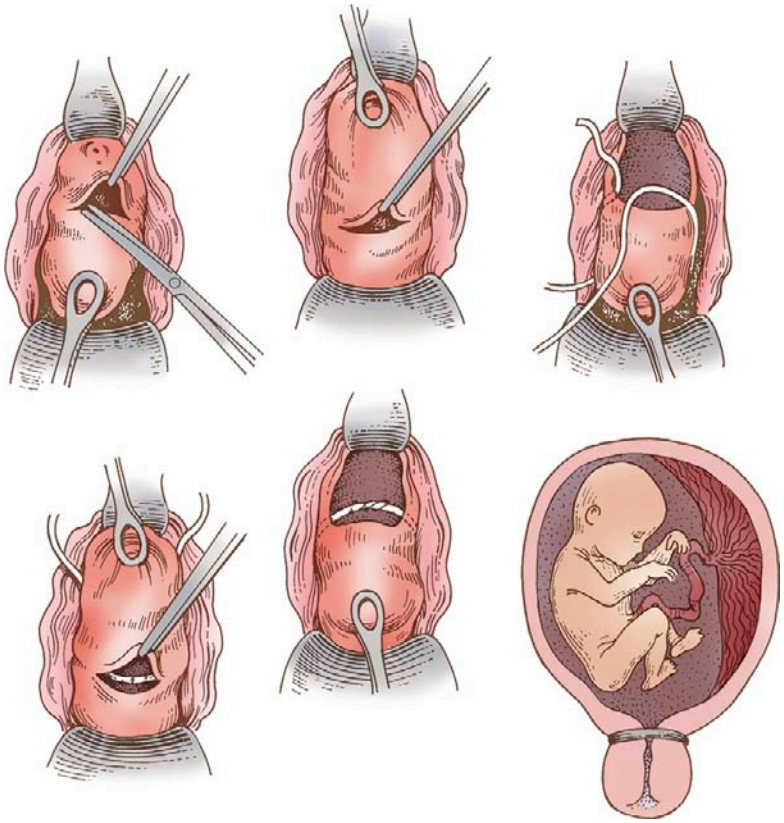


FIGURE 13-51 Principles of Shirodkar operation for treatment of incompetent internal cervical os during pregnancy.

accomplished by way of the vaginal approach (Shirodkar and McDonald approaches) or, much less commonly, the abdominal or laparoscopic approach. The Shirodkar technique involves the *submucosal* placement of a purse-string type of ligature of Mersilene, Dacron tape, heavy nylon suture, or plastic-covered braided-steel suture at the level of the internal os to close it (Genovese, 2007). The McDonald cerclage uses a secured tie or tape placed horizontally and vertically across the cervix. The vaginal cerclage is generally removed in an office procedure when the woman reaches the thirty-seventh week of gestation, or the child may be delivered by cesarean.

Procedural Considerations—Vaginal Approach. Gentle vaginal preparation is carried out. The instrumentation includes the basic vaginal instrument set, with the addition of right and left Deschamps ligature carriers, trocar needles, sutures for the internal os, and the surgeon's preference for closure of the mucosal incisions.

Operative Procedure—Shirodkar/McDonald

1. Anterior and posterior vaginal retractors are placed, and the cervix is pulled down with smooth ovum or sponge-holding forceps. With smooth tissue forceps and dissecting scissors, the mucosa over the anterior cervix is opened to permit the bladder to be pushed back (Figure 13-51).
2. The surgeon lifts the cervix and incises the posterior vaginal mucosa at the level of the peritoneal reflection. The corners of the anterior and posterior incisions are bilaterally approximated in the area of the lateral mucosa with curved tonsil or Allis forceps.
3. The prepared ligature is placed at the desired level by passage of the material through the approximated tissue and is drawn tight posteriorly to close the cervix. The suture material for the ligature is then tied. It is not necessary to suture the ligature to the underlying tissues. The suture material used for this ligation is 5-mm Dacron or Mersilene tape. The anterior and posterior mucosal incisions are usually closed with 2-0 absorbable suture to complete the procedure.
4. The McDonald cerclage is performed in a similar manner, using the same instrumentation, supplies, and preparation. The suture is not buried in the submucosa in the McDonald technique (Figure 13-52).

Procedural Considerations—Abdominal Approach. The transabdominal cerclage is reserved for select women who have a cervix that is so short or damaged that the vaginal approach is not feasible. A vaginal and abdominal prep is performed. A Foley catheter may be placed to ensure the urinary bladder remains decompressed. A basic vaginal set and an abdominal set are needed for instrumentation. Sutures used for the transabdominal cerclage are identical to those used in the vaginal approach.

Operative Procedure—Abdominal Approach

1. The abdomen is opened and the viscera retracted. The Trendelenburg's position may be used to facilitate exposure.
2. The suture material or tape is placed around the uterine isthmus medial to the uterine vessels and fixed to the anterior isthmus, to Mackenrodt's ligaments, and to the insertions of the uterosacral ligaments.

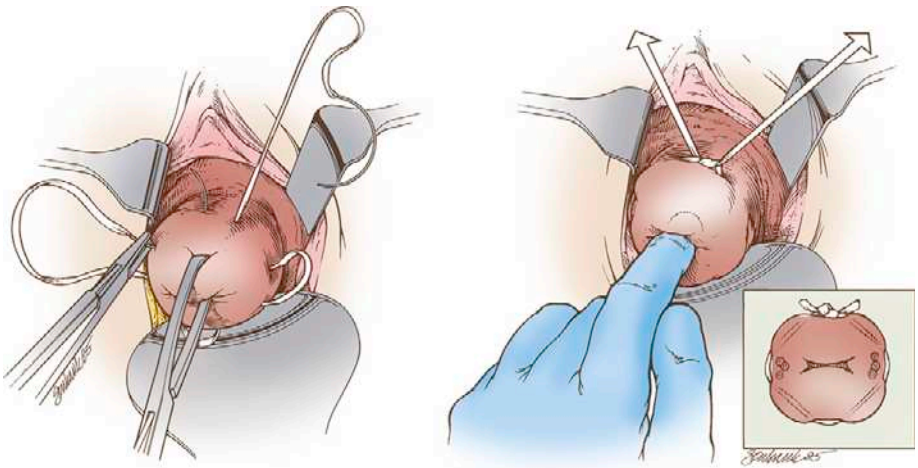


FIGURE 13-52 McDonald cerclage.

3. The abdominal wound is closed as described for laparotomy closure (see Chapter 10).
4. Abdominal dressings and a perineal pad are applied.

Procedural Considerations—Laparoscopic Approach. The laparoscopic approach may be associated with decreased postoperative pain and morbidity compared with the laparotomy approach. Standard laparoscopic equipment commonly used in gynecologic procedures is required.

Operative Procedure—Laparoscopic Approach

1. The laparoscopic camera and ports are placed for a standard laparoscopic approach, and pneumoperitoneum is established.
2. The bladder peritoneum is opened at the level of the uterine isthmus.
3. The surgeon creates a window through the broad ligament medially to the uterine vessels at the level of the internal os.
4. A strip of polypropylene mesh is placed retroperitoneally through the window circumferentially around the isthmus above the cardinal and sacrouterine ligaments.
5. The mesh is anchored with a nonabsorbable suture.
6. The laparoscopic instruments are removed, and the wounds are closed.

ABDOMINAL SURGERY DURING PREGNANCY

The incidence of the immediate need for abdominal surgery occurs as frequently among pregnant women as among nonpregnant women of childbearing ages. Diagnosis of the abdominal problems in the pregnant woman is challenging because of the enlarged uterus and displaced organs. Mild leukocytosis and increased levels of alkaline phosphatase and amylase are normal during pregnancy and may also indicate surgical intraperitoneal processes. Abnormally high or rising laboratory values should be noted. Radiographic evaluation is contraindicated in most instances during pregnancy (McAteer, 2007).

Laparotomy or laparoscopy may be required for conditions such as appendicitis and intestinal obstruction. Appendicitis is the most common nonobstetric surgical condition that complicates pregnancy and occurs with equal frequency in each of the trimesters and the postpartum period in approximately 1 in every 2000 pregnancies (McAteer, 2007).

Fetal Surgery

Developments in prenatal diagnosis have progressed to the point where clinicians may consider the fetus to be the patient. Serious congenital anomaly is diagnosable by ultrasonography, alpha-fetoprotein specimen, amniocentesis, chorionic villi sampling, or percutaneous umbilical blood sampling. When an anomaly is identified, a multidisciplinary team reviews the mother's complete medical history and prenatal ultrasonograms.

Depending on the anomaly and the immediate danger posed to the fetus, the family will be counseled on their options. If no treatment is available and the condition is fatal, the family may elect to terminate the pregnancy if it is earlier than 24 weeks of gestation or may choose to carry the fetus to term. If postnatal correction is possible, the family may consider terminating the pregnancy or may continue the pregnancy with monitoring, hoping for successful correction after delivery. Lethal and nonlethal anomalies may be treated with prenatal surgery. If a family elects this option, both the mother and the fetus are evaluated to determine if they will be acceptable surgical candidates. Fetal surgery was previously confined to treatment of anomalies that would result in fetal death before term or during the immediate postnatal period, but it now includes treatment of nonlethal conditions in selected cases. Conditions treated by fetal surgery include congenital diaphragmatic hernia (Figure 13-53), congenital cystic adenomatoid malformation, bronchopulmonary sequestration, obstructive uropathy, sacrococcygeal teratomas (Figure 13-54), twin-to-twin transfusion syndrome, thoracic lesions, twin reversed arterial perfusion syndrome, monochorionic twins, discordant twins, and myelomeningocele (Figure 13-55) (Jancelewicz and Harrison, 2009). Fetal surgery may be accomplished by way of laparotomy and hysterotomy or, in some instances, with endoscopic techniques.

Postoperatively, preterm labor is of great concern, and uterine contractions, fetal heart rate, and fetal electrocardiogram (ECG) are closely assessed. Tocolytic medications are titrated to control uterine contractions. The mother is educated in self-monitoring of uterine contractions, and tocolytic therapy

is continued on an outpatient basis. Frequent fetal ultrasonic scans are performed postoperatively to monitor fetal growth, amniotic fluid volume, and the adequacy of the surgical repair. Fetal surgery may also place the mother at risk for uterine rupture in subsequent pregnancies.

Cesarean Birth

Cesarean birth, also referred to as *cesarean section* or *C-section,* is delivery of the fetus or fetuses through abdominal (laparotomy) and uterine (hysterotomy) incisions. In general, cesarean birth is employed whenever further delay in delivery may seriously compromise the fetus, the mother, or both, and vaginal delivery cannot be safely accomplished. In recent years the use of cesarean birth has increased as a result of fetal monitoring, fetal scalp blood sampling for pH determination, and the widespread emphasis on recognition of actual or suspected impairment of fetal well-being if delivery was delayed or vaginal delivery attempted. Reasons for cesarean birth include failure to progress, malposition and malpresentation, cephalopelvic disproportion, abruptio placentae, toxemia, fetal distress, uterine dysfunction, placenta previa, prolapsed cord, previous pelvic surgery, cervical dystocia, active herpes progenitalis, and diabetes. Multiple pregnancies may also be an indication for cesarean delivery. In certain situations, and after appropriate counseling, elective cesarean delivery may be a medically acceptable option. Thus cesarean births may be classified as primary (woman's first cesarean), repeat (indicates a previous cesarean birth), elective (a scheduled procedure in either of the previous categories or at maternal request), or emergency (there is an immediate need for intervention) (Roberts and Mangan, 2009).

Cesarean delivery is ranked as the second most frequently performed major surgical operation in the United States. Approximately 1,479,646 cesarean sections were performed in 2007 (HCUPnet, 2007). Rates have decreased slightly because of increased use of labor trials and vaginal birth after cesarean birth (VBAC) in selected patients.

Cesarean delivery may take place in the obstetric labor and delivery suite or in the OR suite. Patients about to undergo cesarean birth need careful assessment and emotional support. Because cesarean birth frequently involves emergency situations, the mother may express grave concern for the infant's well-being. If the mother has participated in childbirth classes, she may believe that she has failed in some way. The perioperative nurse must be aware of the psychologic as well as physiologic needs of this patient population. Mothers may choose to remain awake after administration of a regional anesthetic; the mother's birthing partner may be permitted to accompany and support her in the OR and witness the birth (based on hospital policy). The birthing partner may need the perioperative nurse's assistance in preparing for the delivery by washing hands and donning scrub attire or a protective gown. The perioperative nurse may need to reassure and encourage the birthing partner to coach and lend support to the mother during this intensely stressful time. The birthing partner can be included in the bonding process that is initiated at birth.

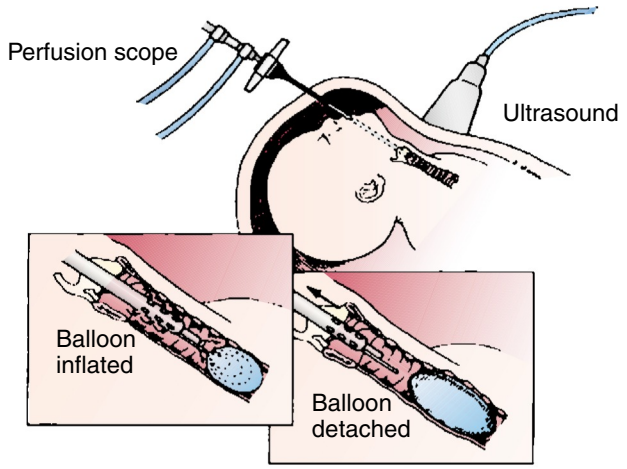


FIGURE 13-53 Fetal surgery for congenital diaphragmatic hernia. The trachea is isolated in preparation of hemoclip placement.

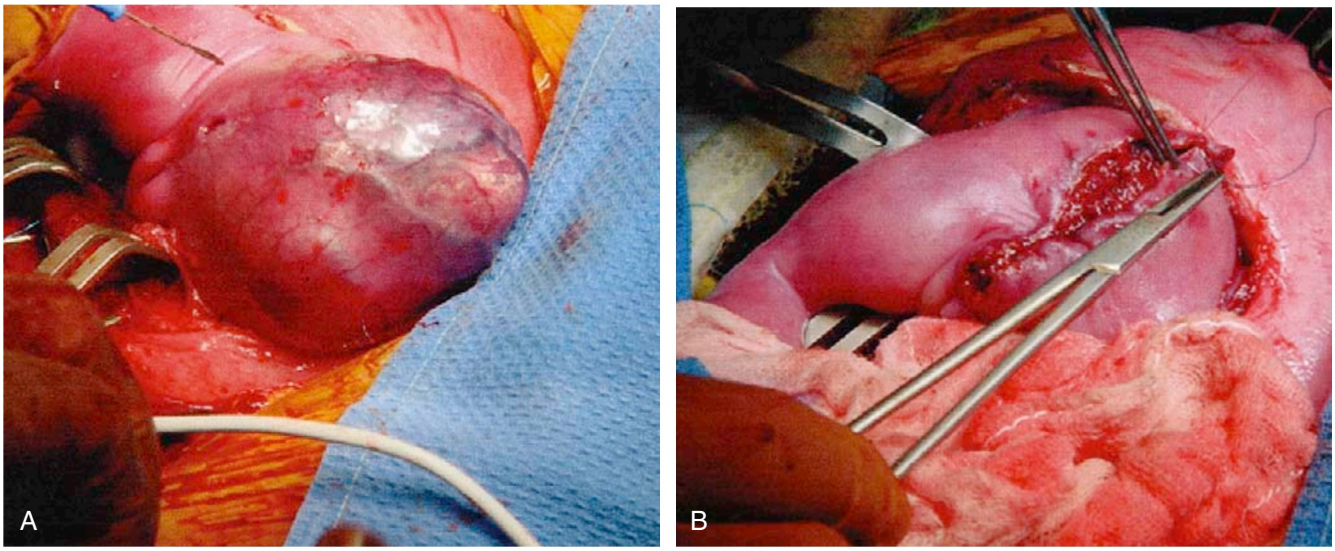


FIGURE 13-54 **A**, Start of fetal resection of a sacrococcygeal teratoma at 21 weeks of gestation. **B**, Closure of the defect.

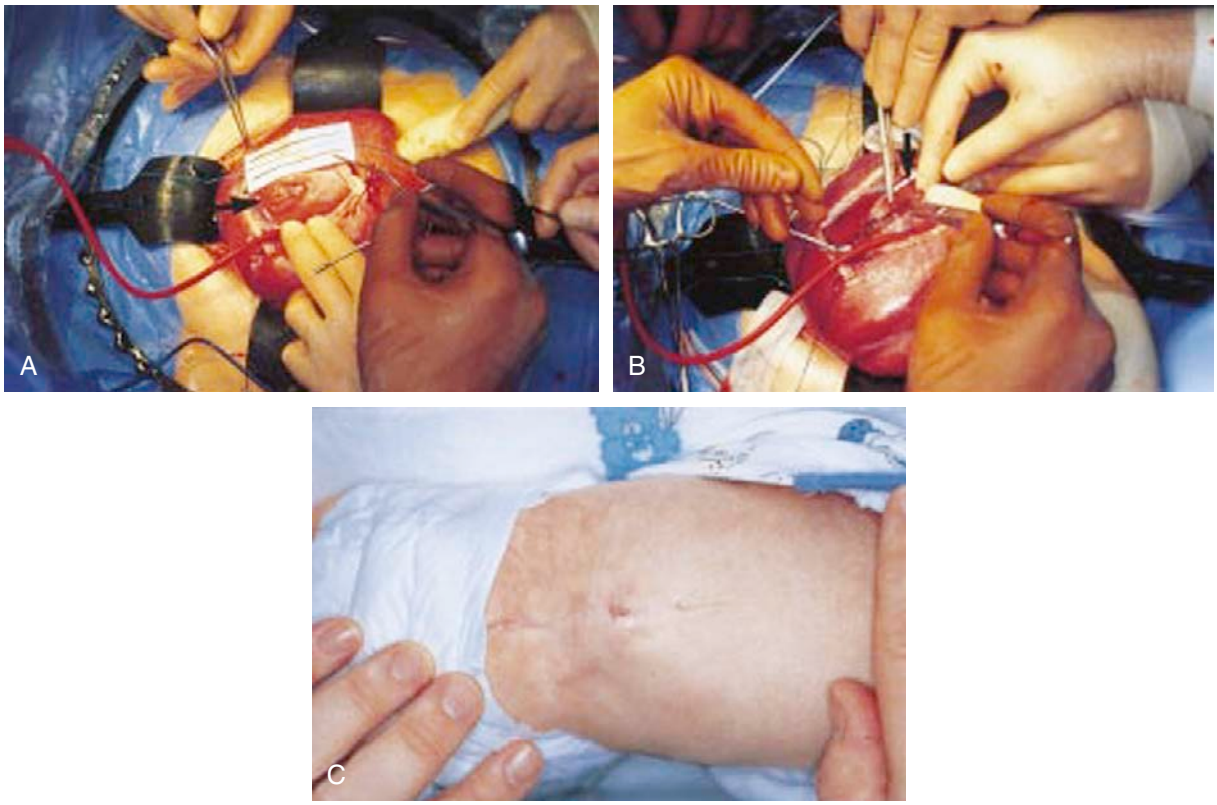


FIGURE 13-55 **A**, Myelomeningocele. **B**, Uterus is opened over defect. **C**, Myelomeningocele repair completed, appearance postdelivery.

The mother, if awake and stable, is shown and encouraged to hold the infant. The perioperative nurse promotes a positive family-oriented experience.

If the cesarean delivery is performed as an emergency, the family-oriented approach may not be feasible. In this emergency situation, the mother's support persons need to be directed to the surgical waiting area, where information will be communicated regarding the condition of the mother and infant. Support persons may then be able to accompany the infant as he or she is transferred to the nursery. In an emergency cesarean birth, certain perioperative procedures may be omitted, such as an initial surgical count. When this occurs, an abdominal x-ray is usually completed before the patient leaves the OR (Roberts and Mangan, 2009). The perioperative nurse should follow the institution's protocol for documenting the x-ray and its results, along with the reasons why the initial count was omitted.

A complication that may occur in conjunction with a cesarean delivery is amniotic fluid embolism. The perioperative nurse must be familiar with this complication and recommended treatment to resolve it (Rapid Response Team box).

Procedural Considerations. The patient should be in a supine position with elevation of the right side to displace the uterus and prevent aortocaval compression. Bony prominences are padded, and the patient is positioned in good body alignment with a safety strap above the knees. The perioperative nurse may assist the anesthesia provider with the administration of a regional anesthetic before placing the patient in the supine position. Throughout this process, maternal vital signs and fetal heart tones are monitored and recorded per institutional protocol.

If a general anesthetic is to be employed, all preparations—including skin prep, bladder drainage, draping, suction connection, counts, and gowning and gloving of all scrubbed personnel—are done before induction. In many hospitals, healthcare providers qualified to deliver newborn care and resuscitation are in attendance for the delivery. A radiant warmer and resuscitative equipment for immediate postdelivery care of the infant are available in the OR because these infants are considered to be at risk until there is evidence of physiologic stability.

The skin is prepped as for abdominal surgery. The vagina is not prepped. An indwelling urinary catheter is inserted. Instrumentation includes the basic abdominal gynecologic set, with the addition of Lister bandage scissors, Foerster sponge-holding (ring) forceps, Pennington forceps, cord clamps, a DeLee retractor, delivery forceps, a head extractor (if desired), laboratory tubes for cord blood, a drain (optional), and a bulb syringe.

Operative Procedure

1. The surgeon makes an infraumbilical vertical incision or lower transverse Pfannenstiel incision. The incision should be just long enough to allow the infant to be delivered without difficulty. Therefore the length of the incision varies with the estimated size of the fetus.
2. The abdominal wall is opened in layers. The rectus and pyramidalis muscles are separated in the midline by sharp and blunt dissection to expose the underlying transversalis fascia and peritoneum.

RAPID RESPONSE TEAM

Rapid response systems, endorsed by the American College of Obstetricians and Gynecologists, include case detection that triggers a crisis team response, and provision of a readily available response team. Within the OR setting, dedicated facility rapid response teams may or may not respond to perioperative emergencies, but in the case of obstetric emergencies, it may be necessary to summon a medical emergency team with experience in perinatal care. Perioperative nurses can positively impact outcomes by recognizing situations where early intervention is essential to prevent maternal morbidity. Amniotic fluid embolism (AFE) is an example of a situation that requires early recognition and swift action to save the mother and her child. Perioperative nurses may be responsible to summon an obstetric rapid response team for AFE if involved in cesarean section or assisting with a complicated vaginal delivery in the OR, or may be involved in assisting in the treatment of AFE in the labor and delivery department.

Although uncommon, AFE occurs when amniotic fluid containing particles of debris (e.g., hair, skin, vernix, meconium) enters the maternal circulation. The woman's pulmonary vessels become occluded and respiratory distress and circulatory collapse with coagulopathy may ensue. AFE can transpire at any point during labor and delivery and occurs in 7.7 per 100,000 births with a fatality rate between 21.6% and 37%.

The most common symptom of AFE is acute dyspnea followed by severe hypotension. Risk factors for AFE include multiparity, advanced maternal age, male fetus, cesarean section or operative vaginal delivery, abruptio placentae, placenta previa, and cervical laceration or uterine rupture. Emergency interventions are summarized below:

- Administer oxygen by face mask (8-10 L/min) or Ambu bag with 100% oxygen.
- Prepare for mechanical intubation and ventilation.
- Initiate or assist with cardiopulmonary resuscitation. Tilt the pregnant woman 30 degrees to the left to displace the uterus.
- Administer IV fluids.
- Administer blood: packed cells, fresh frozen plasma.
- Insert indwelling catheter and monitor urine output.
- Correct coagulation failure.
- Monitor fetal and maternal status.

Newer treatment modalities for AFE that may be more easily accessed in the OR include the following:

- Cardiopulmonary bypass
- Cell salvage
- Extracorporeal membrane oxygenation
- Intra-aortic balloon counterpulsation
- Invasive cardiac and hemodynamic monitoring
- Nitric oxygen therapy
- Transesophageal echocardiograpy
- Ventricular assist device

Modified from Dobbenga-Rhodes YA: Responding to amniotic fluid embolism, *AORN J* 89(6):1079-1088, 2009; Gosman GG et al: Introduction of an obstetric-specific medical emergency team for obstetric crises: implementation and experience, *Am J Obstet Gynecol* 198:367e1-367e7, 2008; Piotrowski KA: Labor and birth complications. In Lowdermilk DL, Perry SE, editors: *Maternity and women's health care,* ed 9, St Louis, 2007, Mosby.

3. The peritoneum is elevated with two Crile hemostats about 2 cm apart. The peritoneum between the two clamps is palpated to rule out the inclusion of bowel, omentum, or bladder. The surgeon opens the peritoneum and enters the abdominal cavity.
4. Bleeding sites anywhere in the abdominal incision may be clamped but not ligated until later, unless the clamps obstruct exposure. When the patient has been administered a general anesthetic, speed is important to prevent an anesthetized infant. The ESU may be used for hemostasis, especially if the patient is awake and a regional anesthetic has been administered.
5. The surgeon quickly palpates the uterus to determine the size and presenting part of the fetus as well as the direction and degree of rotation of the uterus.
6. The reflection of the peritoneum (serosa) above the upper margin of the bladder and overlying the anterior lower uterine segment is gently separated by sharp and blunt dissection.
7. The developed bladder flap is held downward beneath the symphysis with a bladder retractor such as the DeLee.
8. The uterus is opened with a knife through the lower uterine segment about 2 cm above the bladder flap. Once the uterus is opened, the incision can be extended by cutting laterally with a large bandage scissors or by simply spreading the incision by means of lateral pressure applied with each index finger when the lower uterine segment is thin.
9. The presenting membranes are incised. Suction is imperative here, and many surgeons prefer no suction tip (only the large, open end of the suction tubing) during the expulsion and suctioning of amniotic fluid.

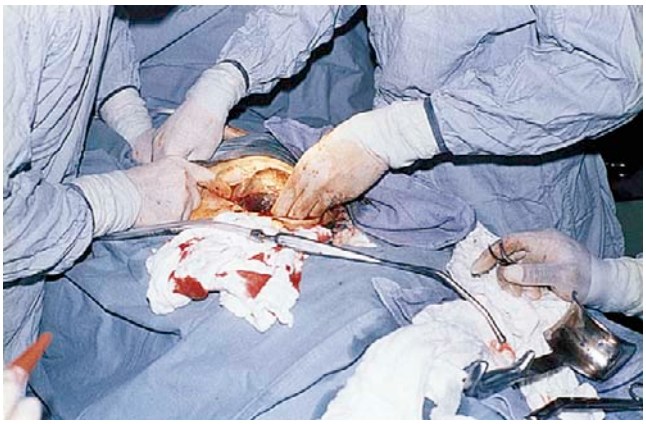


FIGURE 13-56 Fundal pressure applied. Infant's head emerging from hysterotomy.

10. All retractors are removed. The fetal head is gently elevated, either manually or by use of obstetric forceps, through the incision, aided by transabdominal fundal pressure (Figure 13-56) to help expel the fetus.
11. As soon as the head is delivered, a bulb syringe or aspirator tip is used to aspirate the exposed nares and mouth to minimize aspiration of amniotic fluid and its contents.
12. Oxytocin (20 units per liter of fluid or as directed by the surgeon) may be administered intravenously by the anesthesia provider as soon as the shoulders are delivered (or after delivery of the infant), so that the uterus contracts. This use of oxytocin minimizes blood loss.

FIGURE 13-57 Cord clamped in preparation for passing infant off field.

13. On delivery of the entire infant, the cord is clamped and cut (Figure 13-57), and the infant is given to the member of the team who is responsible for resuscitation efforts as needed. A sterile gown or sheet should be provided to the individual receiving the infant to avoid any break in aseptic technique and to maintain Standard Precautions during transfer of the infant.
14. The edges of the uterine incision are promptly clamped with Péan forceps, ring forceps, or Pennington clamps.
15. The placenta is delivered and placed in a large receptacle provided from the back table. Fundal massage or manual removal may be employed to hasten delivery of the placenta and reduce bleeding.
16. One or two separate layers of suture may be used to close the uterine incision. The perioperative nurse and surgical technologist conduct a count to verify no objects have been retained in the uterine cavity.
17. After determination that there is no further bleeding after closure of the uterine incision, the cut edges of the serosa overlying the uterus and bladder are approximated with a continuous suture.
18. Any blood, blood clots, vernix, and amniotic fluid in the pelvis and peritoneal cavity are removed. The fallopian tubes and ovaries are also inspected. Tubal ligation may be carried out at this point.
19. The peritoneum and each abdominal layer are closed.
20. After the wound is closed, the perioperative nurse massages the patient's fundus and cleans any clots that are expressed from the vagina.
21. The abdominal dressing and a perineal pad are applied.

REFERENCES

American Cancer Society (ACS): *Cancer facts and figures 2009*, Atlanta, 2009, The Society.

Andrews RT et al: Patient care and uterine artery embolization for leiomyomata, *J Vasc Interv Radiol* 20:S307–S311, 2009.

Aschkenazi SO, Goldberg RP: Female sexual function and the pelvic floor, *Expert Rev of Obstet Gynecol* 4(2):165–178, 2009.

Association of periOperative Registered Nurses: *Perioperative standards and recommended practices*, Denver, 2009, The Association.

Birnbach DJ, Browne I: Anesthesia for obstetrics, In Miller RD, editor: *Miller's anesthesia*, ed 6, Philadelphia, 2005, Churchill Livingstone.

Cheong Y, Ledger WL: Hysteroscopy and hysteroscopic surgery, *Obstet Gynaecol Repro Med* 17(4):99–104, 2007.

Denholm B: Tucking patient's arms and general positioning, *AORN J* 89(4):755–757, 2009.

Dooley M: Innovative treatments for abnormal uterine bleeding, *OR Nurse* 6(1):18–21, 2007.

Fanning J et al: Robotic radical hysterectomy, *Am J Obstet Gynecol* 198:649.e1–649.e4, 2008.

Faust RJ et al: Patient positioning, In Miller RD, editor: *Miller's anesthesia*, ed 6, Philadelphia, 2005, Churchill Livingstone.

Genovese SK: Antepartal hemorrhagic disorders, In Lowdermilk DL, Perry SE, editors: *Maternity and women's health care*, ed 9, St Louis, 2007, Mosby.

Goeser AL, Hasiak MJ: An overview of hysterectomy: Types of hysterectomy and methods of hysterectomy, US Pharmacist 33(9):HS11-HS20, 2008. available at www.medscape.com/viewarticle/582384_3. Accessed August 12, 2009.

Hastings-Tolsma M, et al: Essure: hysteroscopic sterilization, *J Midwifery Womens Health* 51:510–514, 2006.

Healthcare Cost and Utilization Project (HCUPnet): Statistics for U.S. community hospital stays, principle procedure based on clinical classifications software, 2007, available at www.hcup.ahrq.gov. Accessed June 26, 2009.

Jancelewicz T, Harrison MR: A history of fetal surgery, *Clin Perinatol* 36:227–236, 2009.

Jhingran A, Levenback C: Malignant diseases of the cervix: microinvasive and invasive carcinoma: diagnosis and management, In Katz VL et al: *Comprehensive gynecology*, ed 5, Philadelphia, 2007, Mosby.

Katz VL: Benign gynecologic lesions, In Katz VL, et al: *Comprehensive gynecology*, ed 5, Philadelphia, 2007, Mosby.

Lobo R: Ectopic pregnancy. In Katz VL et al: *Comprehensive gynecology*, ed 5, Philadelphia, 2007, Mosby.

Lowdermilk DL: Structural disorders and neoplasms of the reproductive system. In Lowdermilk DL, Perry SE: Maternity and women's health care, ed 9, St Louis, 2007a, Mosby.

Lowdermilk DL: Infertility. In Lowdermilk DL, Perry SE: Maternity and women's health care, ed 9, St Louis, 2007b, Mosby.

McAteer J: Medical-surgical problems in pregnancy. In Lowdermilk DL, Perry SE, editors: *Maternity and women's health care*, ed 9, St Louis, 2007, Mosby.

Parker WH: Uterine myomas: Management, *Fertil Steril* 88(2):255–271, 2007.

Reynolds RK, Advincula AP: Robot-assisted laparoscopic hysterectomy: technique and initial experience, *Am J Surg* 191:555–560, 2006.

Roberts C, Mangan S: Know the risks of cesarean delivery, *OR Nurse* 3(12):22–30, 2009.

Robins JC, Carson SA: Female fertility: what every urologist must understand, *Urol Clin N Am* 35:173–181, 2008.

Scheurig C, et al: Uterine artery embolization in patients with symptomatic diffuse leiomyomatosis of the uterus, *J Vasc Interv Radiol* 19:279–284, 2008.

The Practice Committee of the American Society for Reproductive Medicine: Indications and options for endometrial ablation, *Fertil Steril* 90(5):S236–S240, 2008.

World Health Organization (WHO): Violence against women fact sheet, 2008, available at www.who.int/mediacentre/factsheets/fs239/en/. Accessed July 2, 2009.

CHAPTER 14

Genitourinary Surgery

HELENE KOREY MARLEY

Advances in genitourinary surgery, with the use of robotics, laparoscopic techniques, cryotherapy, brachytherapy, lasers, ultrasonography, lithotripters, innovative diagnostic measures, and minimally invasive surgical approaches, have expanded treatment options. As urologic surgery becomes more complex and far more precise, the perioperative nurse has challenges in maintaining up-to-date knowledge, documented competence, and new technical skills. More procedures are being done on an ambulatory or short-stay basis, allowing limited time for patient and family education and discharge planning. The success of surgical intervention and patient outcomes depends greatly on the nurse's ability and knowledge in designing, developing, and implementing a perioperative plan of care.

Surgical Anatomy

The normal genitourinary system includes one pair of kidneys, two ureters, the urinary bladder, the urethra, and the prostate gland in the male. Also considered essential to the genitourinary system are the adrenal glands, male reproductive organs, and the female urogynecologic system.

Urine is excreted by the kidneys and conveyed to the bladder through the ureters. Urine is stored in the bladder, which serves as a reservoir until its full capacity (350 to 700 ml) is reached, and is eliminated from the body by way of the urethra. Normal urinary output ranges from 0.5 to 1.0 ml/kg of body weight per hour for the average adult.

Kidneys

The kidneys are located in the retroperitoneal space along the lateral borders of the psoas muscle, one on each side of the vertebral column at the level of the twelfth thoracic to the third lumbar vertebrae. Usually the right kidney is several centimeters lower than the left because the liver rests superior and anterior to the right kidney (Figure 14-1).

Each kidney is surrounded by a mass of fatty and loose areolar tissue known as *pararenal fat*. A capsule enclosing the renal space is known as the *fascia renalis*. This is composed of *Gerota's fascia* (anterior renal fascia) and *Zuckerkandl fascia* (posterior renal fascia). These structures help keep the kidneys in their normal anatomic position. The anterior and posterior relationships of the kidneys are shown in Figure 14-2.

On the medial side of each kidney is a concave area known as the *hilum,* through which the renal artery and vein enter and exit. The renal pelvis, a funnel-shaped structure that lies within the kidney and posterior to the renal vascular pedicle, divides into several branches called *calyces* (Figure 14-3). When surgery is indicated in these structures, a posterior flank approach is preferred. When surgery for removal of a mass is anticipated, a transabdominal or thoracoabdominal incision may be chosen.

The kidneys are highly vascular organs that process approximately one fifth of the entire volume of blood at any one time. The blood supply to the kidney is conveyed through the renal artery (a large branch of the aorta) and leaves through the renal vein. On entering the kidney, the renal artery divides into anterior and posterior sections. These undergo further division into interlobular arteries from which smaller afferent branches pass to the glomeruli. Efferent arterioles in the glomeruli then pass to the tubules of the nephron.

The renal lymphatic supply originates beneath the capsule of the kidney and empties into the lumbar lymph nodes at the junction of the renal vascular pedicle and aorta. The nerves of the autonomic (involuntary) nervous system originate from the lumbar sympathetic trunk and from the vagus nerve. Removal of the nerve pathways does not impair renal function. The renal artery and vein with their accompanying nerves and lymphatics are referred to as the *pedicle* of the kidney.

Adrenal Glands

The adrenal glands lie retroperitoneally beneath the diaphragm, capping the medial aspects of the superior pole of each kidney. On the right side, the gland is triangular and adjacent to the inferior vena cava; on the left side, it is a rounded, crescent-shaped gland posterior to the stomach and pancreas. Each adrenal gland has a medulla, which secretes epinephrine (adrenaline), and a cortex, which secretes steroids and hormones. Secretions from the adrenal cortex are influenced by the activity of the pituitary gland. The adrenal glands are liberally supplied with arterial branches from the inferior phrenic and renal arteries and from the aorta. Venous drainage is accomplished on the right side by the inferior vena cava and on the left by the left renal vein. The lymphatic system accompanies the suprarenal vein and drains into the lumbar lymph nodes.

Ureters

Each ureter is a continuation of the renal pelvis. The ureter extends in a smooth S curve from the renal pelvis to the base of the bladder (Figure 14-4). It is approximately 25 to 30 cm long and 4 to 5 mm in diameter in the adult. This fibromuscular cylindric tube is lined by transitional epithelium (urothelium) and lies on the psoas muscle, passing medially to the sacroiliac joints and laterally to the ischial spines. As urine accumulates in the renal pelvis, slight distention initiates a wave of

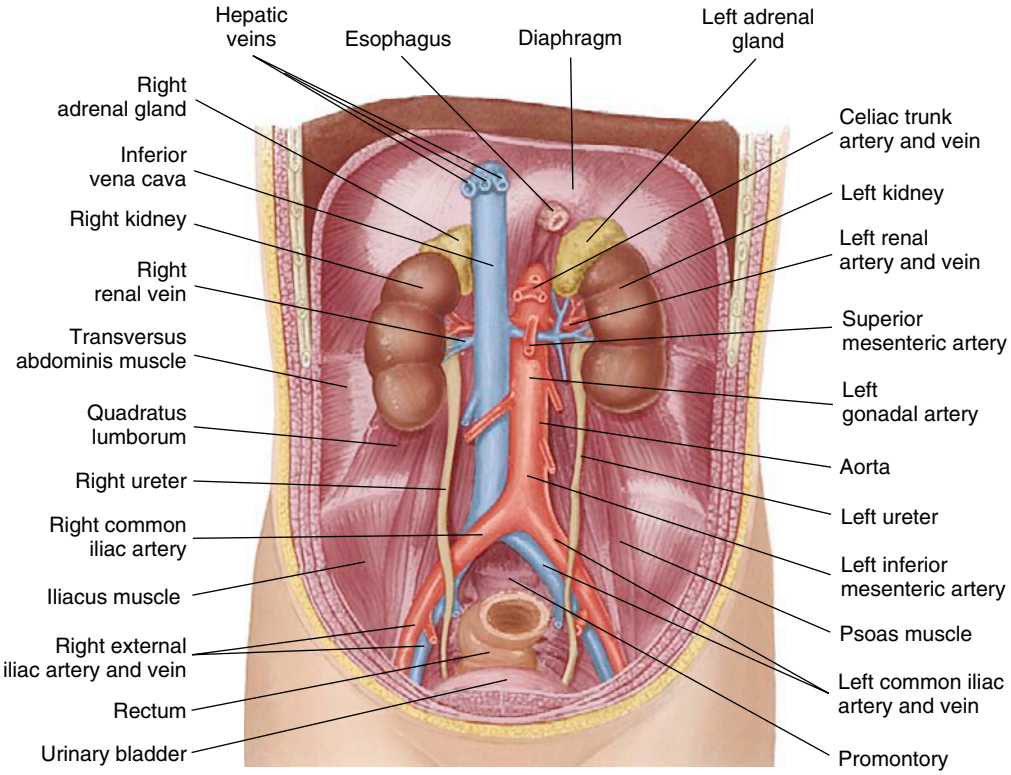


FIGURE 14-1 Location of urinary system organs.

muscular contractions. This peristaltic activity continues down the ureter, propelling urine into the bladder.

Urinary Bladder

The adult urinary bladder is a hollow, muscular viscus that acts as a reservoir for urine until micturition (voiding) occurs. It has an outer adventitial layer and inner urothelial layer. The trigone, a triangular area, forms the base of the bladder. The three corners of the trigone correspond to the orifices of the ureters and the bladder neck (opening of the urethra) (Figure 14-5). The ureteral orifices, on the proximal trigone at the interureteric ridge, are 2.5 cm apart. The bladder neck (internal sphincter) is formed from converging detrusor muscle fibers of the bladder wall that pass distally to form the smooth musculature of the urethra. Physiologically, the bladder fills with urine and expands into the abdominal cavity. The extraperitoneal location is advantageous because a suprapubic (above the pubic arch) incision may be performed without violating the peritoneum and potentially causing intraperitoneal complications.

The main arterial supply of the bladder comprises the superior, middle, and inferior vesical arteries. These vessels are derived from the internal iliac (hypogastric) artery, the obturator and inferior gluteal arteries, and in females the uterine and vaginal arteries. The bladder has a rich venous supply that drains into the internal iliac (hypogastric) vein. The lymphatic system is served by the vesical, external and internal iliac, and common iliac lymph nodes.

The bladder's size, position, and relation to the bowel, rectum, and reproductive organs vary according to the bladder's distention. In the female the vagina lies dorsal to the base of the bladder and parallel to the urethra (Figure 14-6). In the male the prostate gland is interposed between the bladder neck and the urethra (Figure 14-7). These anatomic relationships influence the symptoms that a patient experiences preoperatively and are important landmarks during pelvic surgery.

The process of bladder evacuation appears to be initiated by nerve cells from the sacral division of the autonomic nervous system. These sacral reflex centers are controlled by higher voluntary centers in the brain. Stimulation of the sacral centers results in contraction of the bladder muscles and relaxation of the bladder outlet sphincters. Muscles inside and adjacent to the urethral wall and from the pelvic floor maintain closure of the sphincters of the bladder, thus enabling continence.

Urethra

The male urethra, normally 20 to 25 cm long, extends from the bladder neck to the tip of the penis and varies in diameter from 7 to 10 mm. It is divided into two portions: the proximal (sphincteric) urethra and the distal (conduit or anterior) urethra, both of which undergo further subdivision. The proximal urethra is commonly referred to as the *posterior urethra,* where it is elevated by the verumontanum, extending from the bladder neck through the prostate and the membranous portion. Within the posterior urethra lie the prostatic and membranous portions (see Figure 14-5). As the urethra exits the prostate and crosses the pelvic (urogenital) diaphragm, it is called the *membranous urethra.* The distal urethra, commonly called the *anterior urethra,* is subdivided into the bulbar, pendulous (penile), and glandular urethras. The bulbar urethra is the area most prone to urethral strictures in the male. The prostatic urethra is approximately 3 cm long and is the widest portion of the urethra. On the floor of the prostatic urethra is the

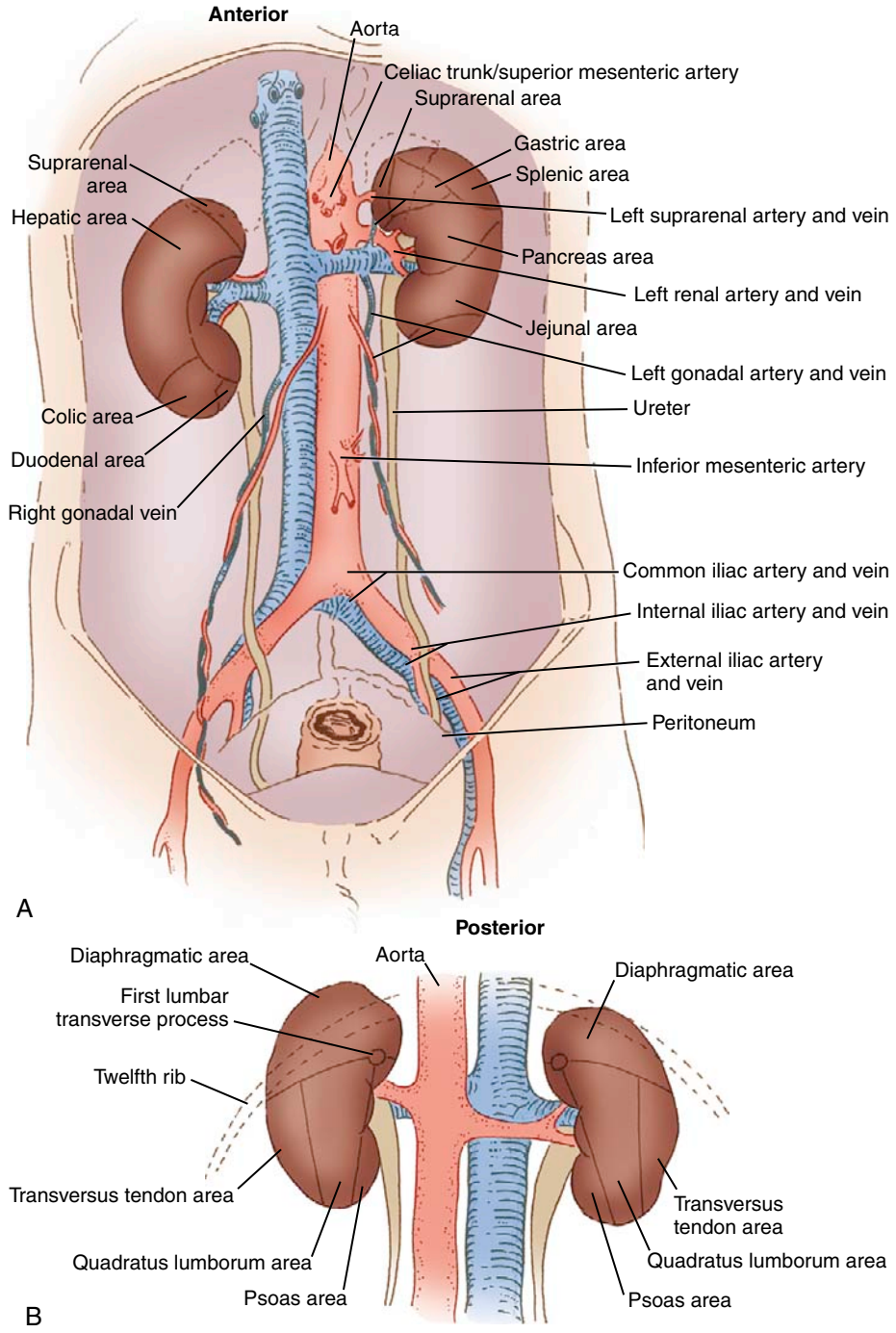


FIGURE 14-2 **A**, Blood supply of kidneys and relationship of kidneys and ureters to the main arteries and veins and the intraperitoneal organs. **B**, Relationship of the kidneys and ureters to the spinal column.

verumontanum, which contains the openings of the ejaculatory ducts. The membranous urethra is the shortest portion, measuring approximately 2.5 cm and extending from the external sphincter to the apex of the prostate. The penile, or pendulous, urethra lies within the corpus spongiosum. The urothelium of the urethra is continuous with that of the bladder.

The female urethra is a narrow, membranous tube about 3 to 5 cm in length and 6 to 8 mm in diameter. Slightly curved, it lies behind and beneath the symphysis pubis, anterior to the vagina. It passes through the internal and external sphincters and the urogenital diaphragm. The periurethral glands of Skene open on the floor of the urethra just inside the meatus. Because the female urethra is so short and in proximity to the anal and vaginal areas, microorganisms find easy access to the bladder and can cause urinary tract infections (UTIs).

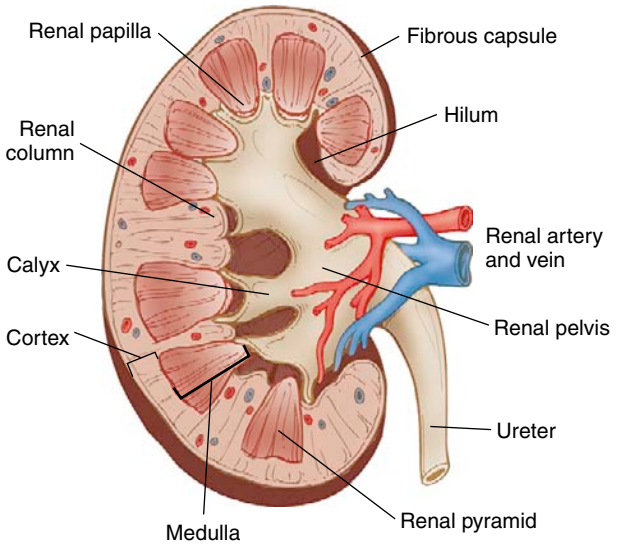


FIGURE 14-3 Normal kidney.

Prostate Gland

The prostate gland is a donut-shaped organ composed of fibromuscular and glandular components. It is located at the base of the bladder neck and completely surrounds the urethra. The gland is about 4 cm at the base, is about 2 cm in depth, and normally weighs 20 to 30 g (see Figures 14-5 and 14-7).

The four glandular regions within the prostate have two major zones (the peripheral zone and the central zone) and two minor zones (the transitional zone and the periurethral zone). Many clinicians still refer to prostate lobes as intraurethral lobes (right and left lateral) and extraurethral lobes (posterior and median). The posterior lobe is readily palpable during rectal examination and prone to cancerous degeneration. Benign prostatic hyperplasia (BPH, often referred to as hypertrophy) generally occurs in the transitional zone (intraurethral lobe).

Behind the prostatic capsule is a fibrous sheath known as the *true prostatic capsule,* which separates the prostate gland and the seminal vesicles from the rectum. This fascia is an important landmark during perineal prostatectomy.

The lobes of the prostate gland secrete highly alkaline fluid that dilutes the testicular secretion as it is excreted from the ejaculatory ducts. These secretions are believed to be essential to the passage of spermatozoa and helpful in keeping them alive. The arterial supply to the prostate is derived from the pudendal, inferior vesical, and hemorrhoidal arteries.

Male Reproductive Organs

The male reproductive organs include several paired structures: the testes, epididymides, seminal ducts (vasa deferens), seminal vesicles, ejaculatory ducts, and bulbourethral glands. Other organs of the reproductive tract are the penis, prostate gland, and urethra.

The *scrotum* is located behind and below the base of the penis and in front of the anus. Within the scrotum are two cavities, or sacs, that are lined with smooth, glistening tissue—the tunica vaginalis. Normally, a small amount of clear fluid is contained in the tunica vaginalis. Each loose sac contains and supports a testis, an epididymis, and some of the spermatic cord. The two sides of the scrotum are separated from each other by a median raphe (septum).

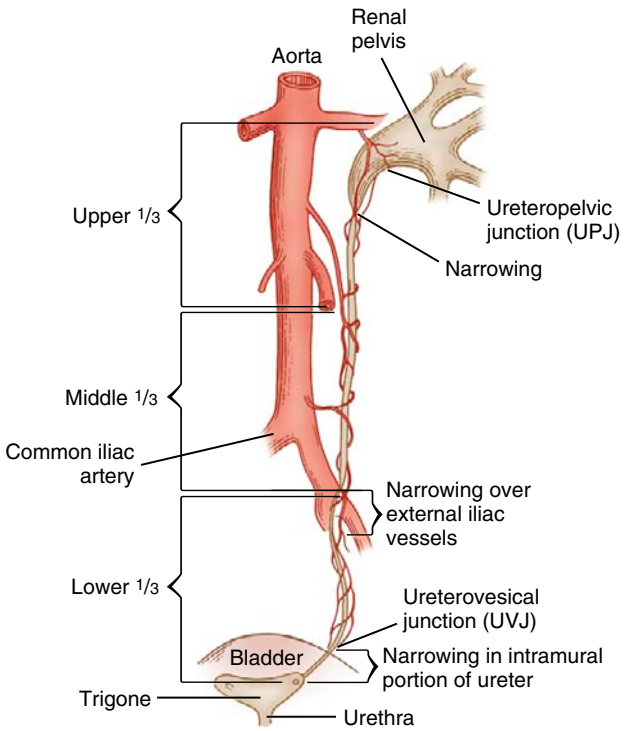


FIGURE 14-4 Anatomy of ureter.

The *testes* manufacture the spermatozoa and also contain specialized Leydig's cells that produce the male hormone *testosterone.* Each testis consists of many tubules in which the sperm are formed, surrounded by dense capsules of connective tissue. The tubules coalesce and continue into the adjacent epididymis, where the sperm mature and are stored. At the upper pole of the testis is the appendix testis, a small body that may be pedunculated (stalked) or sessile (flat).

The *epididymis* is a long, convoluted duct located along the posterolateral surface of the testis. It is closely attached to the testicle by fibrous tissue and secretes seminal fluid, which gives the sperm a liquid medium in which to migrate. The vas deferens (ductus deferens, seminal duct) is a distal continuation of the epididymis as it enters the prostate gland and conveys the sperm to the seminal vesicle.

The *vas deferens* extends from the epididymis into the abdomen and lies within the spermatic cord in the inguinal region. The spermatic cord also contains veins, arteries, lymphatics, nerves, and surrounding connective tissue (cremaster muscle), which give support to the testes. The terminal portion of each vas deferens is called the *ejaculatory duct;* it passes between the lobes of the prostate gland and opens into the posterior urethra.

The *accessory reproductive glands* include the seminal vesicles, prostate gland, and bulbourethral gland. The seminal vesicles unite with the vas deferens on either side, are situated behind the bladder, and produce protein and fructose for the nutrition of the sperm cell. Sperm and prostatic fluid are discharged at the time of ejaculation.

Cowper's glands (bulbourethral glands) are located on each side at the juncture of the membranous and bulbar urethras. Each gland, by way of its duct, empties mucous secretions into the urethra.

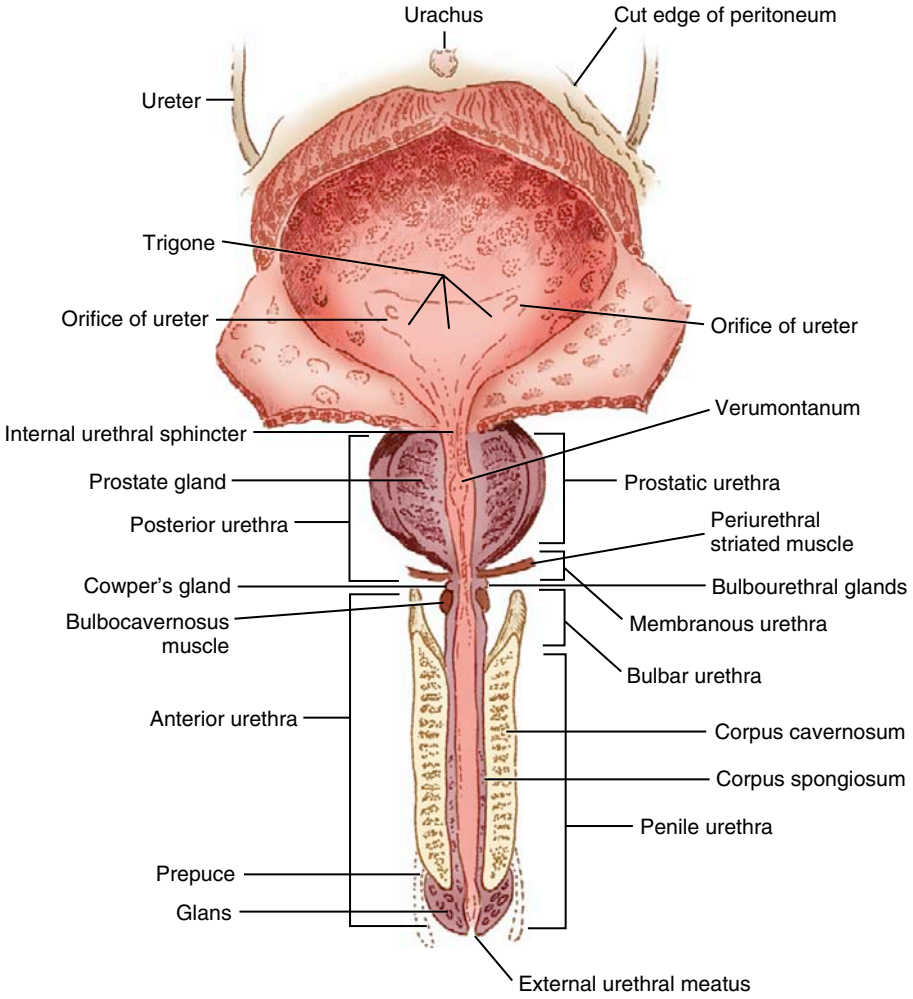


FIGURE 14-5 Anatomy of male urinary bladder, prostate gland, and urethra.

The *penis* is suspended from the pubic symphysis by the suspensory ligaments. The penis contains three distinct vascular, spongelike bodies surrounding the urethra: two outer bodies called the *right corpus cavernosum* and *left corpus cavernosum* and an inner body, the *corpus spongiosum urethrae*. These tissues contain a network of vascular channels that fill with blood during erection (see Figure 14-5). At the distal end of the penis, the skin is doubly folded to form the prepuce, or foreskin, which serves as a covering for the glans penis. The glans penis contains the urethral orifice.

Perioperative Nursing Considerations

Assessment

Patients entering a hospital or ambulatory surgery unit for genitourinary surgery exhibit many emotions and reactions, including fear, embarrassment, helplessness, hostility, anger, and grief. To most, a successful surgical outcome is of prime importance. The urology patient population varies from infants with congenital anomalies to elderly people with physiologic impairments. Because of the dramatic increase in same-day admissions and ambulatory surgeries, the nursing staff must prepare to meet patients' specific needs, from preoperative teaching to postoperative home care. The families of patients need to be involved in this preparation process. Patient education begins in the urologist's office. Communication between the office and perioperative nursing staff allows continuity of care and increases the efficiency and effectiveness of surgical procedures.

In addition to routine admission information, the perioperative nurse will obtain the patient's urologic and cardiac histories. This information includes but is not limited to vital signs, allergies (including latex), the patient's primary problem, history of the present illness, nature of symptoms, and limitations imposed by the disease condition. In some cases, patients may be seen who are not having a primary urologic procedure; instead, these patients may be scheduled for an ancillary urologic procedure, such as the insertion of ureteral catheters or stents to facilitate positive identification of the ureters and reduce the potential for severing or ligating them during pelvic or abdominal procedures. All data pertinent to the proposed operative procedure should be reviewed. Nursing observation should include the patient's general physical appearance as well as nonverbal behaviors, such as restlessness, which may indicate discomfort or anxiety. Any limitations in mobility or sensory deficits should be noted. Urologic procedures frequently require positions that create unusual stress for the patient, both

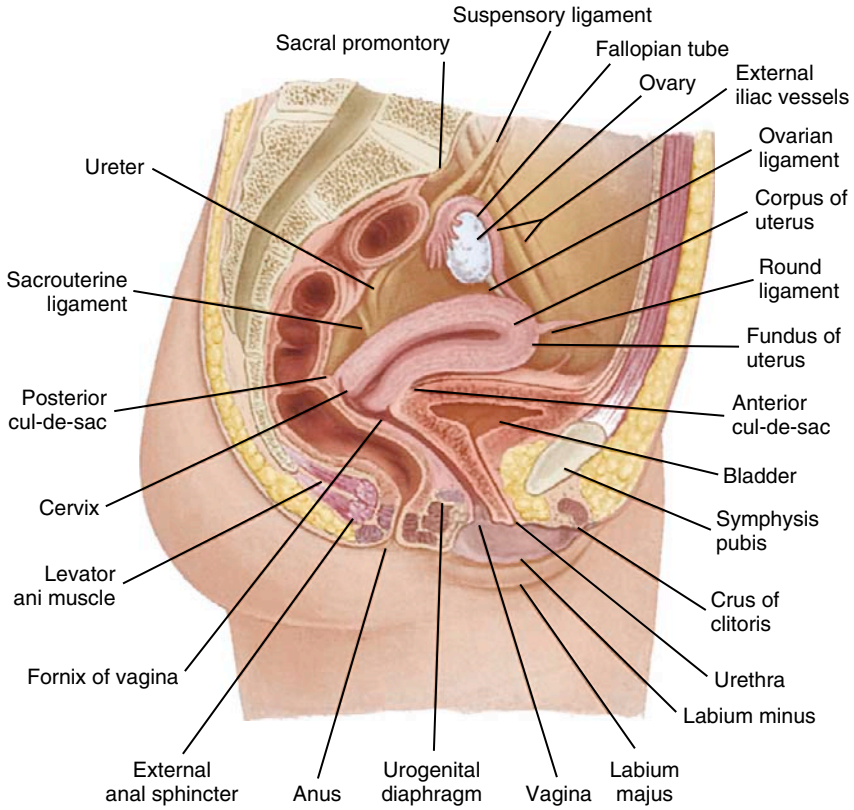


FIGURE 14-6 Female genitourinary and reproductive anatomy.

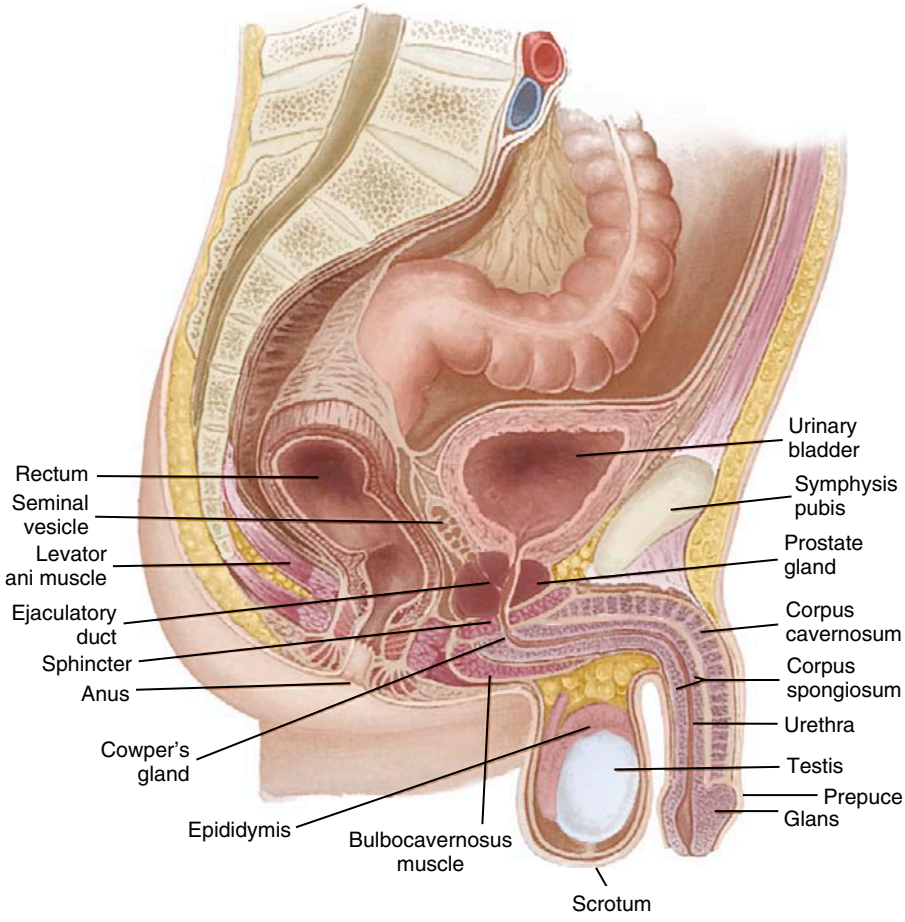


FIGURE 14-7 Male genitourinary and reproductive anatomy.

TABLE 14-1

Common Preoperative Laboratory Analyses for Patients with Genitourinary Disorders

Laboratory Studies	Normal Range (Adult Values)
COAGULATION PROFILES	
Bleeding time	<175 sec
Partial thromboplastin time (PTT)	60-70 sec
Platelet count	150,000-400,000/mm^3
Prothrombin time (PT)	11-12.5 sec
FERTILITY PROFILES (MALE)	
Follicle-stimulating hormone (FSH)	1.42-15.4 milliinternational units/ml
Luteinizing hormone (LH)	1.24-7.8 milliinternational units/ml
Testosterone (total)	280-1080 ng/dl
Sperm count	≥20 million/nl; mobility ≥50% at 1 hr
HEMATOLOGY VALUES (LOW: FEMALE; HIGH: MALE)	
Hematocrit (Hct)	37%-52%
Hemoglobin (Hgb)	12-18 g/dl
Red blood cells (RBCs)	4.2-6.1 million/mm^3
White blood cells (WBCs)	5000-10,000 million/mm^3
SERUM PROFILES (LOW: FEMALE; HIGH: MALE)	
Bicarbonate	23-30 mEq/L (HCO_3^-)
Blood urea nitrogen (BUN)	10-20 mg/dl
Calcium (Ca^{++})	9-10.5 mg/dl
Chloride (Cl^-)	98-106 mEq/L
Cholesterol	<200 mg/dl
HDL (high-density lipids)	Male >45 mg/dl; Female: >55 mg/dl
LDL (low-density lipids)	60-180 mg/dl
VLDL (triglycerides)	7-32 mg/dl
Creatinine	0.5-1.2 mg/dl
Glucose (blood sugar)	70-110 mg/dl
Osmolality	285-295 mOsm/kg H_2O
Potassium (K^+)	3.5-5 mEq/L
Phosphorus (P)	3-4.5 mg/dl
Prostate-specific antigen (PSA)	<4 ng/dl
Prostatic acid phosphatase (PAP)	0.013-0.63 unit/L
Protein	6.4-8.3 g/dl
Sodium (Na^+)	136-145 mEq/L
Uric acid	2.7-8.5 mg/dl
URINE PROFILES (VALUES NOT LISTED SHOULD BE NEGATIVE)	
Calcium (Ca^{++})	100-250 mg/day
Chloride (Cl^-)	110-250 mEq/L/day
Creatinine	88-137 ml/min
Glucose (24 hr)	50-300 mg/day (<0.5 g/day)
Osmolality (random)	50-1200 mOsm/kg H_2O
Phosphorus	0.4-1.3 g/24 hr
Potassium (K^+)	25-100 mEq/L/day
Protein	0-8 mg/dl
Red blood cells (RBCs)	≤2 cells
Sodium (Na^+)	40-220 mEq/L/day
Uric acid	250-750 mg/day
White blood cells (WBCs)	0-4 per lower field
pH	4.6-8 (average: 6)
Specific gravity	1.005-1.030

Data from Chernecky CC, Berger BJ: *Laboratory tests and diagnostic procedures,* ed 5, St Louis, 2008, Saunders; Pagana K, Pagana T: *Mosby's diagnostic and laboratory test reference,* ed 9, St Louis, 2009, Mosby.

anatomic and physiologic, such as compression of the vena cava and dependent lung during lateral positioning. Also, large amounts of irrigating fluids are frequently used intraoperatively in urologic procedures, which may impact the patient's electrolyte status. Assessment provides the perioperative nurse with data adequate to support preoperative planning, intraoperative implementation, and postoperative evaluation.

The patient may undergo several studies preoperatively, including measurement of levels of serum and urine electrolytes, blood glucose, and blood urea nitrogen (BUN); urinalysis and urine cultures; cardiac enzymes; complete blood count (CBC); prothrombin time (PT) and partial thromboplastin time (PTT); blood chemistry profiles (Table 14-1); electrocardiogram (ECG); and chest x-ray examination. The nurse reviews the patient's medical history, focusing on medication use (including the use of over-the-counter medications and herbal supplements), any infectious processes, or chronic diseases. Specific genitourinary studies can be found in the patient's medical record. They may encompass all or some of the following: computerized tomography (CT) scans, magnetic resonance imaging (MRI), bone and dual energy x-ray absorptiometry (DEXA) scans, positron emission tomography (PET), ProstaScint scans, intravenous (IV) pyelograms or urograms (IVPs or IVUs, respectively), genitourinary flat plate (KUB [kidney, ureter, bladder]), urinary flow studies, fluoroscopic examinations (angiography, cavernosography), prostate-specific antigen (PSA), and ultrasonography. After the nurse reviews the medical record, assessment information is compiled, perioperative nursing diagnoses are identified, and the perioperative plan of care is formulated.

Nursing Diagnosis

Nursing diagnoses related to the care of patients undergoing genitourinary surgery might include the following:

- Anxiety
- Risk for Perioperative Positioning Injury
- Impaired Urinary Elimination
- Risk for Deficient Fluid Volume
- Impaired Gas Exchange
- Sexual Dysfunction

Outcome Identification

Outcomes identified for the selected nursing diagnoses could be stated as follows:

- The patient will verbalize an acceptable anxiety level to the perioperative nurse.
- The patient will be free from injury related to the surgical position.
- The patient will demonstrate or regain a normal pattern of urinary elimination.
- The patient will maintain adequate fluid volume and electrolyte balance.
- The patient will maintain adequate oxygen supply and alveolar ventilation.
- The patient will discuss fears and concerns regarding sexual function.

Planning

Plans of care are the organizing framework for perioperative nursing activities, wherein nursing interventions are clinical processes in a quality health outcome model. Frequently the urology patient presents a complex medical picture. Any alterations in the patient's physical, mental, or emotional status may greatly influence both the surgical and the postoperative course. A review of the patient's record; communication with the patient or family; recognition of specific psychosocial, cultural, ethnic, and spiritual needs of the patient and family; and knowledge gained from other members of the patient care team are all used to formulate the nursing database. A Sample Plan of Care for the patient undergoing genitourinary surgery is shown below.

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Anxiety

OUTCOME
The patient will verbalize an acceptable anxiety level to the perioperative nurse.

INTERVENTIONS
- Provide an accepting and supportive environment.
- Use touch (as appropriate) to convey caring and support.
- Encourage expression of feelings.
- Promote feelings of self-worth.
- Provide comfort measures (e.g., warm blankets, pillow).
- Facilitate or assist patient in using personally effective coping strategies (e.g., relaxation, deep breathing, music, imagery).
- Maintain patient privacy.
- Encourage participation of patient and family in plan of care.

NURSING DIAGNOSIS
Risk for Perioperative Positioning Injury

OUTCOME
The patient will be free from injury related to the surgical position.

INTERVENTIONS
- Maintain proper body alignment.
- Assess range of motion and musculoskeletal, peripheral vascular, and cardiovascular status preoperatively.
- Pad all bony prominences.
- Avoid compression of vulnerable nerves and neurovascular bundles.
- Secure patient to OR bed without friction or pressure.
- Provide support stockings or sequential compression devices (SCDs) as indicated.
- Initiate measures to warm patient and maintain normothermia.

NURSING DIAGNOSIS
Impaired Urinary Elimination

OUTCOME
The patient will demonstrate or regain a normal pattern of urinary elimination.

INTERVENTIONS
- Include catheter care and measures to facilitate voiding after catheter removal as part of preoperative patient and family education and discharge planning.
- Instruct patient in importance of any postoperative antibiotic or anticholinergic therapy.
- Follow aseptic technique during catheter insertion and connection to drainage device.
- Maintain closed urinary drainage system.
- Note amount, color, and character of urine; report abnormalities.
- Keep drainage tubing and collection device below the level of the patient's bladder.
- Keep urine draining freely; avoid kinks in tubing.
- Check patency of catheter after all position changes.
- Secure drainage tubing to patient to prevent pulling or retraction during transfer.
- Assess bladder for distention.
- Provide patient with information/referral on preventing recurrent urinary tract infection (UTI).

NURSING DIAGNOSIS
Risk for Deficient Fluid Volume

OUTCOME
The patient will maintain adequate fluid volume and electrolyte balance.

INTERVENTIONS
- Provide appropriate intravenous (IV) solutions, volumetric pumps, and fluid warmers.
- Monitor patency of all IV lines.
- Record volume of IV and irrigating fluids instilled.
- Monitor electrocardiogram (ECG), vital signs, and cardiopulmonary status as appropriate.
- Monitor blood loss and volume replacement.
- Monitor urinary output, and note color; report output less than 30 ml/hr and changes in color or clarity.
- Collaborate with anesthesia provider in monitoring serum electrolyte status.
- Monitor pH and specific gravity of urine as appropriate.

NURSING DIAGNOSIS
Impaired Gas Exchange

OUTCOME
Patient will maintain adequate oxygen supply and alveolar ventilation.

INTERVENTIONS
- Review breathing exercises and use of incentive spirometer with patient preoperatively.
- Position patient to provide maximum lung perfusion; have positioning devices available; check that these are clean and functioning properly.
- Assist anesthesia provider in applying cardiac monitor leads, blood pressure cuff, and pulse oximeter.
- Collaborate with anesthesia provider in monitoring ventilation or perfusion.
- Administer oxygen as required; assist with intubation and maintenance of airway during positioning.
- Assist with collection of arterial blood gases; report results promptly.

NURSING DIAGNOSIS
Sexual Dysfunction

OUTCOME
The patient will discuss fears and concerns regarding sexual function.

INTERVENTIONS
- Clarify patient's understanding of risks and benefits of surgical procedure.
- Provide an open, accepting environment for the patient to discus potentially embarrassing issues.
- Maintain patient privacy and dignity.
- Consider making a referral for patient to discuss options available to achieve sexual function postoperatively.

Implementation

The perioperative nurse begins implementation of the patient care plan during the patient interview. Information that is concise and simply presented enhances the final surgical outcome. Meeting the patient's emotional needs is a nursing priority. A calm patient retains more information and is cognitively and emotionally more receptive to perioperative teaching. The nurse provides explanations of what to expect throughout the operative period to allay the patient's fears and nurture confidence in the nursing care provided. Establishment of this relationship is key to assisting patients to minimize the effect of the surgical experience on their coping ability and to be emotionally comfortable. Perioperative nursing care requires not only the collection of pertinent patient data but also the coordination of numerous supplies and equipment to support the smooth implementation of the plan of care.

Patient Safety. The perioperative nurse considers several factors in advocating for the patient during the intraoperative period. Institutions have various protocols and processes in place to support patient safety. The rapid response team is one example of a protocol or process that focuses on safety (Rapid Response Team box). A critical safety protocol that the nurse is responsible to follow is to ensure the correct patient, correct procedure, and correct site surgery. Such a protocol includes proper patient identification, proper operative site identification, proper procedure identification, and proper medication identification. All wrong site, wrong procedure, and wrong patient surgery occurrences are considered sentinel events by The Joint Commission. In addition, the Association of periOperative Registered Nurses (AORN) has established guidelines for patient safety (AORN, 2009).

To fulfill these requirements, preoperative verification, surgical site marking, and time-out processes must occur for every surgical procedure. What the patient expresses as the intended surgical procedure is compared with what is documented on the operative permit and other items, such as the OR schedule. Patient identification is achieved by also asking the patient to state his or her full name and birth date. This information is compared with the patient identification bracelet. Documentation of the processes implemented is completed on the designated institutional form or forms.

The surgical site is marked with a permanent nontoxic marking pen. The patient should be involved in this process. A standard policy needs to be developed within the particular facility as to how marking will be accomplished for urologic, endoscopic, and abdominal procedures, particularly when they involve laterality. This mark should be clearly visible following prepping and draping.

"Time out" is a pause in the activity that occurs before the start or incision on all procedures. The entire team stops to verbally confirm the patient's identity, verify the patient's position, state and agree on the procedure and surgical site, and review that all implants and necessary equipment are available and ready (Patient Safety). The nurse documents this process according to hospital policy.

When medications are used intraoperatively the containers should always be marked with the medication and dose (refer to Chapter 2 for a full discussion of medication safety). The surgical technologist verifies the medication and dosage verbally when passing the drug in its administration device to the surgeon. Local anesthetics that contain epinephrine should be used with caution in urology. Many urologic interventions involve "end-organs," for example, the scrotum, testicles, and penis. The use of epinephrine in these areas can result in an ischemic situation and should be avoided.

Positioning. Thorough understanding of the urologic OR bed and its functions is essential for optimum patient positioning. The position in which the patient is placed for surgery is determined by the particular operation to be performed. For urologic operative procedures, the patient may be placed in the lateral, supine, prone, or lithotomy position. Any of these positions may be exaggerated to give optimum access to the organ involved, particularly in radical surgery of the prostate and bladder. When the patient is supine, his or her arms are placed on padded armboards with the palms up and fingers extended. Armboards are maintained at less than a 90-degree angle to prevent brachial plexus stretch. If there are surgical reasons to tuck the arms at the side, the elbows are padded to protect the ulnar nerve, the palms face inward, and the wrist is maintained

RAPID RESPONSE TEAM

A rapid response team (RRT) is used when patients display subtle warning signs of deterioration. These teams respond to the first sign of patient decline by bringing critical care assessment skills to the bedside of the patient in order to identify and treat issues before a patient codes. When activated, the RRT, which consists of a critical care nurse, respiratory therapist, med-surg nurse, ICU resident, admitting resident, and the surgical resident, assembles at the patient's bedside to assist with treatments and help determine if transfer to a higher level of care is necessary. The team is available 24/7.

In most cases, the RRT is not utilized in the perioperative setting. Exceptions occur when PACU is used as an overflow unit and ancillary staff is unavailable. At one particular institution, the RRT was only utilized twice in this respect. In both cases, the team was called to the scene because of apnea/shortness of breath and in neither case was CPR initiated.

Health professionals are not the only persons with access to the rapid response team. At this institution, a sign is placed in all public areas of the hospital to provide notice to patients, families, and visitors about the RRT. There is also an information sheet provided to all new admissions that details patient and visitor activation of the RRT. Each patient phone is equipped with a purple and white "glow in the dark" instruction to call the emergency operator and ask for the rapid response team in case of emergency. The operator will immediately alert healthcare professionals, who will soon arrive to assess the situation. Allowing family members and visitors to access rapid response ensures patients' medical, social, and spiritual needs will be met with compassion, skill, and respect.

Modified from University of Pennsylvania Health System: *Rapid response team, 2000,* available at Uphsxnet.Uphs.Upenn.Edu/Pahhome/Nursing/Rapidresponse. Accessed April 10, 2009.

PATIENT SAFETY

Improving Teamwork to Reduce Errors

Publication of the 1999 Institute of Medicine report focused attention on medical errors and the critical importance of patient safety. Reducing errors (such as wrong person, wrong procedure, or wrong site surgery) requires, in part, human solutions, such as improving teamwork and communication in the OR team. Interdisciplinary teamwork is especially important in the so-called high-risk areas in hospitals, such as the OR. Perioperative nurses have long believed that a team approach to patient care reduces errors. Effective teamwork in perioperative patient care consists of knowledge, attitudes, and skills. Developing sustainable efforts to improve teamwork requires thoughtful application. Interventions focused on changing the behavior of team members must first take into account their attitudes. Subsequently, skills and knowledge are assessed, and a training program can be designed to improve teamwork. The benefits of improved teamwork are well exemplified in the time-out process, which aims to enhance effectiveness, increase efficiency, and lower the possibility of error. Preoperative verification processes and the time-out result in fewer errors because these processes are planned by each institution and standardized through use of the Universal Protocol of The Joint Commission. Each member of the OR team knows his or her own responsibilities as well as those of teammates; members look out for each other and note errors before they happen; and members trust one another's judgments and concerns. Teamwork during preoperative verification and the time-out allows proper integration and execution of clinical activities, gives caregivers increased control over their work environment, and provides a safety net against error.

Modified from Kaissi A et al: Measuring teamwork and patient safety attitudes of high-risk areas, *Nurs Econ* 21(5):211-218, 2003; Rajnish P et al: Fires in the operating room and intensive care unit: awareness is the key to protection, *Anesth Analg* 102:172-174, 2006.

in a neutral position (Denholm, 2009). A drape secures the arms. It should be tucked snuggly under the patient, not under the mattress. This prevents the arm from shifting downward intraoperatively and resting against the OR bed rail. Acting as the patient's advocate, the nurse takes considerable care to ensure that the surgical position does not interfere with respiration or circulation. It is essential to avoid displacement of the joints and undue tension on neurovascular bundles or ligaments. A patient positioned laterally (flank position) for renal surgery has the spine extended for greater access to the retroperitoneal space. Padding and stabilized support with gel pads, pillows, sandbags, and straps should be available for precise anatomic positioning and safety (see Chapter 5). When an electrosurgical unit (ESU) is to be used, care must be taken that the patient does not contact metal parts of the OR bed.

In some procedures involving stones of the kidneys or ureters, intraoperative fluoroscopy may be required. When fluoroscopy (C-arm) is to be employed, the patient must be placed on an OR bed compatible with its use. Whenever possible, the perioperative nurse takes measures to protect the patient from undue radiation exposure to the thyroid and chest areas by using small leaded shields. In urologic procedures it generally is not feasible to shield the reproductive organs.

Aseptic Techniques and Safety Measures. Prevention of infection is an important nursing goal in the care of the genitourinary patient. It is, however, seldom possible to confirm freedom from infection intraoperatively or immediately postoperatively. Aseptic techniques must be carefully maintained and monitored. Skin preparation and draping procedures (see Chapter 3) vary, depending on the surgery to be performed and institutional protocols. Special care must be taken when cleansing the perineal area to avoid contamination from the rectum to the urethra. Prepping solutions should be applied with downward strokes and the sponge discarded once it has contacted the inner vaginal or anal areas. Transurethral passage of instruments and catheters requires meticulous technique to prevent retrograde infections of the urinary tract, which account for 32% of all healthcare-associated infections (Scott, 2009).

Visualization of the bladder during transurethral procedures is often enhanced by darkening the room. Provision should be made for proper adjustments to lighting. ESUs and fiberoptic light systems are common adjuncts in urologic surgery. The nurse and surgical technologist must be familiar with the manufacturer's safety precautions and recommendations during their use.

Use of Irrigating Fluids. When the bladder is entered, sterile distilled irrigating fluid is administered to distend it for effective visualization. Commercially prepared sterile irrigation solutions with appropriate closed administration sets are highly recommended. Such closed systems prevent the inherent risks of cross-contamination. Large volumes of irrigating solutions are frequently used, particularly during more extensive endoscopic procedures. When these solutions are at the room temperature of the OR, they are cold compared with the patient's internal body temperature and can cause hypothermia. Solution-warming units are available commercially and are a useful tool to help decrease this risk. The drawback to these units may be that the warmth delays clotting, thus increasing the risk of blood loss.

Commercially prepared sterile irrigation solutions are available in collapsible bags and rigid plastic containers, both of which have the same advantages: neither depends on air, and each may be hung in series, thus providing continuous irrigation without interruption. Air bubbles, a problem that distorts visibility during the procedure, are eliminated with these systems.

For simple observation cystoscopy, retrograde pyelography, and simple bladder tumor fulgurations, sterile distilled water may be used without complication. However, during transurethral resection of the prostate (TURP), venous sinuses may be opened and varying amounts of irrigant are invariably absorbed into the bloodstream. Studies indicate that the use of distilled water during TURP may result in hemolysis of erythrocytes and possible renal failure. Other important complications include dilutional hyponatremia and cardiac decompensation (Risk Reduction Strategies).

Therefore a clear, nonelectrolytic, and iso-osmotic solution should be used. The most widely used urologic irrigating fluids are 3% sorbitol, an isomer of mannitol, and 1.5% glycine, an aminoacetic acid solution. In dilute solutions, sorbitol and glycine have many properties that make them particularly useful for irrigation during transurethral prostatectomy. At slightly hypotonic concentrations, they do not produce hemolysis.

RISK REDUCTION STRATEGIES

TURP Syndrome

Transurethral resection of the prostate (TURP) commonly is performed in older men. A variety of irrigants can be used to aid in visualization and electrosurgery during TURP. During TURP, venous sinuses within the gland may be opened and varying amounts of irrigant are invariably absorbed into the bloodstream. Depending on the type and amount of fluid used, several complications, collectively known as TURP syndrome, may occur. Patients may manifest signs and symptoms of hyponatremia and hypervolemia earlier when local and spinal anesthetics are used. Complications are more prevalent in the postoperative stage. A delay in recognizing the symptoms can be catastrophic. The perioperative nurse plays a critical role in reducing the risk of TURP syndrome and can have a positive impact through the following nursing interventions:

- **Positioning and draping.** The nurse assists with positioning the patient in the lithotomy position on the urologic table with the buttocks positioned slightly off the break in the table to provide a barrier to fluid escaping down the perineum and under the patient. The drapes should be applied in a manner that prevents pooling or loss of fluids so that losses can be monitored.
- **Maintenance of continuous irrigation.** Commercially prepared sterile irrigation solutions are available in collapsible bags and have the advantage of not depending on air, and each can be hung in series, providing continuous irrigation without interruption. The nurse retains the empty irrigation bags to assist with the fluid use calculation.
- **Volume monitoring.** The nurse monitors the amount of irrigation recovered and subtracts it from the amount of irrigation used. The total of the irrigation used minus the irrigation recovered is referred to as the volume deficit. If the cause for the deficit cannot be identified, it should be considered reabsorbed. Minimum amounts of fluids should be given and urine output carefully monitored. Irrigation fluid should be under as little pressure as possible and the bladder emptied before it reaches full capacity to prevent intravesical pressure.
- **Intraoperative observation.** Close observation during the intraoperative period is essential. Signs and symptoms such as sudden restlessness, apprehension, irritability, confusion, nausea, slow pulse rate, seizures, dysrhythmias, and rising blood pressure may be suggestive of TURP syndrome, a severe hyponatremia caused by systemic absorption of irrigating fluid used during surgery. IV diuretics such as furosemide (Lasix) may be required to prevent possible pulmonary edema associated with administration of hypertonic saline. If the patient's reaction is severe, surgery may have to be terminated.
- **Postoperative fluid management.** Immediate postoperative fluid management includes monitoring vital signs; confirming normal breath sounds in which no rales or wheezing are present; monitoring urinary output to ensure adequate volume (e.g., a minimum rate of 30 ml/hour); assessing skin color; observing blood count and electrolyte levels to confirm they are within normal limits; and maintaining IV therapy as needed.

Modified from Young E et al: Perioperative fluid management, *AORN J* 89:167-178, 2009.

However, if too much intravasation occurs with glycine, an encephalitic state can result from the ammonia produced (Surgical Pharmacology). Because the solutions are nonelectrolytic, they do not cause dispersion of high-frequency current with consequent loss of electrosurgical cutting capacity, as occurs with normal saline.

During ureteropyeloscopy, sterile normal saline is the irrigant of choice unless electrosurgery is to be employed. This solution most closely approximates a physiologic solution—an important factor if perforation and extravasation of fluid into the retroperitoneum occur. If electrosurgery is required, as with a TURP, 3% sorbitol or 1.5% glycine should be used.

Thorough knowledge of the potential hazards encountered intraoperatively during transurethral surgery is extremely important. Although complications are more prevalent in the postoperative stage, close observation during the intraoperative period is essential. Signs and symptoms such as sudden restlessness, apprehension, irritability, confusion, nausea, slow pulse rate, seizures, dysrhythmias, and rising blood pressure may be suggestive of TURP syndrome, a severe hyponatremia caused by systemic absorption of irrigating fluid used during surgery (Han and Partin, 2007). Minimum amounts of fluids should be given and urine output carefully monitored. Irrigation fluid should be under as little pressure as possible and the bladder emptied before it reaches full capacity to prevent intravesical pressure. During ureteropyeloscopy it is frequently necessary to use a pressure bag to ensure adequate visualization of the upper urinary tract. Serum electrolyte values should be obtained, and if a low serum sodium value is reported, hypertonic sodium chloride is administered by means of a slow IV drip, often on a volumetric pump. IV diuretics such as furosemide (Lasix) may be required to prevent possible pulmonary edema associated with the administration of hypertonic saline. If the patient's reaction is severe, surgery may have to be terminated.

Endoscopic and Ancillary Equipment. Cystoscopic and ancillary equipment often varies from one institution to another. Therefore it is valuable to have a reference manual or standard setup cards that illustrate and describe in detail the required instrumentation for each specific procedure.

The basic cystoscopy tray should include instruments and accessory items that are routinely used for all cystoscopy procedures. If ureteral catheterization is planned, catheterizing telescopes or an Albarrán bridge, which can be packaged and sterilized separately, may be easily added to the basic cystoscopy setup. Instruments for transurethral surgery and other special procedures may be wrapped, sterilized, and placed on separate trays so that they are available on request. This concept minimizes handling of the delicate lensed instruments and ultimately reduces costly repairs.

Cystoscopic procedures frequently require additional instrumentation. Instruments of various types and sizes, such as a visual obturator, biopsy forceps, urethral sounds, Phillips filiforms and followers, and Ellik evacuators, are available as prepackaged, sterile, disposable items. The reusable products may also be packaged separately and sterilized.

Urethral and Ureteral Catheters. A variety of urethral and ureteral catheters are designed for specific procedures. Ureteral catheters are manufactured of polyurethane material and

SURGICAL PHARMACOLOGY

Agents Used in Urologic Surgery

Category	Dose/Route	Purpose/Action	Adverse Reactions	Nursing Considerations
BULKING AGENTS				
Contigen Durasphere EXP	Transurethral, periurethral injection	Correct UH, ISD, SUI	Swelling, urinary retention Local tissue infarction/ necrosis, vascular occlusion, embolus	Avoid use of Contigen in patients sensitive to bovine products Avoid injection into blood vessels Do not use bulking agents in presences of acute cystitis, urethritis, or other genitourinary infection
IRRIGANTS				
Glycine (monocarboxylic amino acid)	1.5%, 3-5 L, intravesical	No hemolysis or dispersion of electrocurrent	Increased ammonia production Encephalitic reaction Biosynthesis of heme Blurred vision CNS disturbances TURP syndrome if absorbed	Contraindicated with clozapine usage Use with caution in diabetic patients, patients with liver disease; inhibitory neurotransmitter
Sorbitol (nonelectrolytic, iso-osmotic, hypotonic aminoacetic acid)	3%, 3-5 L, intravesical	Isomer of mannitol, no hemolysis or dispersion of electrocurrent	TURP syndrome if absorbed	Hyperglycemia may occur in patients with diabetes mellitus Use with caution in patients with renal or cardiac compromise
Water	Distilled, 3-5 L, intravesical	Irrigant, lyse cancer cells	Hyponatremia, hemolysis of erythrocytes	Avoid with TURP Intravasation can lead to dilutional hyponatremia, cardiac decompensation, and renal failure
Normal saline	0.9%, 3-5 L, intravesical	Physiologic irrigant	Hypernatremia	Not for use with electrosurgery Disperses electrocurrent
IONIC RADIOPAQUE CONTRAST AGENTS (HIGH OSMOLAR)				
Conray 60 Hypaque 50 Renografin-60	30 ml half-strength; intraurethral, intraureteral, intravesical, intrarenal	Retrograde pyelography, renal arteriography, retrograde cystourethrography	Asthmatic response, rash, lactic acidosis, anaphylaxis	Contraindicated in patients with iodine-seafood allergy, severe renal disease, dehydration Use with precaution in patients who take metformin
NONIONIC RADIOPAQUE CONTRAST AGENTS (LOW OSMOLAR)				
Omnipaque 300 Optiray 320	30 ml half-strength; intraurethral, intraureteral, intravesical, intrarenal	Retrograde pyelography, renal arteriography, retrograde cystourethrography	Back pain, dizziness, headache, diarrhea	Contraindicated in anuria, pregnancy, dehydration, severe renal and/or hepatic disease, serum creatinine >3 mg/dl Use with precaution in reduced clearance with renal disease; consider pretreatment with steroids; metformin usage

Continued

SURGICAL PHARMACOLOGY

Agents Used in Urologic Surgery—cont'd

Category	Dose/Route	Purpose/Action	Adverse Reactions	Nursing Considerations
INJECTABLES				
Indigo carmine	40 mg, IV or local	Colorize urine, vessels	Hypertension	Moderately reduces oxygen saturation
Phenylephrine (Neo-Synephrine)	0.05% (5 mg), Sub-Q	Vasoconstriction for priapism	Hypertension, reflex bradycardia	May decrease renal blood flow Contraindicated in patients with hypertension
Papaverine	30 mg/ml, 2 ml in solution, intercavernosal	Vasodilation, antispasmodic	Dizziness, dysrhythmia, hypotension, flushing, hypothermia	Contraindicated in AV block, pregnancy Depressed AV or intraventricular conduction, physiologic antagonist
Vasopressin (Pitressin)	20 units/ml: 2 ml (40 units) in solution, local	Vasoconstriction	Water intoxication, dizziness, headache, pallor	May cause tenesmus, tremors, cramps, abdominal pain, hyponatremia; retards absorption of local anesthetics Contraindicated in patients with uremia, coronary artery disease, hypertension
TOPICAL				
Methylene blue	1 ml/100 ml NS, topical	Colorize tissues, vessels	Hypertension, dizziness, headache, anemia, diaphoresis	Do not use in patients with severe renal disease, hemolytic anemia Destroys erythrocytes, may cause methemoglobinuria
OTHER				
B&O suppository (belladonna/opium)	16.2 mg/30 mg, rectal	Prevent/decrease bladder/ureteral spasm	Constipation, decreased sweating	Use with precaution in patients who take MAOIs, agents that affect GI motility, select narcotics May cause cardiovascular instability, paralytic ileus, respiratory depression, toxin-mediated diarrhea, pseudomembranous enterocolitis

AV, Atrioventricular; *CNS,* central nervous system; *GI,* gastrointestinal; *ISD,* intrinsic sphincter dysfunction; *IV,* intravenous; *MAOIs,* monoamine oxidase inhibitors; *SubQ,* subcutaneous; *SUI,* stress urinary incontinence; *TURP,* transurethral prostatectomy; *UH,* urethral hypermobility.

Data compiled from Daily Med Current Medication Information, available at http://dailymed.nlm.nih.gov/dailymed/about.cfm. Accessed May 23, 2009; Hodgson BB, Kizior RJ: *Saunders nursing drug handbook 2009,* St Louis, 2009, Saunders; NCBI PubChem, available at http://pubchem.ncbi.nlm.nih.gov/. Accessed May 23, 2009.

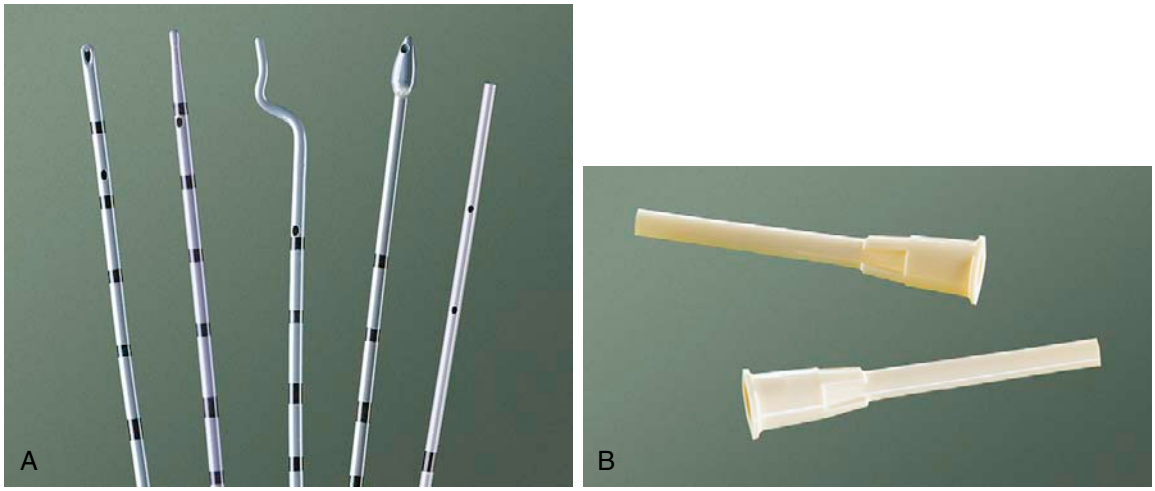


FIGURE 14-8 **A**, Ureteral catheters. **B**, Adapters.

are graduated so that the urologist may determine the exact distance the catheter has been inserted into the ureter (Figure 14-8, *A*). Most manufacturers provide sterile disposable catheters wrapped in peel-open packages to allow aseptic handling during ureteral insertion. Some indications for the use of ureteral catheters are to (1) perform retrograde pyelography, (2) identify the ureters during pelvic or intestinal surgery, and (3) bypass partial or complete obstruction that may be present as a result of ureteral tumors, calculi, or strictures. Not uncommonly, it is necessary to insert a ureteral stent in a pregnant female because of hydronephrosis or obstructing calculi.

The most commonly used catheters include the open-ended, whistle tip, cone tip, and olive tip. When a retrograde ureterogram is indicated, a cone-tipped ureteral catheter may be helpful in occluding the ureteral orifice to accomplish the x-ray study effectively. When a ureteral catheter is left indwelling, a special adapter (Figure 14-8, *B*) may be connected to the end of the ureteral catheter to facilitate connection to a closed urinary drainage system. A small slit may also be created in the Foley catheter, and the distal end of the ureteral catheter can be slipped into it and taped in place.

Indwelling double-pigtail or double-J stents are available and are passed cystoscopically to reside within the ureter (Figure 14-9). When the guidewire is removed from the core of the stent, a proximal and distal J or "pigtail" forms in the tubing to retain the stents. Many of these stents have a nonabsorbable suture attached to the distal end, which extends through the urethral meatus. A suture may be easily tied to the distal end of those that do not. The surgeon can then remove the stent in the office setting postoperatively without needing to perform a cystoscopy.

Urethral catheters have a multitude of functions as stents, as drainage tubes, and in diagnostic studies in the OR. They are generally divided into two categories—plain and indwelling (retention)—and range in different French (F) sizes, most commonly 10 through 30. The Foley catheter is the most frequently used retention catheter and is manufactured with a variety of balloon sizes, tip styles, lengths, and eye arrangements.

After transurethral prostatic surgery, a three-way Foley catheter with a 30-ml balloon capacity may be left indwelling. This type of catheter is preferred because it facilitates

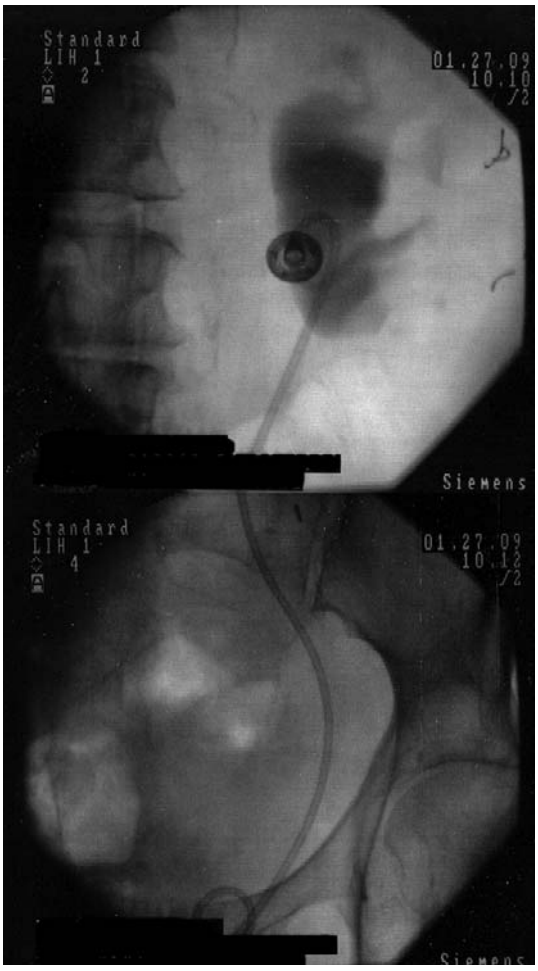


FIGURE 14-9 Double-pigtail stent set.

continuous bladder irrigation (CBI), and the large balloon aids in achieving hemostasis in the prostatic bed. The urologist may apply light traction on the Foley catheter with a leg strap, adhesive catheter anchor, tape, or a commercially available device such as the FoleyGoalie (Figure 14-10). This traction

FIGURE 14-10 FoleyGoalie.

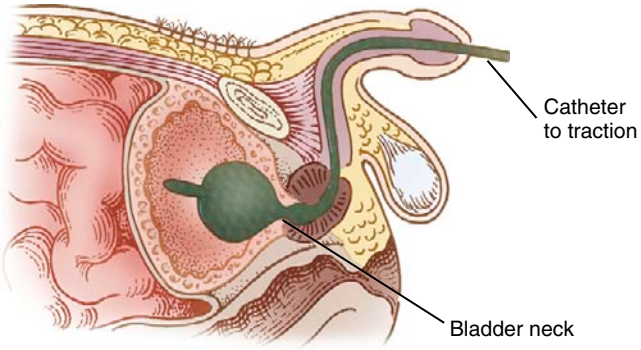


FIGURE 14-11 Balloon of Foley catheter inflated to size that prevents catheter from being pulled into prostatic fossa.

causes pressure against the bladder neck and aids in hemostasis (Figure 14-11). The FoleyGoalie is designed to prevent traumatic catheter removal in men. It is a cylindric device of helically arranged fibers that fits over the catheter and penis, secures with a Velcro strap to the base of the penis, and tapes to the catheter (Figure 14-12). If force is applied to pull out the catheter, the device tightens around the penis and catheter, holding it in position. When the force is released the FoleyGoalie loosens.

A hematuria catheter, a three-way Foley specifically for patients with excessive clot formation, is also available. This catheter is reinforced with a stretch spiral wire within the catheter lining that permits vigorous aspiration without fear of lumen collapse.

Diagnostic studies performed in the cystoscopy suite may require special catheters for specific studies. A Davis or Trattner triple-lumen double-balloon urethrographic catheter or any of a variety of urodynamic catheters may be used to diagnose

FIGURE 14-12 Attaching FoleyGoalie to catheter and penis; Velcro at base of penis, drawstring and Velcro at distal end of device to allow tightening in place.

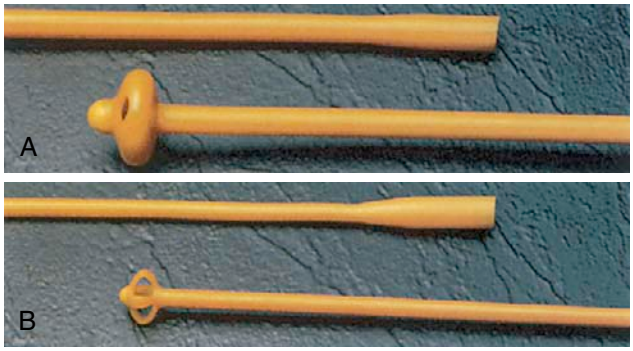


FIGURE 14-13 **A**, Pezzer (mushroom) catheter. **B**, Malecot (bat-winged) four-winged catheter.

lesions of the female urethra, such as urethral strictures, diverticula, and fistulas. To accomplish female urethrography, the catheter is inserted through the urethra into the bladder; the two balloons on the catheter are inflated, one in the bladder and one at the external urethral orifice, effectively isolating the urethra. Contrast medium is injected to visualize the entire urethra.

Another type of self-retaining catheter frequently used in the OR is Pezzer's catheter, also known as a *mushroom* catheter (Figure 14-13, *A*). It may be straight or angulated with a large single channel and a preformed tip in the shape of a mushroom. The flexible mushroom tip helps keep the catheter in place. This catheter is used primarily for suprapubic bladder drainage, often for poor-risk patients who have uremia, neurogenic bladder syndrome, or possibly long-standing urinary retention. The catheter is inserted into the bladder through a midline or small transverse abdominal wall incision and secured to the abdomen with suture or tape. The Malecot four-winged catheter, often used as a nephrostomy tube to provide temporary or permanent diversion of urine after kidney surgery and when renal tissue needs to be restored, may also be used for suprapubic drainage (Figure 14-13, *B*). A Foley catheter of preferred size is frequently chosen for either purpose. Nephrostomy tube replacement is accomplished by introducing the catheter into the surgical tract with a straight catheter guide and securing it in place with a suture or a nephrostomy retention disk that is

one size smaller than the nephrostomy tube being used. The flanges of the disk are taped or sutured to the skin. The use of other variations of urethral catheters is described throughout the chapter.

Photography in Urology. The use of photographic and video imaging equipment in urologic surgery serves to document the patient's disease, the progress of a disease process, and long-term follow-up study. It is also an important teaching resource. Video equipment adapts to endoscopic instrumentation and has the capability of projecting an enhanced image on a television monitor, permitting members of the surgical team to observe and learn during the actual surgical procedure. Other visual aids, such as slides and photographs, are used in teaching, as visual references in publication, and as documentation in patient records.

When any form of photography or video imaging is used, the patient's privacy must be ensured and an informed consent should be obtained. Special release forms should also be signed preoperatively by the patient for any videotapes or photographs to be used in teaching or publications.

Evaluation

Before the patient is taken to the postanesthesia care unit (PACU) or observation unit, the perioperative nurse evaluates the patient's general condition. The skin is assessed, and bony prominences, prepped and draped areas, and areas contacted by the attachment of ancillary equipment are observed for signs of pressure, irritation, or other changes from the preoperative status.

Many urology patients are discharged to the PACU with catheters and drains inserted, including urethral, ureteral, suprapubic, and wound drains. A local anesthetic may have been used for either primary analgesia or postoperative pain management (preemptive analgesia); preoperative or intraoperative infiltration of the surgical site blocks sensory input, resulting in postoperative analgesia. A hand-off report to the PACU nurse should include intraoperative position, problems encountered specific to the patient, and the patient's preoperative physical status as well as comprehension and anxiety levels. Documentation of medications administered from the sterile field or by the perioperative nurse intraoperatively should include time of administration, name of medication, dosage, site and route of administration, and the name of the person who performed the application or injection. Drains should be documented as to size and type, insertion site, time and date of insertion, type of collection device, name of the person who performed the insertion, and character of drainage. When several drains are in place, additional labeling on the collection devices is beneficial. Any postoperative observations before or during transport should be recorded. Evaluation should also address whether the patient met the identified outcomes related to specific nursing diagnoses in the perioperative nursing plan of care. Attainment of identified desired outcomes, included in the documentation and report to the PACU, may be phrased as follows:

- The patient verbalized an acceptable anxiety level to the perioperative nurse.
- The patient had no evidence of positional injury; neurovascular status was consistent with preoperative level, and skin integrity was intact.
- The patient maintained patency of the urinary catheter with no signs of blockage or retention. Urinary output remained within normal limits. The patient should void without difficulty after catheter removal.
- The patient had no evidence or signs of fluid volume or electrolyte imbalance; vital signs were stable, arterial blood gases were within normal limits, and urinary output was maintained at acceptable levels.
- The patient maintained adequate gas exchange; lung expansion and O_2 saturation were satisfactory.
- The patient discussed fears and concerns regarding sexual function.

Patient and Family Education and Discharge Planning

Patient and family education and preparation for discharge allow perioperative nurses to plan for the urologic surgery patient's care across a continuum. General guidelines for preoperative education are presented in Box 14-1. Information is tailored according to the procedure and the patient's status (Ambulatory Surgery Considerations). Information provided should be presented in language the patient can understand (lay terms) and clarified with the patient by having the patient repeat back in his or her own words the information provided. When possible and with the patient's approval, family members or others who will serve as caregivers should be included in the educational process at the outset. Institutions may find it helpful to inventory the patient education materials available for select surgical procedures. An example of patient education for home care after nephrectomy is presented in the Patient and Family Education box on p. 495.

Discharge instructions should be printed and include community resources and support groups as appropriate for the surgical intervention and the patient's diagnosis. These too should be presented in easily understood terms, reviewed, and confirmed by having the patient repeat back in his or her own words the information provided. Any requisite skills that the patient or family will require should be demonstrated, with return demonstrations as time permits. Perioperative nurses may find it helpful to involve institutional resource persons or departments such as the social services department in developing information related to home care services, durable medical equipment, and transfers to aftercare facilities other than home (skilled nursing center, rehabilitation facility, other long-term care facility). Patients and their families need preparation for mastering information and tasks that need to be performed. The goal of such interdisciplinary discharge planning is to provide information for the patient that is comprehensive and easy to use. This is part of perioperative nursing's ethical and professional responsibility to patients; it also meets The Joint Commission's requirements of providing consistent patient and family education.

Surgical Interventions

INTERVENTIONAL URORADIOLOGY

Many procedures that were once reserved for the OR are now being performed in the radiology department by specialists in uroradiology. As technology advances, procedures performed in the radiology department become a more common event.

BOX 14-1

Preoperative Teaching

DEFINITION

Assisting a patient to understand and mentally prepare for surgery and the postoperative recovery period

ACTIVITIES

1. Inform the patient and family/significant others of the scheduled date, time, and location of surgery, and how long the surgery is expected to last.
2. Determine the patient's previous surgical experiences and level of knowledge related to surgery.
3. Appraise the patient's level of anxiety relating to surgery; determine what the patient considers an acceptable anxiety level.
4. Provide time for the patient to ask questions and discuss concerns.
5. Describe the preoperative routines (e.g., anesthesia, diet, bowel preparation, tests/labs, voiding, skin preparation, IV therapy, clothing, family waiting area, transportation to OR), as appropriate.
6. Describe any preoperative medications, the effects these will have on the patient, the rationale for using them, and when they will be administered.
7. Inform the family/significant others of the location of the surgical waiting area.
8. Provide information on what will be heard, smelled, seen, tasted, or felt during the preoperative and intraoperative phases of care.
9. Discuss pain management strategies and the use of pain rating scales.
10. Explain the purpose of frequent postoperative assessments.
11. Describe postoperative routines/equipment (e.g., medications, respiratory treatments, tubes, machines, support hose, surgical dressings, ambulation, diet, family visitation), and explain their purpose.
12. Reinforce information provided by other healthcare members as appropriate.
13. Determine the patient's expectations of the surgery.
14. Correct unrealistic expectations of the surgery as appropriate.
15. Instruct the patient to use coping techniques directed at controlling specific aspects of the experience (e.g., relaxation, imagery) as appropriate.
16. Include the family/significant others as appropriate.

Modified from Johnson M et al: *NANDA, NOC and NIC linkages,* ed 2, St Louis, 2006, Mosby.

AMBULATORY SURGERY CONSIDERATIONS

Cystoscopy, Transrectal Guided Ultrasound of the Prostate

A commonly performed outpatient urologic procedure is a cystoscopy, transrectal ultrasound guided biopsy of the prostate (Cysto/TRUS). To minimize complications, patient selection is determined by the healthcare team. Patients classified as physical status 1 or 2, as per the American Society of Anesthesiologists, generally pose no great risk for procedures performed with general, intravenous moderate sedation (IV sedation), and local anesthetics. The majority of Cysto/TRUS patients have this procedure performed with IV sedation/local. To decrease pain during and immediately after the procedure, a viscous local anesthetic is injected into the rectum and also the urethra after IV sedation is initiated.

Preoperative and postoperative teaching of the patient and his family is most essential since the family will be the primary caregiver on discharge. Teaching begins in the surgeon's office. The office staff provides patients with a prescription for antibiotics with instructions to begin the medication 24 hours before the procedure and to continue oral antibiotics postoperatively until the prescription is completed. The office staff also advises the patient to take a cleansing enema 2 to 3 hours before the procedure. Both the antibiotics and the enema decrease the chances of postoperative infection.

Patient and family anxiety levels will be high pending the postoperative diagnosis. The patient may also be anxious because of the nature of the procedure and anesthetic used. The perioperative nurse plays a key role in supporting the patient and his family throughout the ambulatory surgical experience.

Discharge assessment following anesthesia includes the following:

- Airway patency, respiratory function, and oxygen saturation
- Stable vital signs
- Hypothermia resolved
- Level of consciousness and muscular strength
- Adequate pain control
- Mobility
- Skin color and condition
- Condition of the surgical site
- Intake and output
- Comfort
- Anxiety
- Significant other interaction
- Numeric score if used

Before discharge the nurse will instruct the patient to increase his clear liquid intake and monitor his urine output. Postoperative burning upon urination and blood in the urine as well as blood draining from the rectum are common. Patients are instructed to keep the perineum clean. The nurse ensures the patient has a prescription for pain medication, clarifies the instructions for dosage and frequency, and instructs the patient to call the surgeon for any temperature higher than 101° F. The nurse provides all instructions verbally and gives the patient and his family a written copy of the instructions. Patients call the physician as directed for results of the biopsy.

A postdischarge phone call to the patient is recommended. This phone call allows the nurse to review the patient's postoperative status, provide reassurance if necessary, and reinforce any teaching. The call also provides the patient and his family an opportunity to ask any additional questions.

PATIENT AND FAMILY EDUCATION

Home Care Education for the Nephrectomy Patient

Give the patient and the caregiver both verbal and written instructions. Provide them with the name and telephone number of a physician or nurse to call if questions arise. At the end of reviewing home care instructions, have the patient or family member repeat back, in his or her own words, information provided.

GENERAL INFORMATION

- Review the purpose and explain the type of procedure performed: partial or total nephrectomy.

WOUND/INCISION CARE

- Instruct the patient on caring for the incision and changing the dressing:
  - Wash hands.
  - Inspect the incision for signs of infection.
  - Cleanse the area with an antiseptic agent.
  - If there is no evidence of drainage, leave the site open to the air. Otherwise, cover the incision with sterile gauze squares held in place with tape.
- Teach the patient how to care for the nephrostomy tube, if present.

SPECIAL INSTRUCTIONS

- Inform the patient that showering and bathing may be resumed as recommended by the physician.
- Explain how to measure urine output as indicated.

WARNING SIGNS

- Review the signs and symptoms that should be reported to a physician or nurse:
  - Infection: incision red, warm to touch, painful, with increased or purulent drainage (define)
  - Urinary tract infection: fever, chills, hematuria ("blood in urine"), flank pain, sudden increase in urinary output

ACTIVITY

- Discuss the need to exercise to tolerance and to plan frequent rest periods. Explain that fatigue is common.
- Encourage the patient to discuss allowances and limitations with respect to occupation, recreation, and activities.
- Tell the patient to avoid heavy lifting (>10 lb) for at least 6 weeks.
- Advise the patient to avoid contact sports (e.g., wrestling, football) that could endanger the remaining kidney.

DIET

- Inform the patient that a regular diet can be followed unless there are restrictions related to the underlying reason for nephrectomy.
- Encourage the patient to drink 8 to 10 glasses of fluids per day unless restrictions of the underlying disease apply. Half of these should be fruit juices (to maintain electrolyte balance).

FOLLOW-UP CARE

- Stress the importance of regular follow-up visits. Make sure the patient has the necessary names and telephone numbers.

Modified from Canobbio MM: *Mosby's handbook of patient teaching*, ed 3, St Louis, 2006, Mosby.

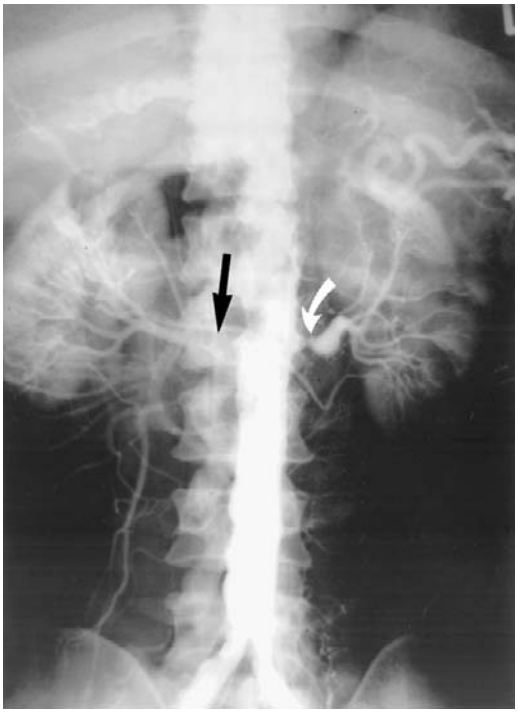


FIGURE 14-14 Bilateral renal artery stenosis. Severe stenosis of the right renal artery *(straight arrow)* is difficult to see because the artery overlies the vertebral body. The left renal artery stenosis is easier to identify *(curved arrow)*.

Those procedures include, but are not limited to, cystoscopy with stent placement, IV urogram, retrograde pyelogram, percutaneous antegrade stent placement and nephroscopic radiography, and ultrasound procedures with percutaneous access. The latter may be done to drain an abscess, to place a catheter or stent, or simply to introduce contrast material for direct fluoroscopic examination. Renal artery hypertension and stenosis may be treated successfully through new and advanced uroradiology methods, such as percutaneously placing stents in stenotic renal arteries (Novick and Fergany, 2007) (Figure 14-14).

DIAGNOSTIC AND ENDOSCOPIC PROCEDURES

Cystoscopy

Cystoscopy is an endoscopic examination of the lower urinary tract, including visual inspection of the interior of the urethra, the bladder, and the ureteral orifices. In a male patient, special attention is given to the examination of the verumontanum (which contains the ejaculatory duct), the bladder neck, and the median and lateral lobes of the prostate. In a female patient, the urethra, bladder neck, and bladder are examined.

Cystoscopy is an important diagnostic tool that provides the urologist with valuable information concerning the patient's urologic condition (History box). Indications for cystoscopy include hematuria, urinary retention, urinary tract infection, cystitis, tumors, fistulas, vesical calculus disease, and urinary incontinence. Urinary incontinence in postmenopausal women may be related to estrogen deprivation.

Procedural Considerations. Once in the preoperative area, all patients should be greeted by name and identified by their

HISTORY

How Cystoscopy Began

The blueprint for all other endoscopes is the cystoscope. In 1805 Philip Bozzini of Germany lit the way with his *Lichtleiter,* a primitive prototype of what we now know as the cystoscope. In 1872 British scientist John Tindell established the principle of internal light reflection inside glass rods. Then in 1877 Maximilian Nitze (the father of the cystoscope), in collaboration with Austrian manufacturer Joseph Leiter, turned Bozzini's prototype into the first direct-vision *kystoskop* for viewing the interior of the bladder, urethra, and larynx. This consisted of an incandescent platinum wire loop that fluoresced the bladder from the inside while magnifying the image externally through a system of lenses.

American physicians, in the meantime, worked with a German immigrant named Reinhold Wappler, who by the 1900s became known as a superior endoscope innovator. Endoscopic devices finally began to gain widespread popularity when Thomas A. Edison developed the incandescent lamp. Through miniaturization, a low-amperage mignon bulb was created from his lamp, allowing for simple, manageable, and low-cost cystoscopes to be produced.

Heinrich Lamm of Germany confirmed in 1930 that optical fibers could transmit images. But it was not until the mid-1950s that fiberoptics entered the scene, replacing these mignon bulbs with glass-fiber bundles. In 1954 fiberoptics became practical when British physicist Harold H. Hopkins produced the first usable system. A suggestion by a Dutch optics professor, Abraham van Heel, to coat the optic fibers with a transparent sheath led to unlocking the key to continuous illumination. This coating protected the fibers and prevented light from "leaking" out.

The contributions of Hopkins and van Heel became the inspirations behind the first fiberoptic gastroscope in 1957 and the first ureteroscope in 1960. Also in 1960, Hopkins introduced a refinement of his original technology, the "rod lens" rigid endoscope. This was created by combining air with long ground-up pieces of glass into an optical surface. In 1967 this method was applied to the cystoscope, thus replacing the previous prisms, mirrors, and lenses.

The 1980s brought the marriage of fibers and lenses into co-axial fiberoptic bundles through which one package of strands carried light and another returned images. These allowed increased flexibility and maneuverability without image distortion. Today endoscopy is so refined that visualization and treatment are achieved with flexible pencil-size tipped cystoscopes, ureteroscopes, and laparoscopes working through spearlike channeled sheaths and trocars.

Modified from Engel RM: Philipp Bozzini—the father of endoscopy, *J Endourol* 17(10):859-862, 2003; Wm. P. Didusch Center for Urologic History of the American Urological Association, Linthicum, Md, available at http://urologichistory.museum/content/milestones/cystoscopy/p1.cfm. Accessed May 16, 2009.

identification bracelet and number. The perioperative nurse should check the chart for operative consent and pertinent laboratory reports; IVPs and any other diagnostic x-ray studies ordered preoperatively should also be available for review. Customarily, the patient voids immediately before transport to the OR. The time of urination and the output volume should be documented for ruling out residual urine in the bladder.

After the patient is placed on the cystoscopy bed, correct positioning requires optimum relaxation of muscles of the legs and perineum. Proper positioning is a vital consideration for patient safety and comfort. Allen and Yellofin stirrups are boot-style stirrups that support the foot and calf. These have thick gel padding within the stirrup and provide optimum patient comfort and protection, relieving pressure on the popliteal space. They are especially beneficial for the patient who has limited hip mobility and altered peripheral circulatory status. The nurse should assess the patient's bilateral pedal pulses preoperatively and postoperatively when using any stirrups. Stirrups should be adjusted carefully to avoid undue pressure on the calf. If knee crutches are employed, the curve of the yoke suspension should flow outward from the perineum, in the same manner as the patient's legs. Padding the knee crutches reduces pressure on the popliteal areas. If sling stirrups that support only the feet are employed, the post should be padded and positioned to prevent pressure on the peroneal nerve. Special pads are designed for use with both of these stirrups.

After the patient is properly positioned, the anesthesia provider may tilt the OR bed so that the patient's head is slightly higher than the buttocks to allow the prep solution to drain into the collecting pan. Pooling of solutions beneath the patient may cause skin reaction and chemical irritation, as well as the potential for burns if an ESU is used. If the cystoscopic procedure requires the use of an ESU, the nurse ensures that the dispersive pad is placed on the patient in direct contact with the skin as close to the operative site as is practical. When placing the ESU pad, the nurse avoids hairy areas, bony prominences, scar tissue, and proximity to prosthetic metal implants or pacemakers.

After properly positioning the patient, the nurse or urologist dons gloves and preps the entire pubic area, including the scrotum and perineum, with an antimicrobial solution. A disposable drape sheet with a sterile screen material incorporated into it is a standard part of the cystoscopy drape pack. The surgeon and surgical technologist drape the patient in a manner that ensures aseptic technique is maintained during the urologic procedure. If a general or spinal anesthetic is required, the anesthesia provider administers it before prepping and draping. If a local anesthetic is preferred, the surgeon instills it into the urethra of the male patient after prepping and draping but before instrumentation. For a female patient, the surgeon places a cotton applicator that has been dipped into the anesthetic solution in the urethral meatus. Usually, viscous lidocaine (Xylocaine), 1% or 2%, is used. If the patient is allergic to lidocaine, instillation of 50 to 60 ml of lubricant accompanied by anesthesia-monitored sedation is often adequate to afford painless access to the urethra and bladder. The patient should be informed that a sensation of pressure is to be expected.

The basic cystoscopy setup requires a cystoscopy pack, a sterile gown or apron, sterile gloves, a fiberoptic light source, a prep cup and solution, gauze sponges, the cystourethroscope (Figure 14-15), a short bridge and fiberoptic light cord, lateral and Foroblique telescopes, a Luer-Lok stopcock, irrigation tubing and sterile water irrigant, and water-soluble lubricant. Additional items that should be sterile and available include a calibrated container to measure residual urine, test tubes with screw tops for urine specimens, an Albarrán bridge and rubber catheter nipples or adapters, a medicine glass for dye, anesthetic solution, disposable 10-ml and 20-ml syringes, medication

FIGURE 14-15 Basic instruments for cystoscopy, catheterization, electrosurgery, and retrograde ureteral pyelography (add ureteral catheter of choice). *Left to right,* Bugbee electrodes, single-horn Albarrán deflecting bridge, nipple adapters, stopcock, short double-horn bridge, 23F and 17F Foroblique cystourethroscopes and sheaths, 30-degree and 70-degree telescopes, double-horn Albarrán deflecting bridge, single-horn examining bridge, visual obturator, and fiberoptic cable.

FIGURE 14-16 Flexible cystoscope.

labels and a marking pen, a penile clamp (to occlude male urethra after local anesthetic is instilled), contrast material, an ESU and dispersive pad, and a Bugbee electrode.

The flexible cystoscope (Figure 14-16) is used for patients with obstructive symptoms resulting from prostatic hyperplasia and rigid prostatic urethra. In addition, the flexible cystoscope can be used for patients who cannot assume a lithotomy position, such as those with spinal cord injuries or severe arthritis. Flexible cystoscopy may be accomplished with the use of a local anesthetic. It affords the patient a higher degree of comfort, is less traumatic to the urethra, and can be performed in the patient's bed on the nursing unit.

Cleaning, sterilization, disinfection, and maintenance of endoscopic equipment are important procedures in the care of fiberoptic lensed instruments. Ultimately this process reduces costly repairs and ensures the availability of properly functioning instruments. See Chapter 7 for the process to correctly process endoscopic equipment.

Endoscopy of the genitourinary tract is considered a class II (clean-contaminated) procedure and, according to the Centers for Disease Control and Prevention (CDC) and the Association for Professionals in Infection Control and Epidemiology (APIC) guidelines, presently requires disinfection rather than sterilization. High-level disinfection with an agent such as activated glutaraldehyde or dialdehyde that can destroy vegetative microorganisms, most fungal spores, tubercle bacilli, and small nonlipid viruses is recommended. In most situations, the routine of meticulous cleaning of endoscopic instruments and making sure that all channels are accessed, followed by appropriate high-level disinfection, provides reasonable assurance that the items are safe to use. The level of disinfection is based on the contact time, temperature, and concentration of the active ingredients of the disinfectant, as well as the nature of microbial contamination.

Many institutions are, however, treating endoscopic interventions as sterile procedures because the sterilization of instruments provides the greatest assurance that the risk of infections transmitted by contaminated instruments has been eliminated (see Chapter 3). Some options available include glutaraldehyde solution, hydrogen peroxide solution, an automated peracetic acid unit, an ETO (ethylene oxide, "gas") sterilizer, a hydrogen peroxide and plasma sterilizing unit, and high-vacuum or gravity steam autoclaving for those components that may be sterilized in this manner. The manufacturer's recommendations should always be followed. If soaking is chosen the lid should remain on the soaking container when not in use; masks should be worn when in direct contact with the fumes. It is also imperative that the instrumentation be thoroughly rinsed in sterile distilled water after removal from soaking solution and before use. Glutaraldehyde residue remaining in the channels or on the lens can result in chemical burns for the patient and the surgeon.

Stone removal, bladder biopsy, and bladder fulguration may be accomplished by using special cystoscopic accessories, such as the Hendrickson-Bigelow lithotrite, which crushes large bladder calculi. This procedure is called a *litholapaxy.* Lowsley forceps, Wappler rigid cup forceps, and flexible foreign body forceps may also be employed. Bladder fulguration requires the use of flexible-stem electrodes available in various French sizes and tip configurations such as the ball, cone, dome, and bayonet.

Operative Procedure

1. The surgeon lubricates the cystourethroscope and introduces it into the urethra, withdraws the obturator, and drains the bladder. Residual urine may be measured at this time if the patient voided before the examination. The specimen may be saved for cultures or cytologic studies.
2. The surgeon connects the cystourethroscope to the irrigating system, and inserts and locks the telescope in place. If the patient is awake, telling the patient to try to urinate also helps facilitate passage of the scope. The surgeon controls the rate of flow and volume of fluid by adjusting the stopcock on the scope. If difficulty is encountered during insertion, the visual obturator may be used to introduce the scope under direct vision. This accessory is constructed to smooth the fenestrated edges of the cystourethroscope. It requires the use of the telescope for direct vision and permits irrigation during introduction.
3. For retrograde ureteral catheterization and pyelography, the surgeon passes ureteral catheters through the cystoscope sheath and then passes them through the ureteral orifice and into the ureter via the Albarrán bridge. A radiopaque substance (e.g., nonionic, low-osmolar agents Omnipaque 300 and Optiray 320; or ionic high-osmolar Renografin-60

and Hypaque 50) is injected (see Surgical Pharmacology, pp. 489-490). Fluoroscopic imaging is used to outline the entire upper urinary collecting system.

Periurethral-Transurethral Injection of Bulking Agents

Collagen injection is an ambulatory surgery procedure achievable with the patient administered a local anesthetic with or without sedation. Collagen (Contigen) is a live bovine dermal natural protein and is prepackaged in a sterile syringe containing the collagen material. Injection needles available are an 8-inch, 23-gauge, noncoring needle for transurethral use or a 5-inch, 22-gauge needle for periurethral insertion. Female patients with intrinsic sphincter deficiency (ISD) demonstrated by urodynamic evaluation and male patients (usually after prostatectomy) with incontinence lasting more than 1 year may benefit from this procedure. Other indications for collagen injection include urethral hypermobility (UH), stress urinary incontinence (SUI) secondary to previous stricture treatment, trauma, or myelodysplasia (Appell and Winters, 2007).

Durasphere is a bulking product consisting of pyrolytic, carbon-coated beads within a water-based viscous medium. Needles for instillation include a 1.5-inch spinal-tip subcutaneous needle and a 15-inch spinal-tip transurethral needle. It is designed to treat women with SUI secondary to documented ISD. Durasphere is not absorbed as readily as collagen and may provide a more durable effect. Durasphere is currently approved by the U.S. Food and Drug Administration (FDA) for use in women only.

Procedural Considerations. Collagen must be kept refrigerated and the FDA guidelines for its use and documentation followed. Durasphere requires no refrigeration. Patients selected for collagen injection must be skin-tested with collagen 1 month before periurethral injection. The patient receiving Durasphere does not require skin testing. A urine culture and sensitivity will be done approximately 10 days preoperatively. It is optimal to use a video system for the procedure. A basic cystoscopy set is required. The patient will usually be in the lithotomy position.

Operative Procedure

1. The surgeon instills urethral anesthetic and may supplement the anesthesia with a perineal block of 1% or 2% lidocaine. Cystoscopic examination is performed before the bulking agent is injected to rule out any associated findings. It is recommended that the irrigation be instilled by use of a pressure bag to minimize extravasation of the material by increasing the intraurethral pressure.
2. The surgeon introduces the injection needle provided by the manufacturer through the cystoscope and places the tip transurethrally, below the urethral mucosa, just distal to the bladder neck. In the female the shorter needle may also be employed for periurethral introduction. Positioning of the needle tip is accomplished when the surgeon sees the indentation of the urethra by the tip while manipulating the needle.
3. The material is injected until the urothelium enlarges and meets in the midline, approximating the appearance of lateral lobe enlargement of the prostate.

FIGURE 14-17 Grade 5 bilateral ureteral reflux.

Transurethral Ureteropyeloscopy

Transurethral ureteropyeloscopy is an endoscopic examination of the ureters and renal pelvis. The use of rigid or flexible ureteroscopes or ureteropyeloscopes provides the opportunity to diagnose filling defects in the ureter and renal pelvis, congenital anomalies (Figure 14-17), hematuria, ureteral obstruction, and damage from trauma. Manipulation, fragmentation, basketing of ureteral and renal calculi, and retrieval of foreign bodies are possible with transurethral ureteropyeloscopy. Extracorporeal shock-wave lithotripsy (ESWL), electrohydraulic lithotripsy (EHL), sonic lithotripsy, or laser lithotripsy may accompany the procedure. It may also be used to manage residual sludge after these treatments.

Ureteral strictures may be treated transurethrally, and biopsies of tumors of the ureter and renal pelvis are performed under direct visualization. Internal ureteral stents may also be inserted for ureteral patency. These range in size from 3F to 8.5F and are available in single-J, double-J, and pigtail configurations.

Procedural Considerations. The setup is similar to that for a cystoscopy with the addition of a rigid or flexible ureteroscope system (Figure 14-18). A critical factor in this procedure is allowing enough time for careful dilation of the ureter under C-arm fluoroscopy. The flexible ureteroscope has gained popularity because of its inherent tip mobility, which provides a more panoramic view of the entire circumference of the ureter. The perioperative nurse must be prepared to tilt the radiolucent operative bed at head and foot and laterally, as well as raise the bed.

In addition to the standard cystoscopy setup, the following items should be available: a rigid or flexible ureteroscope,

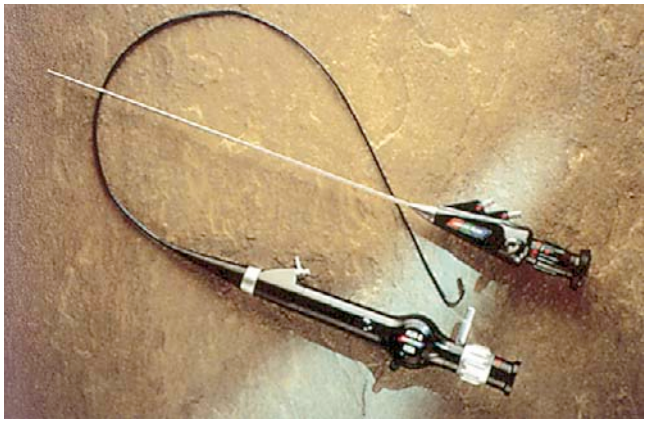


FIGURE 14-18 Flexible ureteropyeloscope and rigid ureteropyeloscope.

ureteral dilators of graduated sizes and styles, size 3-French to 5-French ureteral stone baskets of various styles, a ureteral grasping forceps, biopsy forceps, snare, scissors, catheters of various styles and sizes, stents, guidewires, balloon dilators, and radiographic contrast material. Patient allergies should be checked before the use of radiographic contrast material.

Operative Procedure

1. The surgeon inserts the ureteropyeloscope and accesses the ureter with a guidewire under fluoroscopic control. The ureter is irrigated as the guidewire is advanced. The surgical technologist assists by maintaining slight tension on the wire.
2. The ureter is dilated to 10F to 12F with a balloon dilator or co-axial dilators. If a balloon dilator is chosen, the balloon should be inflated with contrast material, using a pressure syringe to ensure that it does not exceed the maximum allowable atmospheric (ATM) pressure (burst pressure).
3. An additional working guidewire is placed by the surgeon to be used as a safety wire.
4. The surgeon passes the ureteroscope over the working guidewire, biopsies any suspicious lesions, and performs diagnostic pyeloscopy and ureteroscopy. The characteristics of calculi are observed to determine the best treatment approach. Urine may be obtained for cytologic and microbiologic examination. If a calculus is small enough to be delivered through the ureter, the surgeon engages it in a retrieval basket and removes it under visual as well as fluoroscopic control. If, after ureteral dilation, the calculus does not appear to be small enough for delivery, lithotripsy (fragmentation) is performed through the ureteroscope, or ESWL may be performed later. Lithotripsy may be performed with ultrasonic (through a rigid ureteroscope) or electrohydraulic lithotripters or with the tunable pulse-dyed or holmium:yttrium-aluminum-garnet (Ho:YAG) lasers. Appropriate laser precautions must be enforced. Chapter 7 discusses laser safety issues in more depth.
5. The surgeon assesses the ureter for integrity (perforation or laceration) with retrograde pyelography.
6. A ureteral stent is placed over the remaining safety guidewire, and the guidewire is removed.

SURGERY OF THE PENIS AND THE URETHRA

Laser Ablation of Condylomata and Penile Carcinoma

Laser ablation of condylomata or penile cancer is the eradication of diseased tissue by means of a laser beam. Laser therapy has been determined to be effective for condylomata and penile cancers that are refractory to other treatments. One of the major advantages of the laser is that heat is distributed evenly to the tissue underlying the lesion. When any laser is being used, precautions appropriate to that system must be initiated (see Chapter 7).

Procedural Considerations. Laser treatment may be performed successfully with local infiltration of an anesthetic. A U-shaped, craterlike lesion of predetermined depth with a 2-mm radius can be created. A power setting ranging from 2 to 20 watts on continuous or super-pulse mode is commonly used. With laser ablation, less edema and necrosis occur, fibrosis is minimized, and rapid healing is facilitated. The argon, CO_2, potassium-titanyl-phosphate (KTP), and neodymium (Nd):YAG lasers are all suitable for this therapeutic application.

Operative Procedure

1. The surgeon moves the beam transversely across the tissue and then in a crosshatch matrix, thereby treating all perimeters of the lesion. Throughout the procedure the surgeon wipes the area with a sponge moistened in acetic acid (5% vinegar), which results in greater visualization of the diseased tissue and allows therapy to deeper layers.
2. Postoperatively the affected areas may be coated with an antibiotic ointment. Wounds are generally left uncovered.

Circumcision

Circumcision is the excision of the foreskin (prepuce) of the glans penis. Circumcision in adult males is performed for the relief of phimosis, a condition in which the orifice of the prepuce is stenosed or too narrow to permit easy retraction behind the glans. Another condition that may require circumcision is balanoposthitis, an inflamed glans and mucous membrane with purulent discharge. Circumcision may also be done to prevent recurrent paraphimosis, a condition in which the prepuce cannot be reduced easily from a retracted position. (See Chapter 25 for pediatric considerations during circumcision.)

Procedural Considerations. The perioperative nurse assists in positioning the patient in the supine position. A plastic or minor instrument set and a local anesthetic with IV sedation are sufficient. The ESU should be available.

Operative Procedure

1. The surgeon clamps the prepuce in the dorsal midline and incises it toward the coronal margin (Figure 14-19, *A*), leaving about 5 cm of coronal mucosa intact. If the prepuce is adherent, a probe or hemostat may be used to break up adhesions.
2. A similar procedure is performed ventrally. The two incisions are then joined circumferentially. Alternatively, a superficial circumferential incision is made in the skin with a scalpel at the level of the coronal sulcus and the mucosa at the base of the glans.

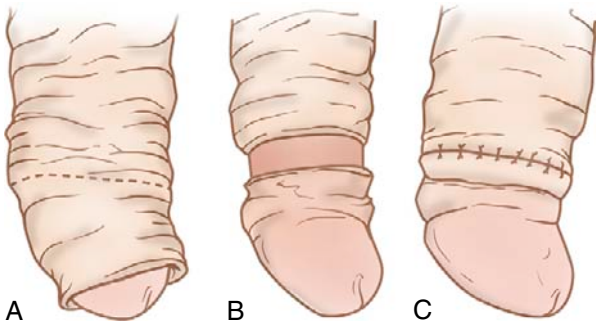


FIGURE 14-19 Circumcision.

3. The surgeon undermines redundant skin between the circumferential incisions and removes it as a complete cuff (Figure 14-19, *B*).
4. Bleeding vessels are coagulated or clamped with mosquito hemostats and ligated with fine absorbable ligatures.
5. The surgeon approximates the raw edges of the skin incision to a coronal cuff of mucosal prepuce, generally with 4-0 or 5-0 absorbable sutures on atraumatic, plastic cutting, or fine gastrointestinal (GI) needles (Figure 14-19, *C*).
6. The wound is dressed with petrolatum gauze.

Excision of Urethral Caruncle

A urethral caruncle is a benign lesion or inflammatory prolapse of the external urinary meatus in the female. Excision entails the removal of these papillary or sessile tumors from the urethra.

Procedural Considerations. The perioperative nurse assists with placing the patient in the lithotomy position. A minor or plastic set, an ESU, and a local anesthetic are used. A urethral catheter of an appropriate size may be required if the distal urethral prolapse is severe.

Operative Procedure

1. The surgeon uses a small, fine-tipped Metzenbaum or plastic scissors to expose the tumor and excise it within a wedge of ventral urethral tissue.
2. Figure-of-eight 4-0 absorbable sutures are placed at the edge of the incision to achieve hemostasis.

Urethral Meatotomy

Urethral meatotomy is an incisional enlargement of the external urethral meatus to relieve congenital or acquired stenosis or stricture at the external meatus.

Procedural Considerations. A male patient is placed in the supine position. Prepping and draping are as described for urethral catheterization. For a female patient, the lithotomy position is used. The surgeon administers local anesthesia. A plastic instrument set is required.

Operative Procedure

1. The surgeon places a straight hemostat on the ventral surface of the meatus.
2. An incision is made along the frenulum to enlarge the opening and overcome the stricture.

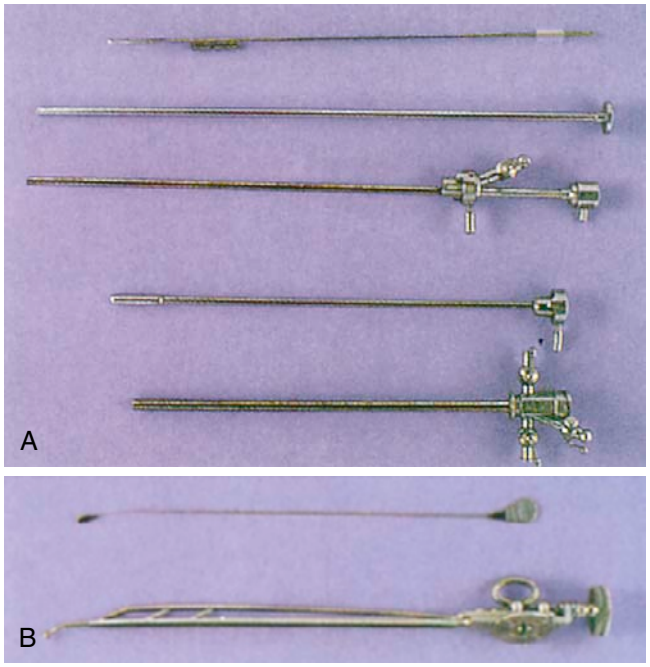


FIGURE 14-20 **A**, Optical internal urethrotome. **B**, Otis urethrotome.

3. Hemostasis is obtained by clamping the bleeding vessels and ligating them with fine absorbable sutures.
4. The surgeon sutures the mucosal layer to the skin with fine absorbable sutures.
5. A dressing of petrolatum gauze is applied.

Urethral Dilation and Internal Urethrotomy

Urethral dilation and internal urethrotomy entail the gradual dilation and lysis of a urethral stricture to provide relief of distal lower urinary tract obstruction. Urethral strictures or narrowing of the urethra may be caused by a congenital malformation that is usually found at the external urinary meatus. Infection or trauma may also contribute to stricture of the membranous and pendulous urethra. Urethral stricture disease may be treated by periodic dilation with Phillips filiforms and followers, Van Buren sounds, or balloon dilation catheters.

Procedural Considerations. The perioperative nurse assists with placing the male patient in the supine position for routine urethral dilation and in the lithotomy position for other procedures. The female patient is placed in the lithotomy position. Prepping and draping are conducted as appropriate to the patient's position and gender. The surgeon administers a local anesthetic either (1) by placing cotton-tipped applicators, which have been dipped into viscous 2% lidocaine (Xylocaine), into the urethral opening or (2) by using a urethral syringe to instill the lidocaine. Female urethral dilation is performed with short, straight metal dilators or with hollow McCarthy dilators. The latter allows a urine specimen to be obtained.

In addition to a cystoscopy setup, required instrumentation includes urethrotomes (Figure 14-20); the resectoscope working element with sheath, obturator, and cold knives; urethral dilators; Phillips filiforms and followers; Van Buren sounds; and a silicone Foley catheter. Before use, the filiforms and

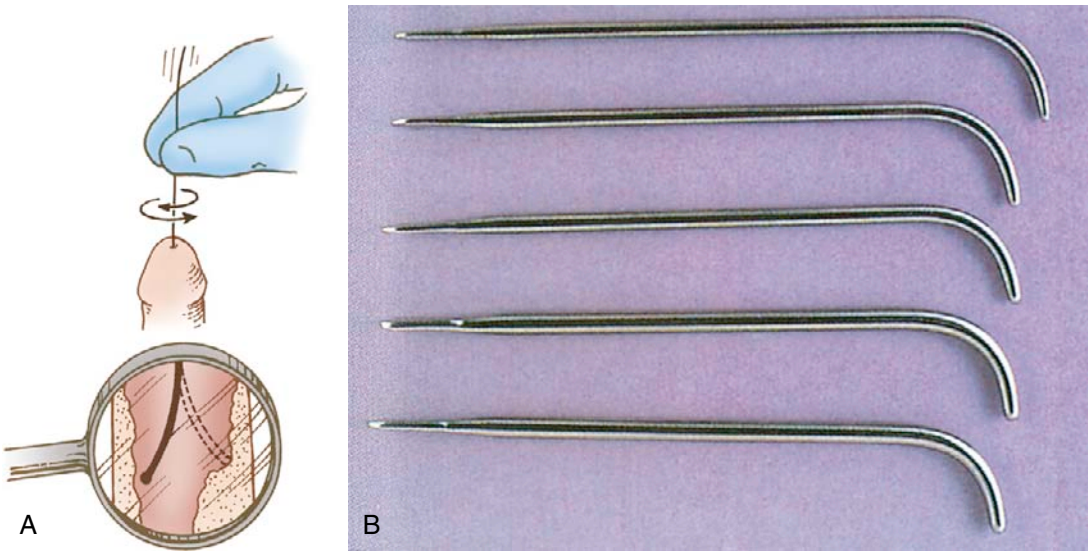


FIGURE 14-21 **A**, Method of using coudé-tipped bougie for passing stricture. **B**, Variety of urethral sounds (dilators).

followers should be carefully inspected for damaged or weak points, particularly around the scored-threaded end.

Operative Procedure

GRADUAL DILATION

1. In a male patient, the surgeon lubricates and anesthetizes the urethra with a viscous anesthetic that is instilled into the urethra with a urethral or Uro-Jet syringe. A penile clamp occludes the penile urethra at the coronal sulcus and keeps the anesthetic within the urethra.
2. Phillips filiforms of various tips and sizes are introduced first in an attempt to pass an instrument beyond the urethral stricture. Followers of increasing size are connected to the filiforms and passed through the strictured portion of the urethra, stretching the scarred area (Figure 14-21, *A*).
3. Slow dilation is also achieved with a small catheter or follower left in the urethra. It leads to softening of the stricture over the course of several days.

INTERNAL URETHROTOMY

1. The surgeon inserts the assembled visualizing urethrotome into the urethra using direct vision.
2. When necessary, the surgeon feeds a filiform or ureteral catheter into the catheterizing channel to help identify the patent portion of the urethra.
3. The surgeon advances the urethrotome to the desired position, and incises the urethral scar with the blade. The normal urethra is incised 1 cm proximally and distally beyond the stricture to achieve optimum results.
4. A silicone Foley catheter is usually left in place for 3 to 5 days after surgery.

Urethroplasty

Urethroplasty is reconstructive surgery of the urethra for strictures, urethral fractures, or narrowed segments of the urethral lumen that are congenital, inflammatory, or traumatic in origin. Urethral grafts are generally required and may include free skin grafts and mobilized vascular flaps. There are many combinations of these procedures, and in all of them some type of temporary urinary diversion may be used, depending on the location and severity of the condition.

Preoperatively, the patient usually complains of obstructive symptoms, frequently associated with a UTI. Techniques used to determine diagnosis include urodynamics (voiding pressures above and below the site of obstruction), urinary flow cytometry, IVU to rule out an upper tract lesion, cystoscopy, and urethrography. The length and density of the diseased urethra are determined to plan the appropriate reconstructive procedure. Any associated UTI must be treated and eradicated before surgical intervention. Definitive repair should not be done for 10 to 12 weeks after use of diagnostic instrumentation to allow the inflammatory reaction to subside.

Procedural Considerations. The patient is placed in the exaggerated lithotomy position by the perioperative nurse and one other person. Routine prepping and draping procedures are employed with precautions for isolating the anus (e.g., the use of an impervious plastic adherent drape). The setup includes a minor instrument set with fine plastic instruments for dissection and plastic repair. Strictures may be located deep, requiring fiberoptic lighting. An ESU may be required.

Operative Procedures

JOHANSON URETHROPLASTY. The Johanson urethroplasty is a two-stage procedure to repair and reconstruct the urethra for severe urethral stricture disease. Approximately 3 months after completion of the first stage, if the operative site is healing and the patient is voiding adequately, a second-stage procedure is performed. Vascularized flaps of preputial or penile skin may be mobilized to the ventrum by leaving them attached to the outer surface of the prepuce or as an island flap. One modification is the transverse preputial island flap neourethra with glans channel positioning for the meatus. Preputial skin is preferred because of its rich reliable blood supply and non–hair-bearing characteristics.

First Stage

1. The surgeon makes an inverted U incision in the perineum from the inner borders of the ischial tuberosities up to and including the base of the scrotum.
2. A Van Buren sound is passed into the urethra up to the stricture (Figure 14-21, *B*). The bulbocavernosus muscle is dissected and retracted laterally.
3. The surgeon makes an incision in the urethra over the strictured area and extends it in each direction at least 1 cm beyond the diseased area. The abnormal scar tissue is excised or simply incised, because scrotal skin ultimately increases the lumen.
4. A 28F sound is passed through both the proximal and the distal urethral lumens to rule out further stricture.
5. The surgeon sutures the remaining urethral mucosa to the scrotal skin with 4-0 absorbable sutures.
6. A cystotomy tube to divert the urinary stream may be left indwelling and removed in 5 to 7 days.

Second Stage (Mobilized Vascular Flap)

1. A red rubber catheter is temporarily inserted into the bladder through the proximal urethral stoma.
2. The surgeon incises the penoscrotal skin longitudinally, adjacent to the urethra.
3. A new urethra is constructed by developing the ventral preputial skin that is dissected free and fanned out. The rectangle of skin is rolled into the neourethra and measured.
4. A channel is sharply created on the ventral aspect of the glans, in a plane just above the corpora.
5. The surgeon removes the glans tissue, forming a groove approximately 14F in diameter.
6. Layers of subcutaneous tissue are dissected free from the dorsal penile skin to create an island flap that is spiraled to the ventrum. The surgeon brings the flaps together in the midline and closes with a continuous or interrupted 4-0 absorbable suture.
7. The neourethra is anastomosed proximally to the urethra and carried to the tip of the glans.
8. The dorsal penile flaps are transposed laterally to the midline, and the surgeon excises the excess skin.
9. Closure is with 4-0 absorbable interrupted mattress sutures around the glans and down the penile shaft. A bulky pressure dressing is applied.
10. Suprapubic cystostomy drainage is an option, but a urethral catheter usually suffices.

HORTON-DEVINE URETHROPLASTY (URETHRAL PATCH GRAFT). Urethral patch graft is a one-stage operative procedure that incorporates a free skin graft to correct a urethral stricture. Free skin grafts should be at full thickness. Because the free graft must be revascularized, it is important that it have a perfect skin cover of well-vascularized dorsal, preputial, penile skin.

1. The surgeon passes a 17F panendoscope into the posterior urethra, and then passes a 20F urethral dilator into the posterior urethra.
2. A perineal vertical midline incision is made into the urethral lumen. The surgeon reinserts the panendoscope and examines the incision to determine if it crosses the stricture.
3. The defect is measured, and the surgeon makes a circumferential incision on the posterior penile shaft to harvest an oval piece of skin the size of the defect.
4. The epidermal side of the graft is defatted, and 4-0 absorbable sutures are placed at the apex and base.
5. The surgeon sutures the apex into position at the proximal and distal ends of the stricture with the epidermal side toward the urethral lumen.
6. The graft is anastomosed proximally to the urethra with the suture line of the graft next to the corpus. The middle glans dart is fixed to the corpus. The graft is formed into a neourethra over a Silastic stenting catheter.
7. The surgeon reinserts the panendoscope and irrigates the urethra to check for suture-line leaks.
8. A Foley or fenestrated catheter is inserted to serve as a stent.
9. The surgeon approximates and closes the corpus spongiosum over the patched area as a separate layer with interrupted 3-0 absorbable sutures. Subcutaneous 4-0 absorbable sutures are placed.
10. The skin and the graft site are closed with interrupted 4-0 sutures.
11. A suprapubic catheter is inserted to divert urine for healing. Petrolatum gauze is wrapped around the penis and covered with gauze sponges and fluffed dressings. A scrotal support is applied to provide support and pressure.

Penectomy

Penectomy is the partial or total removal of a cancerous penis. The procedure selected depends on the extent of involvement and disease stage. Invasive penile cancer not suited for irradiation because of its size, depth, or location is best dealt with by penectomy. Excision of a 2-cm gross tumor margin is adequate for local management. Partial penectomy may afford a sufficient length for directable and upright urination. At least 3 cm of viable proximal shaft is necessary for consideration of a partial penectomy. If the residual stump is inadequate in length, detachment and mobilization of the suspensory ligaments may be an option in selected patients. A total penectomy is generally required when tumor margins are beyond a 2-cm retrievable length from the penoscrotal junction.

Options are available to limit the extent of the disfiguring surgery previously indicated for penile cancer. Chemotherapy agents, often combined with irradiation, are proving effective in shrinking penile carcinomas that would have previously mandated radical penectomy.

Reconstruction is possible after penectomy. Evaluation must take into account sexual, urinary, and cosmetic factors. Extensive or proximally invasive lesions that include the scrotum, perineum, abdominal wall, and pubis necessitate emasculation as well as expanded resection of involved tissues.

Procedural Considerations.

The setup necessary is similar to that for any inguinal surgery, with the addition of a medium Penrose drain for use as a tourniquet.

Operative Procedure

PARTIAL PENECTOMY

1. The lesion is excluded by a towel attached to the planned amputation line. The surgeon applies a penile tourniquet at the base of the penis (Figure 14-22, *A*).
2. After circumferential skin incision, the surgeon divides the cavernous bodies to the urethra with a 2-cm gross margin (Figure 14-22, *B*).

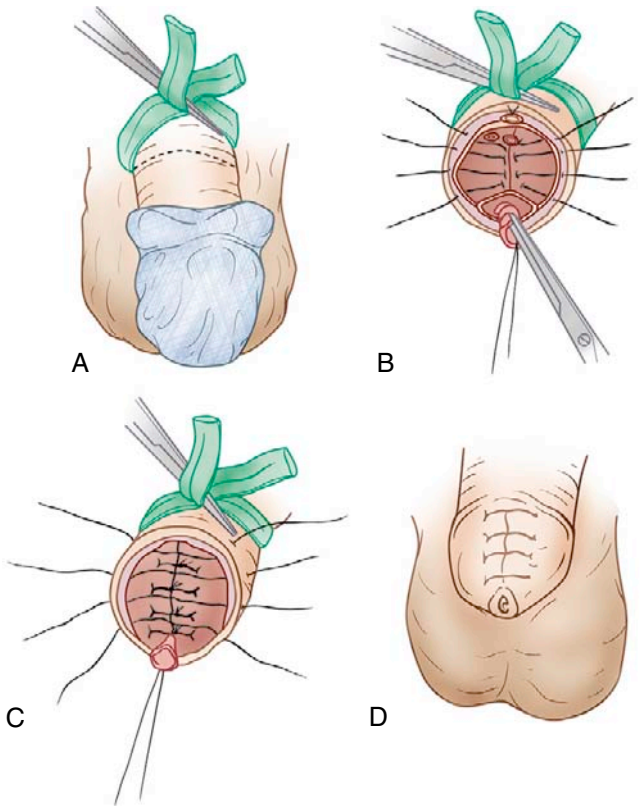


FIGURE 14-22 Partial penectomy.

3. Dorsal vessels are ligated, margins of the tunica albuginea are approximated, and the urethra is dissected proximally and distally (spatulated) to obtain a 1-cm redundant flap (Figure 14-22, *C*).
4. Without sacrificing the tumor margin, the surgeon divides the urethra. Interrupted sutures are placed on the opposite margins of the tunica albuginea to secure the corpora. The tourniquet is removed, and hemostasis is achieved.
5. After the dorsal urethrotomy, a skin-to-urethra anastomosis is performed. The redundant skin flap is then dorsally approximated (Figure 14-22, *D*).
6. A small urinary catheter is inserted, and a nonadherent dressing is applied.

TOTAL PENECTOMY

1. A vertical elliptic incision is made around the penile base (Figure 14-23, *A*).
2. The distal urethra and its ventral traction are divided through an incision in Buck's fascia, mobilizing the urethra and aiding its dissection, which extends from the corpora to the bulbar region.
3. The surgeon separates and ligates the corpora (Figure 14-23, *B*). The suspensory ligaments and dorsal vessels are divided as corporal dissection is carried out.
4. The urethra is transected from the corpora (Figure 14-23, *C*).
5. An ellipse of skin approximately 1 cm in size is taken from the perineal area. A tunnel is fashioned in the perineal subcutaneous layer of tissue. A traction suture through the tunnel, at the penile base, aids dissection for transposition of the urethra to the perineum (Figure 14-23, *D*).
6. The surgeon grasps the urethra with forceps and transfers it to the perineum. The urethra is spatulated, and a skin-to-urethra anastomosis is performed through a buttonhole incision in the perineum (Figure 14-23, *E*).
7. The primary incision is closed horizontally, elevating the scrotum away from the urethral opening (Figure 14-23, *F*).
8. An indwelling urinary catheter is inserted, and the wound is covered with a nonadherent dressing.

Penile Implant

A penile prosthesis is implanted for treatment of organic sexual impotence. Sexual impotence may be caused by (1) diabetes mellitus, (2) priapism, (3) Peyronie's disease, (4) penile trauma, (5) pelvic surgery, (6) neurologic disease (in selected cases), (7) vascular disease, (8) hypertension, and (9) idiopathic impotence. The penile implant serves as a stent to enable vaginal penetration for sexual intercourse. Penile implants are available as malleable one-piece devices, self-contained inflatable devices, and two- and three-piece devices. The procedure described for the inflatable penile implant is for the three-piece device.

Procedural Considerations. The anesthesia provider administers either a spinal or a general anesthetic. The perioperative nurse assists with positioning the patient in either the supine or the lithotomy position, as directed by the surgeon. A 5- to 10-minute skin prep is usually performed before draping is carried out. To prevent urethral injury and potential urinary retention, the surgeon may insert a 14F or 16F Foley catheter to identify the urethra intraoperatively. The ESU may be required. The surgeon may inject a local anesthetic of 0.5% plain bupivacaine (Marcaine) or 1% etidocaine (Duranest) at the beginning of the procedure into the incisional sites. Often, a penile block, composed of 0.9% saline (150 ml), 1% plain lidocaine (50 ml), and 30 mg/ml papaverine (2 ml), is instilled intraoperatively before the incision into the corpus cavernosum. This enables the surgeon to evaluate erectile size and provides some postoperative pain management.

The surgical technologist sets up a separate sterile Mayo stand or small table covered with a plastic drape for the implants. It is recommended that the implants not be in contact with paper or cloth that may shed fiber particles.

The instrument setup includes a minor set with fine instruments, plus Hegar dilators, the penile prosthesis of choice (Figure 14-24), the Furlow inserter, the closing tool, the assembly tool for clamping connectors (Figure 14-25, *A*), and the connectors of choice (Figure 14-25, *B*). Medications needed in the operative field include 50 ml of 1% lidocaine, 150 ml of injectable 0.9% normal saline, 1 ml of methylene blue (optional by surgeon preference), 2 ml of papaverine, 50 ml of 0.5% bupivacaine (Marcaine) or 1% etidocaine (Duranest), 50,000 units of bacitracin, and 80 mg of kanamycin. Medication safety practices must be implemented for all medications on the sterile field.

A serious risk with a penile implant is infection. Infection rates for first-time implantation are low at 1%, but the rate can rise to as high as 18% with reimplantation procedures. Because of the high risk of infection, models that have been irradiated and embedded with minocycline hydrochloride and rifampin (Inhibizone) are now available (American Medical Systems [AMS], 2009). The sterile team should be double-gloved

throughout the procedure. A 5-minute antimicrobial prep of the operative area is critical in reducing skin flora. The anus should be isolated in the perineal approach. Intraoperatively and before insertion of the implant components, a prophylactic antibiotic irrigant of bacitracin and kanamycin in normal saline is used on the implants without Inhibizone and in the insertion sites. Systemic antibiotics may also be required. As with any implant procedure, it is vital to maintain an environment conducive to infection prevention. The perioperative nurse ensures that traffic in and out of the OR is minimized.

It is recommended that the implants with Inhibizone not be soaked in any solution before implantation because this may

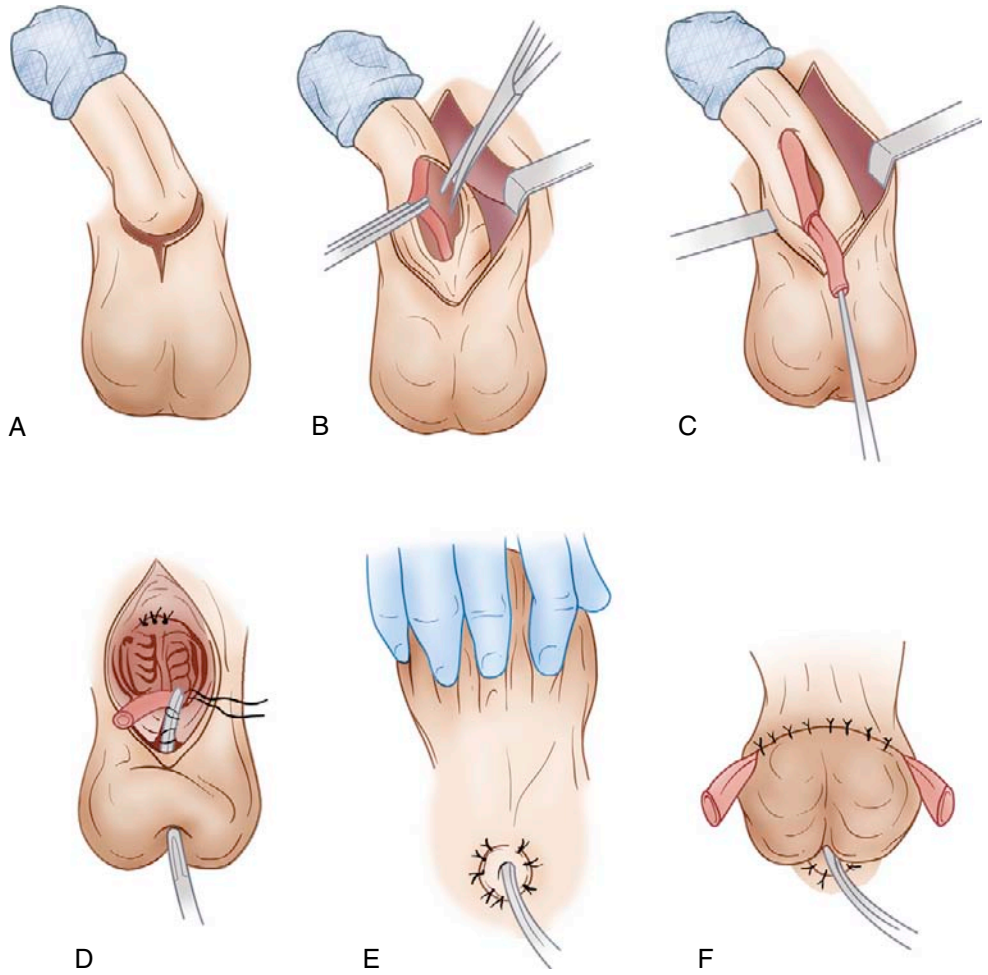


FIGURE 14-23 Total penectomy.

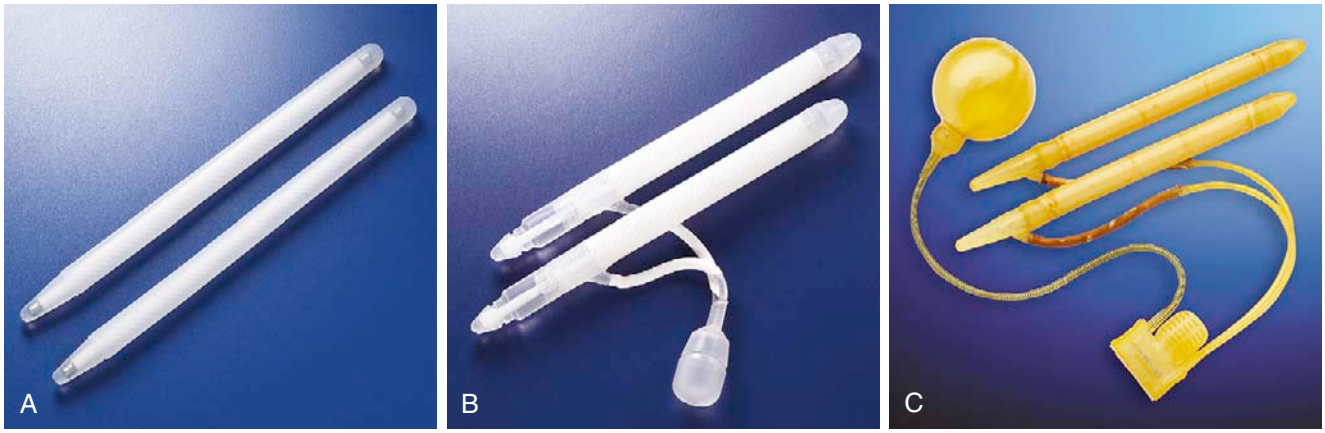


FIGURE 14-24 **A**, AMS malleable 650 penile prosthesis. **B**, AMS Ambicor inflatable two-piece penile prosthesis. **C**, AMS tactile inflatable penile prosthesis, three-piece with rifampin (Inhibizone).

cause the antibiotic component to disintegrate. The area to be implanted may be irrigated with antibiotic solution, and the implant itself may be dipped in a sterile solution of 0.9% normal saline to assist with insertion if desired. Prophylactic antibiotic protocols remain the same.

Operative Procedure

IMPLANTATION OF NONINFLATABLE (SEMIRIGID) PROSTHESIS

1. The surgeon inserts a 14F or 16F Foley catheter and attaches it to a drainage collection device to be maintained within the sterile field. The amount and color of urine are noted. The catheter is left in place intraoperatively to assist in identifying the urethra.
2. A midline incision is made from the base of the penis into the scrotum for approximately 3 cm. Some surgeons may choose a suprapubic or dorsal penile approach.

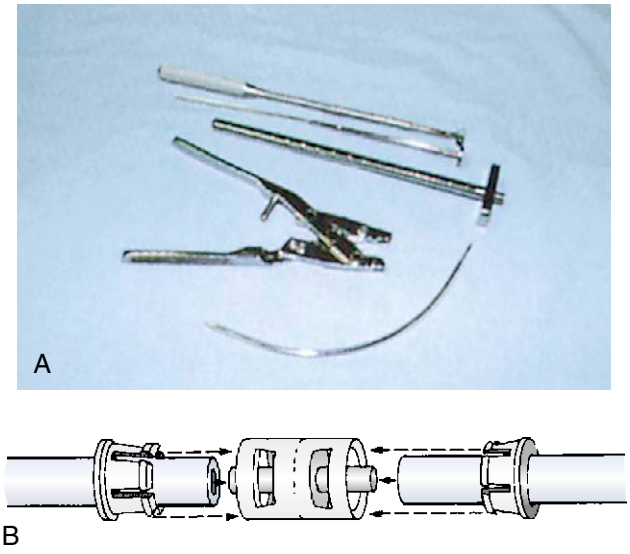


FIGURE 14-25 **A**, *Top to bottom,* Closing tool, Furlow inserter, assembly tool, tubing passer. **B**, Quik-connectors.

3. The surgeon incises the tunica albuginea over the most proximal portion of the corpora in a longitudinal manner, and places stay sutures.
4. The corpora are dilated proximally and distally with 7-mm to 14-mm Hegar dilators, depending on the diameter of the implant chosen. The corpora are dilated to 1 mm more than the implant size. Care is taken to not perforate the urethra.
5. The surgeon measures the corporal length with a Furlow inserter or sizing instrument.
6. After placement of the closure sutures, the surgeon inserts the prostheses into the corpora. Proper placement is evident immediately by a change in the configuration of the penis with no buckling of the glans.
7. The surgeon closes the tunica albuginea using the previously placed 2-0 absorbable continuous suture; 3-0 or 4-0 absorbable interrupted sutures are used for skin closure.
8. Petrolatum gauze or 2-inch Kling tube gauze may be used for the dressing.

IMPLANTATION OF INFLATABLE PROSTHESIS

1. The surgeon inserts a 14F or 16F Foley catheter and attaches it to a drainage collection device to be maintained within the sterile field. The amount and color of urine are noted. The catheter is left in place intraoperatively to assist in identifying the urethra.
2. A midline incision is made from the base of the penis into the scrotum for approximately 3 cm (Figure 14-26, *A*).
3. The surgeon incises the tunica albuginea of each corpus in the most proximal portion, and places stay sutures.
4. The corpora are dilated distally and proximally with 7-mm to 14-mm Hegar dilators. Dilation should be 1 mm more than the diameter of the chosen implant. The 700CX implant is 12 mm at its widest point. When this is used the dilation at the distal end should be 13 mm. The proximal end, however, should be 14 mm to accommodate the input tubing.
5. The surgeon measures the corporal length with the Furlow inserter.
6. Corporal sutures of 2-0 absorbable material are placed along the tunica incision and tagged. Some surgeons prefer to place these sutures last and employ the closing tool to prevent puncture of the cylinders.

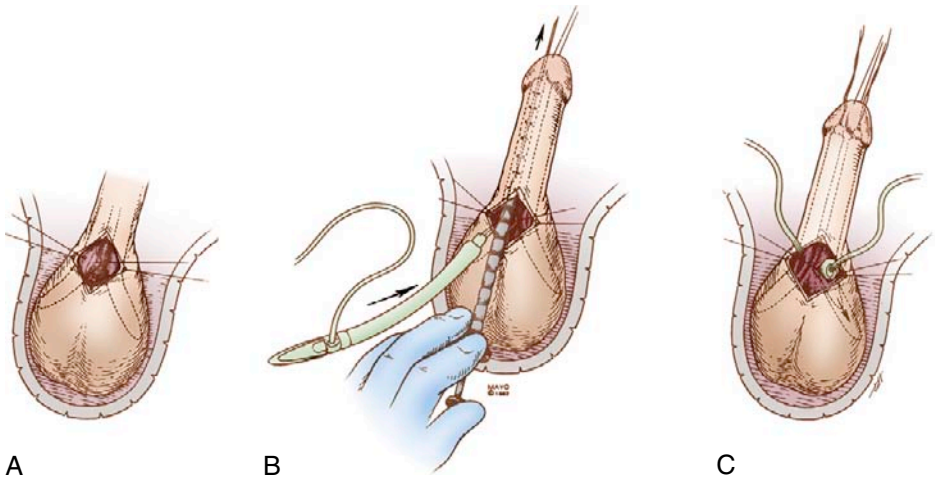


FIGURE 14-26 Penoscrotal approach for inflatable penile implant.

7. The cylinders are packaged with attached traction sutures of 4-0 braided polyester at the distal end. The surgeon places the suture through the eye of a 2½-inch Keith needle, and slides the needle into the groove of the Furlow inserter.
8. The surgeon guides the Furlow inserter along the corporal tunnel, and pushes the plunger to release the Keith needle, which punctures the glans (Figure 14-26, *B*).
9. The Keith needle is grasped with a heavy hemostat and pulled through the glans, allowing the cylinders to slide to the channel opening. The surgeon removes the Furlow inserter, inserts the cylinder, and guides it to its proper position beneath the glans penis (Figure 14-26, *C*).
10. If necessary, rear tip extenders are added to the proximal end of the cylinder. The proximal end is positioned in the crus.
11. The procedure is repeated on the other side.
12. The surgeon palpates the external inguinal ring and uses blunt dissection to create a path. Dissecting scissors are used to separate the transversalis fascia on the inguinal floor. If the Ambicor implant with self-contained reservoir is being placed, steps 12 through 14 are eliminated.
13. The perivesical space is enlarged to allow palpation of the Cooper ligament. The reservoir is then positioned into the perivesical space.
14. The surgeon fills the reservoir with 65 or 100 ml of saline solution (dependent on the reservoir size selected) and pulls it against the floor of Hesselbach's triangle.
15. The pump is then placed into the most dependent portion of the scrotum. It is generally positioned on the patient's dominant side. The space is created by blunt dissection lateral to the testicle.
16. The rods and reservoir tubings are connected to the pump with the connectors of choice, using the assembly tool to clamp them in place, and tested for inflation and deflation.
17. The surgeon closes the tunica of the scrotum over the pump with a running stitch of 3-0 absorbable suture.
18. The prosthetic device is left in a partially inflated position to reduce bleeding and promote healing for 24 hours postoperatively (Figures 14-27 and 14-28). (Following this period the implants are deflated for the remainder of the "healing phase" so the reservoir pocket heals with the reservoir in "full position" to prevent autoinflation.)
19. The surgeon closes the incision with 4-0 absorbable suture in a running subcuticular stitch, and a dressing is applied.
20. The penis is positioned flush with the lower abdomen for patient comfort. Mesh pants are useful as a nonadherent support dressing. An ice pack may be applied to reduce swelling.
21. The Foley catheter is left in place during the immediate 24-hour postoperative period and then usually removed.

Deep Dorsal and Emissary Vein Ligation

Undertaken for vascular compromise–related impotence, this procedure entails the ligation or elimination of the penile deep dorsal vein and its tributaries. Care is taken to avoid damage to the arteries and nerves lying alongside the deep dorsal vein. A common cause of erectile dysfunction in patients with organic impotence is vascular compromise. Before surgical intervention is undertaken, a definitive diagnosis of a corporal leak is made through dynamic infusion cavernosometry and cavernosography. Diagnostic results may indicate failure-to-store or failure-to-fill impotence. Patients with vascular compromise in a given anatomic region tend to be compromised elsewhere as well. Many have diabetes or hypertension. Because of this, the perioperative nurse must exercise great care in positioning the patient to prevent further damage to the patient's altered tissue perfusion. The cavernous and crural veins are suture-ligated. All circumflex and emissary branches are ligated or coagulated. The suspensory ligament is detached, and the entire deep and accessory dorsal vein is removed.

Revascularization of the Penile Arteries

The relationship of focal arterial occlusive disease to sexual dysfunction has prompted efforts to rectify the resulting impotence. Reconstructive surgery has been attempted in patients who demonstrate correctable vascular disease in the large arteries. The most widely attempted repairs are end-to-end and end-to-side microscopic anastomoses of the distal inferior epigastric artery to the proximal deep dorsal artery near the pubic level, below the rectus muscle and Buck's fascia. Paramedian and infrapubic incisions are made, and the arteries are freed and tunneled. This procedure requires both urologic and vascular surgeons.

SURGERY OF THE SCROTUM AND TESTICLES

Hydrocelectomy

A hydrocele is an abnormal accumulation of fluid within the scrotum. The fluid is contained within the tunica vaginalis. Excessive secretion or accumulation of hydrocele fluid may be the result of infection or trauma. A hydrocelectomy is the excision of the tunica vaginalis of the testis to remove the enlarged, fluid-filled sac.

Procedural Considerations. The patient is placed in the supine position. Prepping and draping of the patient include routine cleansing of the external genitalia and draping with a fenestrated sheet. A minor instrument set is required, plus a small drain, a 30-ml syringe with a 20-gauge, 2-inch aspirating needle, and a suspensory dressing.

Operative Procedure

1. The surgeon administers a local anesthetic into the cord at the base of the scrotum with 10 to 15 ml of plain lidocaine 1%.
2. An anterolateral incision is made in the stretched skin of the scrotum over the hydrocele mass with a #10 or #15 blade.
3. Bleeding is controlled with Crile hemostats, electrocoagulation, or vessel ligation with 3-0 absorbable ligatures. Stretching the skin of the scrotum compresses the scrotal vessels.
4. An incision is then made between the blood vessels. The fascial layers are incised to expose the tunica vaginalis.
5. The surgeon uses sharp and blunt dissection to free the hydrocele.
6. The sac is opened, and clamps are placed on each side incorporating the tissue adjacent to the tunica vaginalis and the skin.
7. Using Martius clamps, the surgeon everts the incised edges. The tension placed by the Martius clamp compresses the

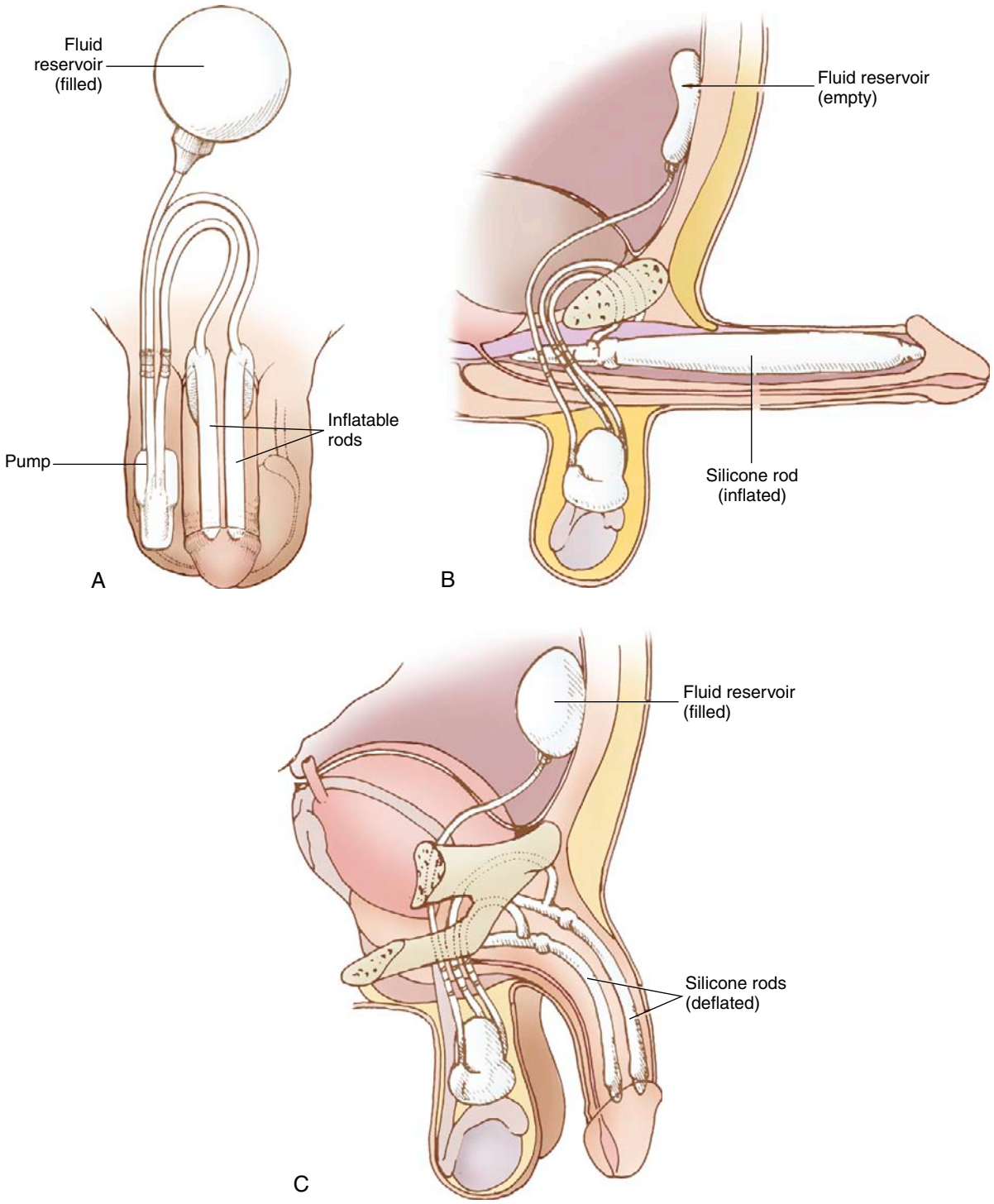


FIGURE 14-27 AMS inflatable 700CX penile prosthesis. **A**, Frontal view. **B**, Sagittal view—penis in erect position. **C**, Sagittal view—penis in flaccid position.

incised edge, controls bleeding, and prevents dissection between the tissue layers.

8. A pouch is created by dissecting between the tunica vaginalis and the dartos layer. Scrotal pressure is released. This pouch will hold the testis after the repair.
9. The surgeon opens the tunica vaginalis and evacuates the fluid contents.
10. The testis is lifted, and the sac is inverted so that it surrounds the testicular attachments and epididymis.
11. Excess tunica vaginalis may be excised. The surgeon sutures the tunica edges along the peritoneal surface with 3-0 absorbable suture in an interrupted fashion to the juncture of the testis. Six to eight sutures are placed around the circumference of the testis (Figure 14-29). Some surgeons

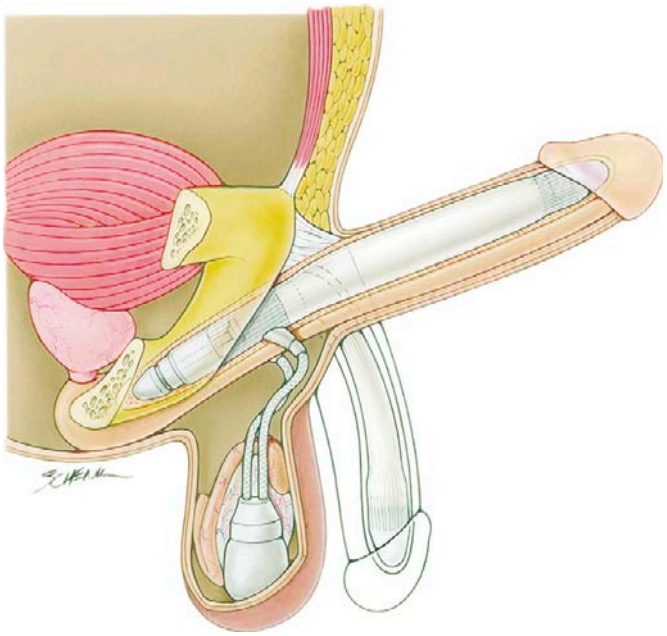


FIGURE 14-28 AMS Ambicor inflatable two-piece implant, sagittal view.

elect to sew the sac behind the spermatic cord in an interrupted fashion, and others may choose a continuous radial stitch around the posterior testis and epididymis.

12. The testis is replaced into the scrotum.
13. A drain may be placed into the scrotum and exteriorized through a stab wound in its most dependent portion. The drain is loosely sutured to the external scrotal wall to prevent migration.
14. The surgeon closes the scrotal incision with 3-0 absorbable sutures in a full-thickness continuous manner or in layers with 3-0 and 4-0 continuous absorbable sutures.
15. A fluff compression dressing contained in a scrotal support or mesh underwear aids in reducing postoperative scrotal edema.

Vasectomy

A vasectomy is the excision of a section of the vas deferens. The operation is usually performed selectively as a permanent method of sterilization. Because of the serious implications of permanent sterilization, particular attention must be paid to acquiring informed consent. Although studies have raised the question of a correlation between prostate cancer and vasectomy, a definitive causal relationship has not been established.

The patient having elective sterilization for birth control is encouraged to return to the office setting for sperm-count analysis. Generally, two successive negative counts are sufficient to indicate that sterility has been achieved. Elective vasectomies are frequently performed in the office setting.

Procedural Considerations. The patient usually lies in the supine position. A local anesthetic is used. A minor instrument set and scrotal support are needed.

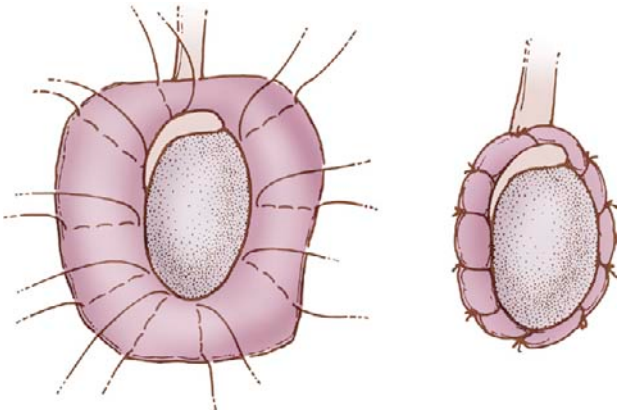


FIGURE 14-29 Hydrocelectomy.

Operative Procedure

NO-SCALPEL APPROACH

The no-scalpel technique was devised in China and has five fundamental principles:

1. Fixation of the vas deferens without entering the scrotal skin
2. Performance under direct vision to prevent damage from blind sharp scrotal penetration
3. Simplified instrumentation
4. Decreased operative time by simplification of the procedure
5. Elimination of an incision or use of a scalpel

The procedure is as follows:

1. The right vas deferens is fixed under the scrotal skin with three fingers.
2. Using a syringe with 1% or 2% plain lidocaine and a small needle, the surgeon raises a small wheal in the median raphe of the scrotum. The needle is advanced along the vas toward the external inguinal ring. Additional lidocaine is injected into the perivasal region.
3. The procedure is repeated on the left side. Pressure is applied to the wheal site to minimize edema.
4. Once adequate anesthesia is accomplished, the right vas is again fixed with three fingers.
5. The surgeon applies a vas ring clamp over the scrotal skin, encircling the vas. Lifting the clamp upward, the skin over the vas is stretched as thin as possible, leaving minimal tissue between the vas and the clamp.
6. The ring clamp is locked in place, and the scrotal skin cephalad to the clamp is stretched with an index finger.
7. The surgeon punctures the skin directly into the vas deferens with the inner prong of the pointed dissecting hemostat. Both prongs of the dissecting hemostat are placed into the puncture site and spread directly on top of the vas.
8. When the surface of the vas is visualized, one prong is used to penetrate the vas itself. The vas is brought out of the wound by twisting the hemostat 180 degrees.
9. The ring clamp is moved to directly encircle the vasal tissue. The vas may then be divided and occluded by intraluminal electrocoagulation, clips, or suture ligation. Fascia should be placed between the severed ends of the vas.

10. The surgeon repeats the procedure on the left side. It is usually possible to place the ring clamp around the left vas through the initial entry site. Sutures are not necessary.
11. After ensuring that there is no bleeding, antibiotic ointment, pressure dressings, and a scrotal support are applied.

Vasovasostomy

Vasovasostomy is the surgical reanastomosis of the vas deferens, using the operative microscope. The number of vasal reanastomosis procedures has increased dramatically. Reanastomosis may often alleviate chronic testicular pain, a not infrequent complication after vasectomy. In addition, a significant number of men who underwent a vasectomy want to regain their fertility. A precise reconnection can be performed with the use of a microscope and a modified two-layer anastomosis. Success rates vary, but in general, patency can be demonstrated by the presence of sperm in the semen within 4 weeks after vasovasostomy (Lipshultz et al, 2007). When there are no longer two viable segments of vas deferens, a similar procedure, the epididymovasostomy, may be performed. This involves anastomosis of a vas deferens to a segment of the epididymis. Postoperative precautions include no lifting or ejaculation for a minimum of 2 weeks. The sperm count and viability of sperm are rechecked at 3- and 6-month intervals. If sperm are not present by 6 months, the operation is considered a failure (Lipshultz et al, 2007).

Procedural Considerations. A minor instrument set is required, with the addition of selected microsurgical instruments and sutures. The procedure is frequently done under monitored anesthesia care with local injection of 0.5% plain bupivacaine (Marcaine) and 1% lidocaine (Xylocaine) in a 50:50 ratio.

Operative Procedure

1. After the vas deferens has been located by external manipulation, the surgeon makes a vertical scrotal incision.
2. The testicle, epididymis, and vas are displaced from the scrotum. The vasectomy site is identified, and the scarred area is excised.
3. The surgeon trims the proximal end of the vas deferens until fluid is expressed. Fluid is collected on a glass slide and examined for the presence of live sperm. Surgery continues even if results for sperm are negative unless an epididymal obstruction exists.
4. The distal end of the vas is resected until a normal lumen is visible.
5. The distal and proximal lumens are then dilated.
6. The surgeon places the two portions of the vas in an approximator clip and inserts a piece of background material underneath to provide contrast and improve visibility. Six stitches of 10-0 nonabsorbable microsuture are placed in the inner layer. The proximal end is sutured through the serosa to the mucosa, and the distal end is sutured through the mucosa to the serosa (Figure 14-30).
7. A second layer of 8 to 10 stitches of 9-0 nonabsorbable suture is placed without penetrating the lumen of the vas.
8. The surgeon closes the incision in two layers with interrupted 3-0 and 4-0 absorbable sutures.
9. Gauze sponges and a scrotal support are placed on the patient to provide a pressure dressing.

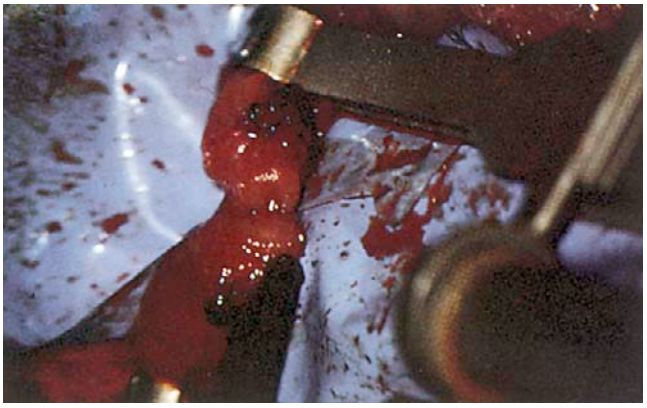


FIGURE 14-30 The two portions of the vas in approximator clip with background material as the proximal end is sutured through the serosa to the mucosa with 10-0 nylon.

Microscopic Epididymal Sperm Aspiration

Microscopic epididymal sperm aspiration (MESA) requires the availability of an in vitro fertilization team so that the aspirated sperm may be immediately processed and used for the selected in vitro technique or frozen for later use. The procedure must be timed according to the partner's cycle of ovulation. Ova are aspirated as an office procedure just before MESA is performed.

MESA should be done using the micropipette technique. The surgeon inserts the tip of a 250- to 350-micrometer (μm) pipette into an epididymal tubule to retrieve sperm cells without contamination by red blood cells. After aspiration, the fluid is given to the in vitro fertilization team to process the sperm cells. Processing involves washing debris from the cells, retrieving the most active cells from the sample, and removing any red blood cells, if possible. This is critical because red blood cells significantly interfere with sperm cell function.

After the sperm cells are aspirated, the surgeon closes the epididymal tubule using microscopic technique. If adequate numbers of sperm cells can be obtained from one testis, the other side may be aspirated to add to the sperm bank if this is desirable. It may be necessary to aspirate sperm cells from the rete testis (tubules between the testicles and the epididymal head that carry cells to the head of the epididymis) if sperm cells are not found in tubules closer to the vas deferens.

The sperm cells retrieved may be used for intracytoplasmic injection into the partner's egg (ICSI), the most successful of the in vitro techniques available. This technique is not as dependent on the quality of the sperm as earlier techniques of in vitro fertilization.

Epididymectomy

An epididymectomy is the excision of the epididymis from the testis. Epididymectomy is rarely performed, usually only as a last-choice treatment for degenerative cystic disease, chronic infection, and intractable pain of the epididymis.

Procedural Considerations. The perioperative nurse assists with positioning the patient in the supine position with his legs slightly abducted. The anesthesia provider administers

a general, spinal, or regional anesthetic. Setup is as described for hydrocelectomy, plus an ESU, if desired.

Operative Procedure

1. The surgeon makes an anterolateral incision over the testis in the scrotum to expose the tunica vaginalis. The tunica is incised to expose the testis and overlying epididymis.
2. An incision is made along the superior head of the epididymis, which is then sharply dissected from the testis. A portion of the vas deferens may also be excised.
3. Bleeding is controlled by electrocoagulation and absorbable ties.
4. The skin wound is closed with 4-0 absorbable sutures.
5. A small drain may be left intrascrotally for 24 to 48 hours.

Spermatocelectomy

Spermatocelectomy is removal of a spermatocele—a lobulated intrascrotal cystic mass attached to the superior head of the epididymis. Spermatocele is usually caused by an obstruction of the tubular system that conveys the sperm and may be a late complication after vasectomy.

Procedural Considerations. The setup for a spermatocelectomy is as described for a hydrocelectomy, plus a microscope and slides, if desired.

Operative Procedure

1. The mass is approached through a scrotal incision as described for hydrocelectomy.
2. The surgeon identifies the structures of the testis and spermatic cord and dissects the cystic structure free.
3. Bleeding is controlled with electrocoagulation.
4. The wound is closed and dressed as described for hydrocelectomy.

Varicocelectomy

A varicocelectomy is the high ligation of the gonadal veins of the testes. Varicocelectomy is done to reduce venous backflow of blood into the venous plexus around the testes and to improve spermatogenesis.

Varicoceles occur more frequently on the left side because the gonadal vein of the left testis unites retroperitoneally with the renal vein at a 90-degree angle and is consequently under greater backpressure. As a result of this unusual backpressure, the pampiniform plexus of the spermatic cord becomes tortuous and engorged, resembling a bag of worms.

Procedural Considerations. The setup for inguinal varicocelectomy is as described for an inguinal hernia repair (see Chapter 12). A microscope may be employed to better visualize the vessels involved.

Operative Procedure

The incision may be through a suprainguinal approach or an oblique inguinal approach over the external inguinal ring.

1. The surgeon identifies the structures of the spermatic cord and dissects the vessels free from the vas deferens.
2. The abnormal dilated veins in the inguinal canal are clamped and ligated. The redundant portions are excised. A drain may be placed.
3. The incision is closed in layers.

Testicular Biopsy

A biopsy of the testicle involves a wedge excision of suspicious tissue for diagnostic confirmation. Men experiencing infertility who are azoospermatic or oligospermatic with a normal or minimally elevated level of follicle-stimulating hormone may be evaluated through this means. Biopsy may also be performed to obtain sperm cells for in vitro fertilization techniques.

Procedural Considerations. The perioperative nurse assists with positioning the patient in the supine position and the anesthesia provider administers a general, regional, or spinal anesthetic. A minor instrument set is used. Special fixatives, such as Bouin's or Zenker's solution, must be available when pathologic confirmation is required. If retrieval of sperm cells is planned the perioperative nurse ensures the biopsy specimen is placed in a small amount of saline, kept warm, and taken immediately to the fertility laboratory for aspiration of cells. Formalin destroys the germinal epithelium and should not be used.

Operative Procedure

1. The scrotum is held firmly on its posterior aspect. This causes the skin on the anterior aspect to stretch tightly over the incisional site, forcing the epididymis to remain posterior and allowing the scrotal skin to part without retraction.
2. The surgeon makes a 1-cm to 2-cm vertical incision taking care to avoid injury to the epididymis.
3. The incision is continued to the tunica vaginalis. As the tunica is incised, there should be a normal efflux of clear fluid.
4. Absorbable 4-0 stay sutures are placed in the tunica vaginalis. Two more are placed in the tunica albuginea.
5. Using the scalpel in a shaving action, no-touch technique, the surgeon resects a small ellipse of tunica with its tubules. The tissue is placed in the fixative or sent to the histology department as a fresh specimen.
6. The wound is closed in three layers with 3-0 and 4-0 absorbable suture.
7. Gauze sponges and fluffed dressings are placed over and around the scrotum. A scrotal support is applied to provide pressure and support.

Orchiectomy

An orchiectomy is the removal of the testis or testes. Removal of both testes is castration and renders the patient sterile and deficient in the hormone *testosterone,* which is responsible for development of secondary sexual characteristics and potency. This operation, like vasectomy, has legal implications that require attention to acquiring informed consent for surgery. Bilateral orchiectomy is usually performed to control symptomatic metastatic carcinoma of the prostate gland. A unilateral orchiectomy is indicated because of testicular cancer, trauma, or infection. Testicular implants are available for cosmetic purposes. These must be ordered preoperatively based on preoperative measurements for size. This procedure has recently been approached through endoscopic techniques, usually in conjunction with laparoscopic herniorrhaphy.

Procedural Considerations. The perioperative nurse assists with positioning the patient supine and the anesthesia provider

administers a general, spinal, or regional anesthetic. A minor instrument setup is required.

Operative Procedure

SCROTAL APPROACH

1. For benign conditions the incision is made over the anterolateral surface of the midportion of the scrotum.
2. The surgeon carries the skin incision through the subcutaneous and fascial layers through the tunica vaginalis, exposing the testicle.
3. Retractors are placed, and bleeding vessels are clamped and ligated.
4. The spermatic cord is divided into two or three vascular bundles. Each vascular bundle is doubly clamped, cut, and ligated, first with 0 absorbable suture ligature and then with a proximal free 0 absorbable tie.
5. The vas is separately ligated with a 0 absorbable tie. The testis is removed.
6. The procedure is repeated on the opposite side if bilateral excision is planned.

INGUINAL APPROACH

1. For malignant conditions the incision is begun just above the internal ring, extending downward and inward over the inguinal canal to the external inguinal ring.
2. The surgeon exposes the inguinal canal and dissects the spermatic cord free, cross-clamps it, and divides it into vascular bundles at the internal ring.
3. Gentle forward traction is applied to the cord, which is dissected from its bed.
4. The testis is everted into the wound from the scrotum and excised.
5. The procedure is repeated on the opposite side if bilateral excision is planned.
6. Bleeding is controlled with electrocoagulation. A small drain may be placed in the empty hemiscrotum if desired.
7. The surgeon reapproximates the external oblique fascia with 2-0 absorbable interrupted sutures.
8. Subcutaneous tissue, including Scarpa's fascia, is closed with 4-0 absorbable sutures.
9. The skin is reapproximated with surgical staples or 4-0 subcuticular sutures.

Radical Lymphadenectomy (Retroperitoneal Lymph Node Dissection)

Radical lymphadenectomy is a bilateral resection of retroperitoneal lymph nodes. Dissection usually includes lymph nodes, channels, and fat around both renal pedicles; the vena cava; and the aorta, including the bifurcation of the aorta. Lymph node dissection is performed for treatment of nonseminomatous testicular tumors or in conjunction with an open prostatectomy for prostate cancer.

Procedural Considerations. The perioperative nurse assists with placing the patient in the supine position. The anesthesia provider administers a general anesthetic. If the dissection is unilateral, the patient is supine with the operative side tilted upward. Long, fine dissection instruments along with basic laparotomy instruments are required.

Although this procedure may be performed laparoscopically, this approach has not yet become the standard of practice because of its technical difficulty.

Operative Procedure

1. The surgeon makes a midline abdominal incision from the xiphoid process to the symphysis pubis.
2. The abdominal contents are explored to determine the degree of gross nodal involvement. The colon is either packed within the abdominal cavity or mobilized and kept moist outside the abdomen.
3. The surgeon opens the posterior peritoneum between the aorta and the vena cava.
4. Using blunt and sharp dissection, the surgeon removes the lymphatic structures and fat en bloc from around both renal pedicles, the vena cava, and the aorta from above the renal hilum to beyond the bifurcation of the iliac vessels on the side of the original testicular neoplasm.
5. The spermatic vessels of the affected side are removed down to and including the stump of the previous orchiectomy.
6. The inferior mesenteric artery may be sacrificed if technically necessary, but the superior mesenteric artery is not disturbed.
7. The ureter on the affected side is skeletonized to remove any perilymphatic tissue.
8. If reperitonealization is desired, the posterior peritoneum is closed with a 2-0 absorbable continuous suture.
9. The surgeon repositions the viscera into the abdominal cavity, and closes the wound in layers, usually without placement of a drain.

SURGERY OF THE PROSTATE GLAND

Glandular hyperplasia of the prostatic urethra usually manifests itself after 50 years of age. Prostatic enlargement may be benign or malignant and may occur in one or more lobes of the prostate but most frequently occurs in the lateral or median lobes. Progressive growth of the hyperplastic gland compresses the remaining normal prostatic tissue, forming what is called a *surgical capsule*. The growth of adenomatous tissue slowly encroaches on the prostatic urethral lumen, causing obstruction of urinary outflow. The surgeon must consider several factors when determining the best route for removal of the prostatic obstruction: the age and medical condition of the patient, the size of the gland and location of the pathologic condition, and the presence of associated medical disease.

Prostate cancer is the most frequently diagnosed cancer in men and is the leading cause of cancer death in men (American Cancer Society, 2008). Because of the prevalence of prostate cancer and the similarity of symptoms to benign prostatic hyperplasia (BPH), the American Urological Association (AUA) recommends that starting at age 40 the prostate-specific antigen (PSA) test and digital rectal examination (DRE) be offered to men at average risk (Evidence for Practice).

A blood sample is drawn to determine the PSA level, followed by a DRE. The blood is often drawn first, since manipulation of the gland has been known to alter the efficacy of the PSA test. The PSA test is considered a valuable tool for early detection of carcinoma of the prostate, but if used alone, it will miss 20% to 30% of all prostate cancers. If the test value is elevated, the patient is at risk for carcinoma of the prostate; a PSA value above 10 ng/ml is highly suggestive of prostatic carcinoma. Clinical evaluation and an elevated PSA usually indicate the need for a transrectal ultrasound needle biopsy to confirm the diagnosis. When the results of the biopsy are positive for

EVIDENCE FOR PRACTICE

Diagnosing and Managing Prostate Cancer

Early detection is important in the diagnosis and management of prostate cancer. Information relating to a patient's profile in initiating the algorithm (see below) includes the following:

RISK FACTORS

1. Age: After 50 years old, the risk increases rapidly; about 64% of all prostate cancer cases are diagnosed in men ages 65 and older. Although the lifetime risk for prostate cancer is 3%, prostate cancer is the most common noncutaneous cancer in men in the United States, and the second leading cause of male cancer mortality.
2. Race: African-American men and Jamaican men of African descent have the highest prostate cancer incidence rates in the world.
3. Diet: High dietary fat is associated with a greater risk for developing cancer.
4. Family history: Risk is increased for men who have first-degree relatives with prostate cancer.

CANDIDATES FOR EARLY DETECTION

1. Men 40 years old or older with a life expectancy of 10 years or longer.

DIAGNOSTIC MEASURES USED IN COMBINATION FOR EARLY DETECTION

1. DRE
2. Serum PSA
3. Biopsy if indicated (three of four men undergoing biopsy will not have cancer)

SCREENING FOR PROSTATE CANCER: CLINICAL SUMMARY OF U.S. PREVENTIVE SERVICES TASK FORCE RECOMMENDATION

Population	Men Younger than Age 75 Years	Men Age 75 Years or Older
Recommendation	**No recommendation Grade: I (Insufficient Evidence)**	**Do not screen Grade: D**
Risk assessment	Prostate cancer is more common in older men, African Americans, and men with a family history of prostate cancer. The same uncertainties about the effects of screening that apply to other men also apply to these higher-risk men.	
Screening tests	The prostate-specific antigen (PSA) test is more sensitive than the digital rectal examination (DRE). The conventional PSA test cut-point of 4.0 g/L misses some early cancer. However, lowering the cut-point would increase the rate of false-positive results. Variations of PSA screening have not yet been demonstrated to improve health outcomes.	
Screening intervals	If PSA screening reduces mortality, screening every 4 years may be as beneficial as annual screening.	
Interventions	Management strategies for localized prostate cancer include watchful waiting, active surveillance, surgery, and radiation therapy. There is no consensus regarding optimal treatment.	
Balance of harms and benefits	• The harms of screening include the discomfort of prostate biopsy and the psychological harm of false-positive test results. • Harms of treatment include erectile dysfunction, urinary incontinence, bowel dysfunction, and death. A proportion of those treated, and possibly harmed, would never have developed cancer symptoms during their lifetime.	
	For men younger than age 75 years, evidence is inadequate to determine whether screening improves health outcomes. Therefore, the balance of harms and benefits cannot be determined.	For men age 75 years or older and for those whose life expectancy is 10 years or fewer, the incremental benefit from treatment of prostate cancer detected by screening is small to none. Therefore, harms outweigh benefits.
Suggestions for practice	Clinicians should discuss the potential benefits and known harms of PSA screening with their patients younger than age 75 years. Men in this age group should be informed of the gaps in the evidence, and their personal preferences should guide the decision of whether to order the test.	
Other relevant USPSTF recommendations	A list of USPSTF recommendations on cancer screening can be found at www.preventiveservices.ahrq.gov.	

BPH, Benign prostatic hyperplasia; *DRE,* digital rectal examination; *PSA,* prostate-specific antigen.

Prostatitis, BPH, and prostate cancer can all be associated with elevated serum PSA levels. Other factors that are known to cause elevations in PSA levels include urethral or prostatic trauma, and infection.

Table from Agency for Healthcare Research and Quality: *Screening for Prostate Cancer: Clinical Summary of U.S. Preventive Services Task Force Recommendation,* AHRQ Publication No. 08-05121-EF-3, August 2008, Rockville, MD, available at www.ahrq.gov/clinic/uspstf08/prostate/prostatesum.htm. Accessed March 4, 2010.

malignancy, additional diagnostic studies are indicated including measurement of free and total serum PSA II levels, bone scans, and CT and MRI scans of the pelvis (Ignatavicius, 2010).

The most commonly used system to grade prostate cancer is the Gleason score. To calculate the Gleason score, the pathologist evaluates the prostatic tissue to determine which type of cell is the most common and which type is the second most common and gives each of the two cell types a score from 1 to 5. The two scores are combined to determine the total score. Higher numbers are an indication of more abnormal, aggressive cancer cells. Men with a Gleason score of 2 to 4 are generally cured by surgery; scores from 5 to 6 indicate mildly aggressive cancer cells; a score of 7 indicates the cancer is moderately aggressive. Scores between 8 and 10 indicate highly aggressive tumors and are associated with a poor prognosis after surgery (Epstein, 2007). Additional prostate cancer staging tools are the TNM (tumor, node, metastasis) system and the American Urological Association (AUA) system (Box 14-2).

If the prostate gland is cancerous, a radical retropubic or radical perineal prostatectomy, in conjunction with open or laparoscopic pelvic lymph node dissection, is usually performed. TURP may also be used in men who cannot have a radical prostatectomy, or to relieve symptoms caused by prostate cancer before other treatments begin. Select patients with well-differentiated or moderately differentiated lesions may be candidates for transperineal, ultrasonically guided implantation of radium seeds (brachytherapy) or cryoablation of the prostate (cryotherapy). Newer therapies for prostate cancer are being developed (Research Highlight). Many patients desire to retain sexual function. The surgeon may attempt to save the neurovascular bundles in what is termed a nerve-sparing approach. The site and size of the prostatic lesion, however, often determine if this can be achieved successfully and without undue risk to the patient.

Three open surgical approaches are possible in removing the benign hyperplastic obstructive prostate gland: retropubic prostatectomy, suprapubic prostatectomy, and perineal prostatectomy. Of these, the one most commonly employed is the suprapubic prostatectomy. All open prostatectomies hold the risk for loss of sexual potency.

TURP is the endoscopic (closed) surgical approach that has been traditionally used. Alternative modalities that have shown moderate to good success in the treatment of BPH are photoselective vaporization of the prostate (PVP), interstitial laser coagulation of the prostate (ILC), transurethral incision of the prostate (TUIP), transurethral laser incision of the prostate (TULIP), holmium laser enucleation of the prostate, and holmium laser ablation of the prostate (HoLAP). A visual laser ablation of the prostate (VLAP) was originally performed with the Nd:YAG laser but may now also be accomplished with the holmium laser (Fitzpatrick, 2007). Proper laser protocol must be followed for the type of laser being employed. The standard

RESEARCH HIGHLIGHT

High-Intensity Focused Ultrasound Prostate Cancer Treatment: A Safe Alternative to Surgery or Radiotherapy

High-intensity focused ultrasound (HIFU) is a noninvasive technique used in the treatment of prostate cancer. It is available in North America, but has not yet been approved by the FDA for use in the United States. Researchers in Europe are reporting impressive results with the technique; a multicenter trial studied 402 patients with localized cancer treated with HIFU. Although 28% of the patients required two treatment sessions, 87% of the treated patients had negative biopsy findings on follow-up; a median PSA level of 0.4 ng/ml was achieved at a minimal follow-up appointment of 6 months. These same investigators later reported a 5-year actuarial negative biopsy rate of 90%. Another group of researchers studied the long-term results in patients with low-risk disease (initial PSA level <10 ng/ml, Gleason score ≤6). In this study, 78% of the patients were considered free of disease (stable PSA level according to American Society for Therapeutic Radiology and Oncology criteria) and had negative biopsy results at 5 years. For those with intermediate-risk cancer, the disease-free rate was 53%; for those with high-risk cancer, the disease-free rate was 36%.

HIFU is highly focused into a small area, creating intense heat of 80° to 100° C, which is lethal to prostate cancer tissue. HIFU destroys tissue by heat, rather than by cavitation or mechanical shearing. Since ultrasound is nonionizing, there is no collateral tissue damage.

For the majority of patients, HIFU is indicated as a curative therapy. The best candidates are clinical/pathologic stages T1c to T3. Because of the limited focal length of HIFU, gland volume cannot be 40 ml or larger. If the gland is larger, then downsizing is required with total androgen ablation. Aside from primary therapy, HIFU can be utilized as salvage therapy, primarily after radiation. HIFU can also be repeated without any increase in risk or complications. In addition, HIFU can be used to treat cryosurgical failures. If necessary, radical prostatectomy can be performed after HIFU.

HIFU is performed as an outpatient procedure, usually after induction of anesthesia with an epidural anesthetic. The HIFU unit consists of a control console, a power generator, a cooling system, and a probe that contains a standard imaging and high-intensity treatment ultrasound head. The HIFU probe is placed into the rectum and multiple gland images are taken. The surgeon selects the treatment zones. The procedure usually lasts 2 to 4 hours. The procedure is completed without blood loss or exposure to radiation.

There will be edema secondary to the thermal effects: therefore at the end of the procedure, a urethral Foley catheter is placed into the bladder. This catheter will remain in place for 2 to 4 weeks. There may be some bladder discomfort for several days, but full activities can be resumed the day following surgery. Once the catheter is removed, the urinary stream may take several months to improve, as the urethra needs to heal, and the gland will take up to 3 months to start shrinking. During this time, some prostate tissue may slough and pass in the urine. The rest of the gland forms scar tissue.

Although HIFU is a relatively new procedure for prostate cancer treatment, it represents what may become the next generation of minimally invasive therapy for prostate cancer. The control and precision that HIFU provides truly allows the surgeon to precisely ablate the prostate gland with pinpoint accuracy and thereby preserve the adjacent structures. Furthermore, because HIFU is nonionizing, there is no collateral tissue damage.

Modified from Chinn D: *Transrectal HIFU: the next generation?* Prostate Cancer Research Institute, available at www.prostate-cancer.org/education/novelthr/Chinn_TransrectalHIFU.html. Accessed May 27, 2009; Marberger M et al: New treatments for localized prostate cancer, *Urology* 72(suppl 6A):36-43, 2008.

BOX 14-2

American Urological Association Prostate Cancer Stages

STAGE A: CLINICALLY UNSUSPECTED DISEASE

A1	Focal carcinoma, well differentiated
A2	Diffuse carcinoma, usually poorly differentiated

STAGE B: TUMOR CONFINED TO PROSTATE GLAND

B1	Small, discrete nodule of one lobe of the gland
B2	Large or multiple nodules or areas of involvement

STAGE C: TUMOR LOCALIZED TO PERIPROSTATIC AREA

C1	Tumor outside prostate capsule, estimated weight ≤70 g, seminal vesicles uninvolved
C2	Tumor outside prostate capsule, estimated weight >70 g, seminal vesicles involved

STAGE D: METASTATIC PROSTATE CANCER

D1	Pelvic lymph node metastases or ureteral obstruction causing hydronephrosis, or both
D2	Bone, soft tissue, organ, or distant lymph node metastases

Modified from Nelson WG et al: Prostate cancer. In Abeloff MD et al, editors: *Abeloff's clinical oncology,* ed 4, Philadelphia, 2008, Churchill Livingstone.

TUIP procedure involves the use of electrosurgery only. Transurethral microwave therapy (TUMT) is another alternative that is performed as an office procedure.

Prostatic Core Needle Biopsy

Needle biopsy of the prostate is indicated for patients in whom prostatic cancer is clinically suspected. It may be accomplished transrectally with a needle designed for this purpose or transperineally.

Procedural Considerations.

Needle biopsy of the prostate has the risk of both intraoperative and postoperative bleeding. A cystoscopic examination may accompany a needle biopsy. Most needle biopsies are performed in the urologist's office or ultrasound department.

The most significant potential complication of a biopsy is systemic infection. This risk can be decreased with antibiotic administration before and after the procedure and bowel cleansing before the examination. The patient is given antibiotic therapy 24 hours before the procedure and is advised to use a sodium phosphate enema 2 to 3 hours before the test is performed. Before the examination, an antiseptic solution mixed with a viscous local anesthetic often is instilled into the rectum and allowed to coat the tissues for 5 to 15 minutes. The surgeon may also inject local anesthetic into the prostate and seminal vesicles transrectally with a 22-gauge, 22-cm injection needle through the needle guide on the transducer.

Operative Procedure

TRANSRECTAL, ULTRASONICALLY GUIDED BIOPSY. Transrectal, ultrasonically guided biopsy is commonly performed in the urologist's office using a high-frequency transrectal ultrasound transducer to assess the prostate gland. The technique allows the urologist to assess the size, volume, and shape of the prostate and the likelihood of the presence of a malignancy. Biopsy specimens of suspicious areas or lesions may be obtained with a needle passed across the rectal wall, with the aid of ultrasound guidance. The needle penetrates the rectal mucosa with a core biopsy system. Color-flow imaging may also be used to help identify areas that are likely invaded with prostatic carcinoma or have acute and chronic inflammation. Highly vascular areas carry a greater probability of harboring a carcinoma. A full bladder helps delineate the base of the prostate.

The urologist visualizes the prostate in three dimensions, allowing more accurate localization of abnormalities and extent of disease. For the axial view, the transrectal transducer is placed deeply into the rectum, just proximal to the seminal vesicles, to about 10 cm above the anal verge. Here the vas deferens may be distinguished. The transducer is slowly withdrawn to the level of the base of the gland, enabling visualization of the inner gland. Seminal vesicles are seen in cross section. To evaluate the prostate in the sagittal planes, the urologist rotates the probe clockwise or counterclockwise (Figure 14-31). A series of 12 biopsy specimens is generally taken with a disposable "core biopsy" needle. These are taken from the right and left medial and lateral apices, the right and left midline, and the right and left medial and lateral bases. Lesions as small as 2 to 3 mm are visible with this procedure.

TRANSPERINEAL BIOPSY. The perioperative nurse assists with placing the patient in the lithotomy or lateral position. The procedure may be performed with the patient receiving a general, regional, or local anesthetic. The surgeon performs a rectal exam to identify the induration. The needle is inserted through the perineal skin and guided ahead until the tip is against the lesion. The biopsy specimen is taken in the same fashion as described for the transrectal approach. Some surgeons may incise the site with the #11 or #15 scalpel and place a 4-0 absorbable closing suture.

The surgeon may also use the transperineal approach to perform template biopsies with ultrasound guidance, utilizing the brachytherapy (seed implant) template. The perioperative nurse assists with placing the patient in the lithotomy position, and secures his scrotum toward the abdomen with a transparent adhesive dressing. The surgeon positions the brachytherapy grid, template fixation device, and probe with cradle adjacent to the patient's perineum. Using the ultrasonic transrectal transducer the surgeon measures the prostate and calculates its total volume. Biopsies are then obtained transperineally through the template grid.

Transurethral Resection of the Prostate Gland

In transurethral resection of the prostate gland (TURP), the surgeon passes a resectoscope into the bladder through the urethra and resects successive pieces of tissue from around the bladder neck and the lobes of the prostate gland, leaving the capsule intact. The resectoscope has a stabilized cutting loop that is used to resect tissue and coagulate blood vessels by means of electric current. The electric current that powers the electrode is supplied by a high-frequency ESU. The current settings are specified by the surgeon, who activates the cutting or coagulating current with a foot pedal during the course of the procedure.

TURP is one surgical method of treating benign obstructive enlargement of the prostate gland. Several factors influence the surgical approach: size of the gland and location of the pathologic condition, age and condition of the patient, and presence of associated diseases.

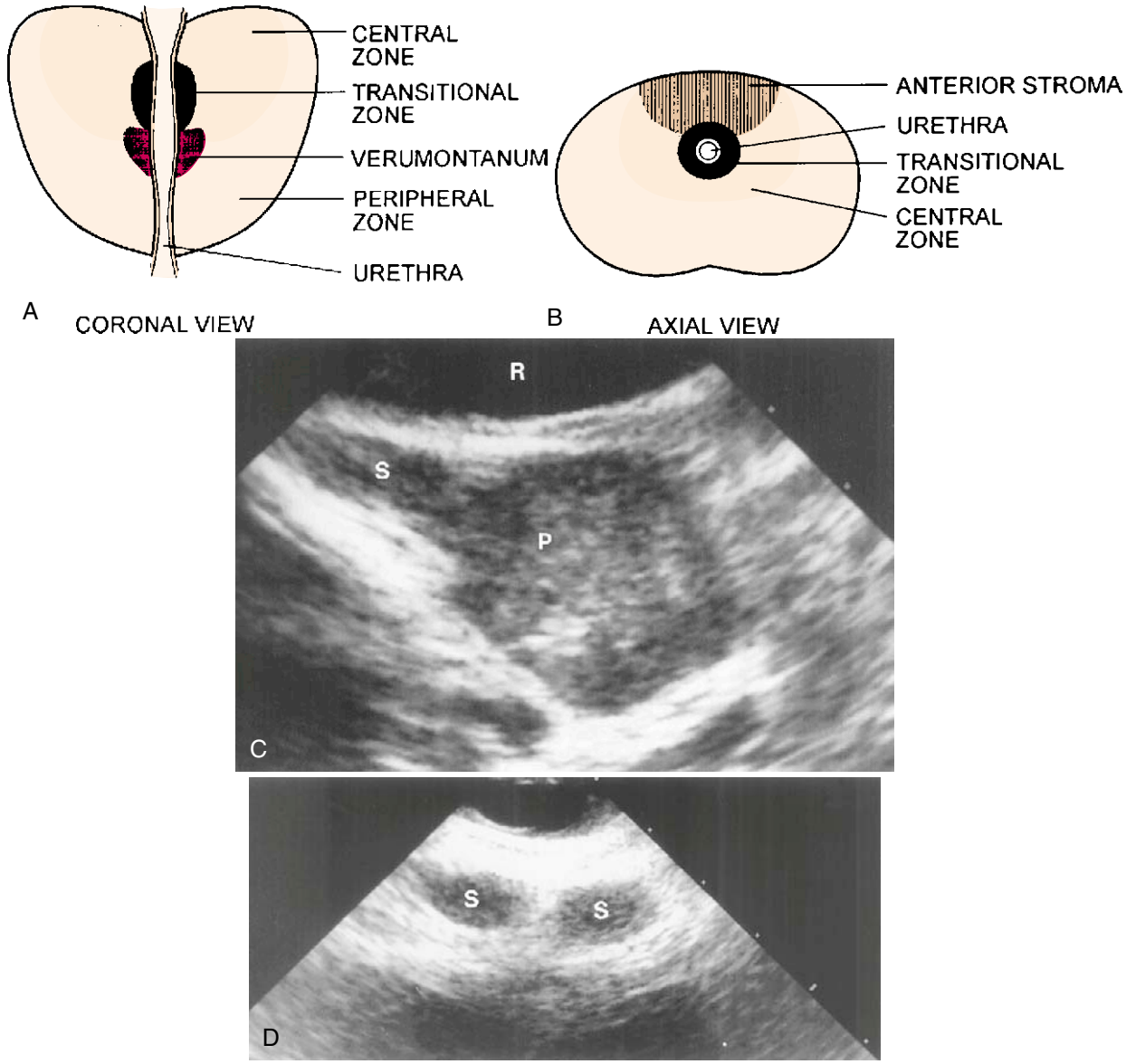


FIGURE 14-31 Schematic drawing of zonal anatomy of the prostate (*nonshaded area* is peripheral zone). **A**, Coronal view. **B**, Axial view and transrectal ultrasound views of prostate during biopsy. **C**, Sagittal image showing prostate *(P)*, seminal vesicles *(S)*, and rectum *(R)*. **D**, Transverse image of seminal vesicles *(S)*.

Procedural Considerations. The instrument setup for TURP is as described for cystoscopy with additional necessary instruments. The four principal types of resectoscopes are McCarthy, Nesbit, Iglesias, and Baumrucker. Adult resectoscopes range in size from 24F to 28F and have the following components: Foroblique telescope, operating element, cutting loops, and postresectoscope sheaths and obturators (Figure 14-32). A TURP requires a resectoscope (multiple working elements); a Foroblique telescope as well as a backup telescope; stabilized or unstabilized cutting loops; a postresectoscope sheath with its corresponding articulated obturator; a high-frequency cord; a short bridge; a Toomey syringe or the Ellik or Urovac evacuator; van Buren sounds; a 22F or 24F, 30-ml, three-way Foley catheter; a disposable urologic drape with rectal sheath; and a system for continuous bladder irrigation and urinary drainage. Supplementary instruments include a resectoscope adapter and a lateral telescope.

The continuous-flow resectoscope (CFR) (Figure 14-33) has unique components that include an outlet stopcock to which a suction tube is attached, an inflow tube on the inner sheath, and outflow holes on the outer sheath. These features enable the surgeon to resect tissue without interruption to empty the bladder, as must be done with the standard resectoscope. In addition to the CFR, which replaces the standard resectoscope, the setup includes thick-walled Silastic suction tubing and a continuous-flow pump. The continuous-flow technique decreases intravesical pressure on the bladder during the procedure, provides a clearer field of vision because of the constant inflow and outflow of irrigant, reduces the operating time because the resection process need not be interrupted

FIGURE 14-32 Resectoscope components: 24F and 26F Timberlake obturators and postresectoscope sheaths with fulgurating electrodes and Iglesias operating element, Foroblique 30-degree and 70-degree telescopes, and fiberoptic cable.

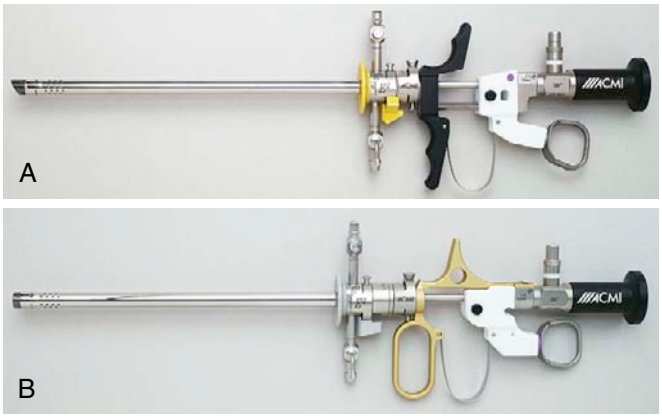


FIGURE 14-33 **A**, Continuous-flow resectoscope (CFR). **B**, Vista CFR bipolar resectoscope.

to evacuate the bladder, and provides a "still" bladder for the resection of bladder tumors.

A continuous flow of isotonic and nonelectrolytic irrigating fluid is necessary to ensure transmission of electric current and clear visualization throughout surgery. Irrigating solution such as 3% sorbitol or 1.5% glycine, 3 to 5 liters, may be connected in tandem to provide a constant flow. Warming units, available for these solutions, help to eliminate the hypothermia often experienced when large amounts of cold irrigants are employed. On the other hand, when solutions are warm, the patient may show a tendency to bleed more. The perioperative nurse must remain alert as to the status of the irrigation solution and replace it as required.

During transurethral prostatic surgery, the return of irrigation fluid must be monitored because intravasation and absorption of fluid into open prostatic venous sinuses or bladder perforation may occur. The perioperative nurse should be aware of the early signs and symptoms and measures employed to remedy these complications (Young et al, 2009). The patient usually experiences significant respiratory changes and abdominal discomfort. Continued extravasation and absorption can lead to hypovolemia and hyponatremia. Other important observations are rigidity and swelling of the lower abdomen, coupled with changes in sensorium. If extravasation of irrigating fluid is evident, the surgical procedure is discontinued and a cystogram is obtained immediately to determine if bladder perforation has occurred. Insertion of a Foley catheter is generally all that is necessary to control the situation. In the rare instance of a major perforation, surgical closure may be accomplished through a cystotomy incision.

Operative Procedure

1. The surgeon dilates the urethra with sounds sized from 20F to 30F.
2. Cystourethroscopy is performed to assess the degree of prostatic obstruction and to inspect the bladder. Some surgeons perform this diagnostic procedure several days before surgery, whereas others perform the examination in the OR immediately before surgery.
3. The surgeon passes a well-lubricated postresectoscope sheath with its fitted Timberlake obturator into the urethra.
4. The Timberlake obturator is removed, and the working element (resectoscope), assembled with the Foroblique telescope and cutting loop, is inserted through the sheath.
5. The irrigation tubing, light cord, and high-frequency cord are appropriately connected, and the surgeon opens the stopcock to allow the irrigation fluid to fill the bladder.
6. With the bladder distended, the surgeon inspects the prostatic urethra and bladder trigone.
7. After determining the location of the ureteral orifice, the surgeon begins electrodissection, alternating cutting and coagulating currents as required (Figure 14-34).
8. The bladder is drained, washing out prostatic tissue and small blood clots. At times the surgeon may use the Ellik evacuator to remove resected prostatic tissue. The Ellik is used by removing the working element of the resectoscope, fitting the nozzle of the evacuator onto the resectoscope sheath, and removing the bladder contents by manual pulsatile pressure. The surgical technologist ensures an Ellik or Urovac evacuator or a Toomey syringe is readily available for manual irrigation. Fluid may be drawn from the irrigant directly into the resectoscope sheath through the already attached tubing.
9. When the resection is completed, the surgeon inspects the prostatic fossa to ensure that all bleeding points have been coagulated.
10. The resectoscope is then removed, and a Foley catheter (22F or 24F, two-way or three-way, 30-ml balloon) is inserted into the bladder for urinary drainage. The balloon is inflated (Figure 14-35, *A*), pulled gently in traction against the bladder neck, and secured, to help control venous bleeding (Figure 14-35, *B*). The Foley balloon must not be inflated within the prostatic fossa (Figure 14-35, *C*), where it may cause excessive bleeding from the resected prostatic capsule. If desired, continuous irrigation with gravity drainage is initiated, with normal saline as the bladder irrigant instead of sorbitol or glycine. A 3-liter to 4-liter urinary drainage system is suggested to avoid frequent emptying of the drainage bag.
11. When VLAP, TUIP, or TULIP is performed, the surgeon may choose to place a standard 18F Foley with a 5-ml or 30-ml balloon connected to straight drainage. If irrigation is required postoperatively, it is then performed manually with sterile solution and a Toomey syringe.

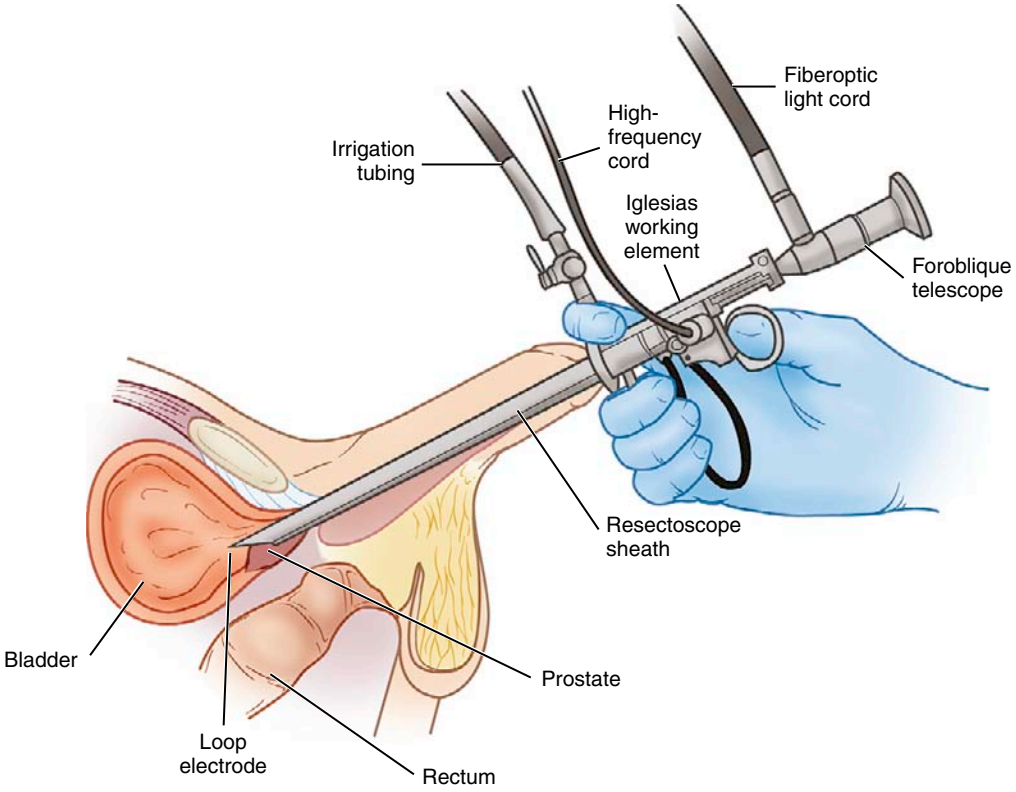


FIGURE 14-34 Sectional view illustrating removal of portion of hypertrophied middle lobe of prostate gland with Iglesias resectoscope.

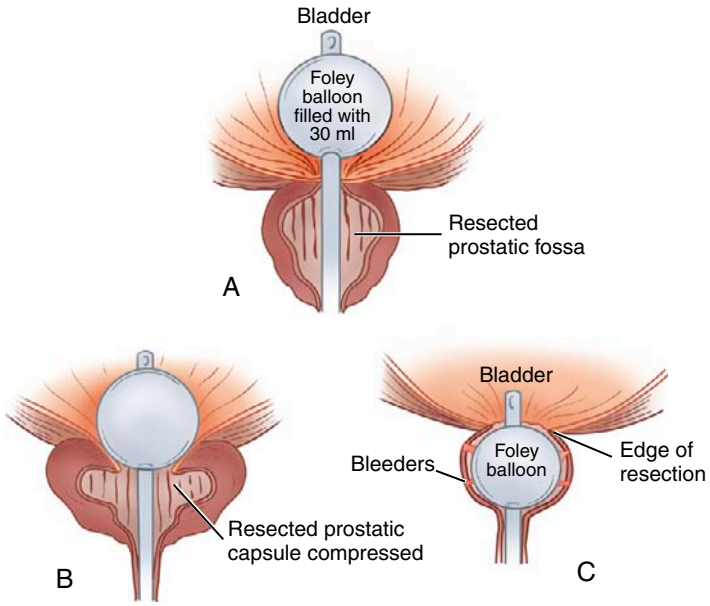


FIGURE 14-35 **A** and **B**, Proper position for Foley catheter with inflated balloon beyond prostatic capsule. **C**, Improper position.

Transurethral Incision of the Prostate (TUIP)

TUIP is a procedure in which the prostate is incised at the 5 and 7 o'clock positions to provide relief of obstruction, with results similar to those provided by a complete transurethral resection but with a lower incidence of bladder neck contracture and retrograde ejaculation. The shorter operative time inherent with the procedure minimizes fluid absorption and may decrease postoperative pulmonary and cardiovascular complications. The procedure may be performed with cold or hot knives as well as the standard resectoscope, or laser fiber (TULIP). This procedure is appropriate for sexually active patients with moderate to small obstructive prostates without a significant

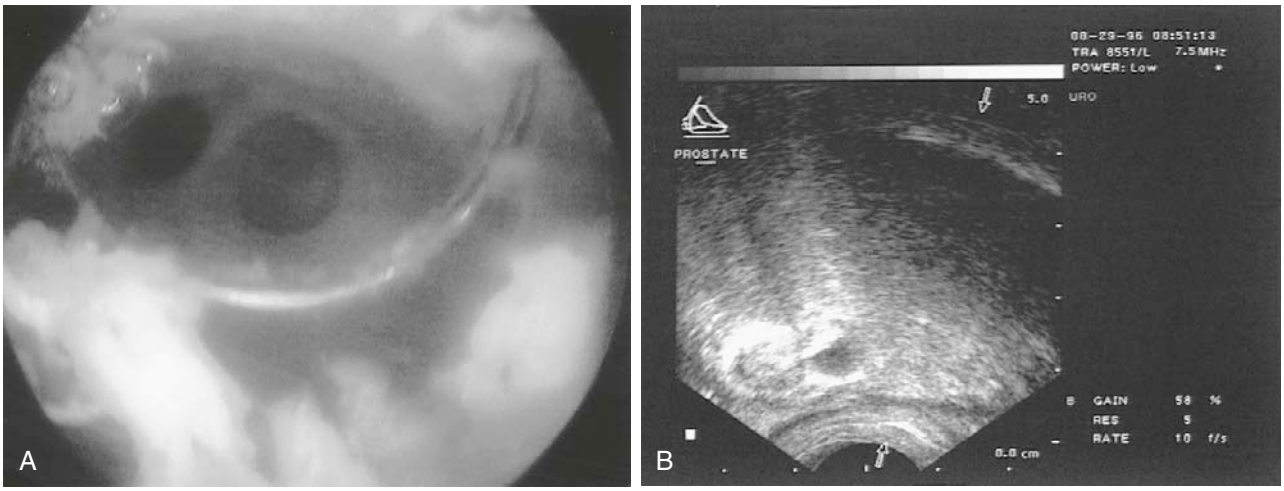


FIGURE 14-36 **A**, Dilated seminal vesicle (ejaculatory duct) with resectoscope loop approaching. **B**, Resectoscope loop entering dilated seminal vesicle (ejaculatory duct).

middle-lobe component. One major disadvantage is the potential for missing occult prostatic cancer. Despite this, some clinicians view this as an underused, feasible form of treatment.

Transurethral Incision of the Ejaculatory Ducts

Transurethral incision of the ejaculatory ducts is performed for the relief of obstructed ejaculatory ducts, a common condition in men with chronic prostatitis and prostatic calculi. Symptoms closely mimic prostatodynia and include aching in the perineal and genital areas with no lasting or significant improvement from conservative therapy (antibiotics and analgesics). The resectoscope loop is guided with transrectal ultrasound imaging to the dilated ejaculatory ducts, and the obstructed ducts are resected (Figure 14-36). Calculi may be fragmented if necessary and removed. A catheter generally is not needed.

Photoselective Vaporization of the Prostate

The KTP laser is now being used to treat BPH or prostatic enlargement. *Green-light PVP* is photoselective vaporization of the prostate and a new minimally invasive approach performed on an outpatient basis. The approach is the same as with other endoscopic techniques. A noncontact laser fiber is used to heat the prostate tissue and rapidly vaporize it to a penetration depth of 0.8 mm with minimal to no blood loss. Vaporization occurs from within the tissues where the collagen matrix eventually bursts as a result of the vapor buildup. The laser is operated in a continuous wave mode and induces a coagulation zone of only 1 to 2 mm in thickness. This prevents the excessive sloughing of necrotic tissue. The patient may not always need a Foley catheter following the procedure.

Interstitial Laser Coagulation of the Prostate

Interstitial laser coagulation (ILC) with the Indigo laser is a minimally invasive procedure for treatment of urinary outflow obstruction secondary to BPH. It is indicated for men older than 50 years with a median or lateral prostatic lobe volume of 20 to 85 ml. Designed for those men who wish to minimize the risk for incontinence and impotence found with conventional TURP, this procedure is now performed in the office setting about 80% of the time.

The procedure is contraindicated for the treatment of prostate cancer and for those patients who had previous brachytherapy with radioactive seeds. However, some physicians may elect to perform ILC before brachytherapy (or cryotherapy) in the hopes of minimizing, if not relieving, the postoperative voiding symptoms associated with these more definitive treatments.

Procedural Considerations. The patient is placed in the lithotomy position and prepped as for cystoscopy. An optional local anesthetic with oral or monitored IV sedation is generally adequate. Oral sedation is used more commonly with the office-based procedure; if the surgery takes place in the hospital or ambulatory center, monitored IV sedation may be used. An ultrasound machine with transrectal capability is often used to measure the size of the prostate gland and determine the appropriate number of laser applications (sticks). Some surgeons choose to measure by cystoscopy alone.

The setup includes a 17F or 23F panendoscope and 30-degree fiberoptic lens, ultrasound and transrectal transducer, and the Indigo laser machine with laser fiber (Figure 14-37). The fiber has graduated black depth markings used to guide placement into the prostate gland. The laser machine automatically times each "stick" for 2 minutes, 30 seconds. The perioperative nurse ensures that all laser safety precautions are observed (Chapter 7).

Operative Procedure

1. The surgeon inserts the transrectal transducer and measures the prostatic volume. (This may have been performed as an office procedure preoperatively.) Local anesthetic may be injected through the transducer guide pin with an 8-inch spinal needle or with the 8-inch collagen injection needle if ultrasound is not employed.
2. Cystoscopy is performed, and the prostatic urethra is evaluated.
3. The surgeon introduces the laser fiber through the panendoscope and passes it into the lateral lobe of the prostate gland through the urethral wall to the desired depth.
4. This is repeated one to three times on each side, depending on the measured prostatic volume.

FIGURE 14-37 Indigo Optima Laser unit with diffuser-tip fiber.

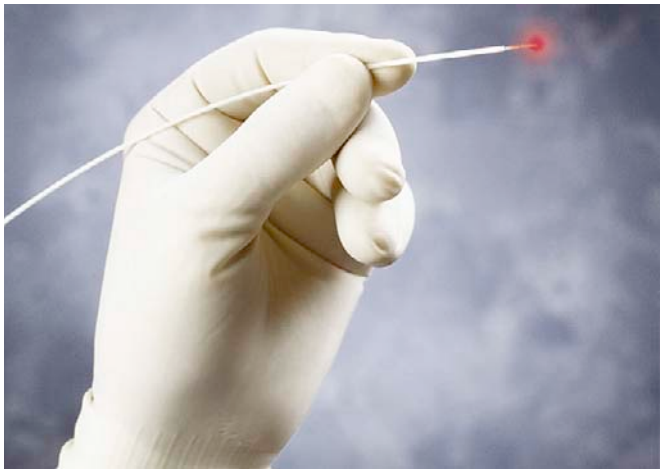


FIGURE 14-38 Indigo bare-tip laser fiber.

5. A TUIP may be performed utilizing the bare-tip fiber (Figure 14-38).
6. A 16F or 18F urethral catheter is inserted and connected to straight drainage. A 16F suprapubic Foley catheter may also be employed and attached to irrigation or drainage.

Transurethral Microwave Therapy (TUMT)/ Transurethral Needle Ablation (TUNA)

TUMT is a minimally invasive method of applying heat to the prostate gland for the relief of the symptoms associated with BPH and bladder-outlet obstruction. TUMT maintains temperatures in the urethra, sphincter, and rectum at a level that is physiologically safe while heating the tissue deep within the transitional zone of the prostate. A water-cooled catheter is combined with microwave radiation to the lobes of the prostate. This treatment is an office-based procedure.

Transurethral needle ablation (TUNA) is also a minimally invasive office procedure for the treatment of BPH of the median and lateral lobes. This technique delivers radiofrequency (RF) energy through two electrodes that are embedded in a special urethral catheter. Specific target areas of the prostate are thermally ablated by the RF energy and combined inductive heating of water molecules, leaving the urethra and the remainder of the prostate intact.

Simple Retropubic Prostatectomy

Simple retropubic prostatectomy is the enucleation of hypertrophic prostatic tissue through an incision in the anterior prostatic capsule by an extravesical approach. The retropubic approach offers excellent exposure of the prostate bed and vesical neck and readily controllable intraoperative and postoperative bleeding.

A preoperative bowel prep and antibiotic therapy are the standard of care for all open prostatectomies.

Procedural Considerations The perioperative nurse assists with positioning the patient in a slight Trendelenburg position with the pelvis elevated and the legs slightly abducted. Although the draping procedure must conform to individual OR policies, the following procedure is suggested for draping the patient:

1. The first towel, with a cuff, is placed under the scrotum.
2. The next three towels are placed around the lower abdominal incision site, followed by a sterile laparotomy sheet.
3. A fifth towel, folded in half, is placed over the penis and scrotum below the retropubic incision site and secured with two nonperforating towel clamps.

The instrument setup includes a basic laparotomy set and bladder and prostatic instruments (Figures 14-39 and 14-40). The following supplies should be readily available: Jackson-Pratt drains; water-soluble lubricant; Toomey and Asepto syringes; urinary drainage system; 20F, 5-ml Foley catheter; 22F or 24F, 30-ml Foley catheter; 10-ml and 30-ml syringes; and a self-retaining retractor such as the adjustable Omni-Tract Surgical UO400 Urology Retractor System (Figure 14-41).

Operative Procedure

1. The surgeon inserts a 20F or 22F Foley catheter with 30-ml balloon into the urethra and through the bladder neck and inflates it. This is clamped and maintained within the sterile field. Frequently, a three-way catheter is used for continuous bladder irrigation.
2. Through a Pfannenstiel or low vertical midline incision, the surgeon incises the anterior rectus sheath along with portions of the internal and external oblique muscles.
3. The rectus abdominis muscles are retracted laterally to expose the space of Retzius.
4. After placement of traction sutures, the anterior portion of the prostatic capsule is incised transversely (Figure 14-42, *A*).
5. The prostatic adenoma may be dissected or finger-enucleated from the surgical capsule (Figure 14-42, *B*).
6. The surgeon places hemostatic sutures at the 5 and 7 o'clock positions, encompassing the vesical neck and prostatic capsule, to ligate the primary blood supply to the prostate. Other bleeding points within the capsule may be suture-ligated with 2-0 absorbable sutures.
7. The prostatic capsule incision is closed with either a continuous or an interrupted 0 absorbable suture (Figure 14-42, *C*).
8. A drain is placed in the space of Retzius and exteriorized through the fascia and skin via a separate stab incision.

FIGURE 14-39 **A**, Right-angle (Mixter) clamps in various tip lengths. **B**, Scissors (*top to bottom*): Strully, curved Jorgenson, long sharp-tip Metzenbaum, standard sharp-tip Metzenbaum. **C**, Same scissor tips, *left to right*. **D**, Curved and straight Lowsley tractors in open position.

FIGURE 14-40 **A**, Urethral suture guides. **B**, Roth grip-tip urethral suture guide.

9. The abdominal incision is then closed in layers, and the wound is dressed.
10. If continuous bladder irrigation is to be used, normal saline solution irrigation is initiated through a 3-liter closed irrigation system.

Suprapubic Prostatectomy

Suprapubic prostatectomy is the removal, through a transvesical approach, of benign periurethral glandular tissue obstructing the outlet of the urinary tract. A low midline, or Pfannenstiel, incision may be used. One advantage of the suprapubic approach is that it allows access for surgical correction of any existing bladder condition such as vesical calculi or vesical diverticula. Control of bleeding is a major consideration in any prostatectomy and is one disadvantage of the suprapubic approach. Because the prostate is located beneath the symphysis pubis, ligation of bleeding capsular vessels is difficult. However, control of hemorrhage and replacement of blood loss, coupled with skilled perioperative nursing care and early mobilization of the patient, have greatly minimized complications.

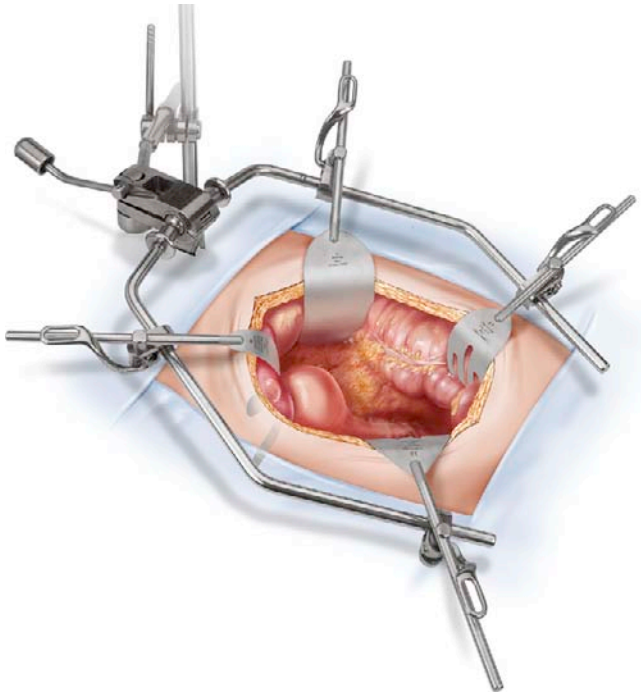


FIGURE 14-41 Adjustable Omni-Tract Surgical UO400 Urology Retractor System.

Procedural Considerations. Spinal, epidural, or general anesthesia may be selected for patients having a suprapubic prostatectomy, depending on their medical condition. The patient is placed in a slight Trendelenburg's position with the umbilicus elevated and the legs slightly abducted. Draping and instrumentation are as described for retropubic prostatectomy.

Operative Procedure

1. The surgeon inserts a 20F or 22F Foley catheter with 30-ml balloon into the urethra and through the bladder neck and inflates it. This is clamped and maintained within the sterile field. This maneuver facilitates identification of the bladder.
2. A transverse or midline lower abdominal incision is made through the skin and the two layers of superficial fascia (Figure 14-43, *A*).
3. The external and internal oblique muscles are cut along the lines of the original incision.
4. Bleeding vessels are clamped, electrocoagulated, or ligated with fine absorbable ties.
5. The rectus muscles are separated in the midline and retracted laterally.
6. After the placement of traction sutures, the surgeon opens the bladder at the dome with a scalpel. Liquid contents are aspirated, and the bladder incision is enlarged.
7. The bladder is visually and manually explored for calculi, a tumor, or diverticula.
8. The surgeon manually enucleates the adenomatous tissue using the tip of the index finger inserted through the vesical neck into the prostatic urethra (Figure 14-43, *B*). If difficulty is experienced with the enucleation, the surgical assistant may place a finger into the rectum to elevate the prostate gland. Aseptic technique is maintained during enucleation with the use of a sterile second glove on the hand used in the rectum.

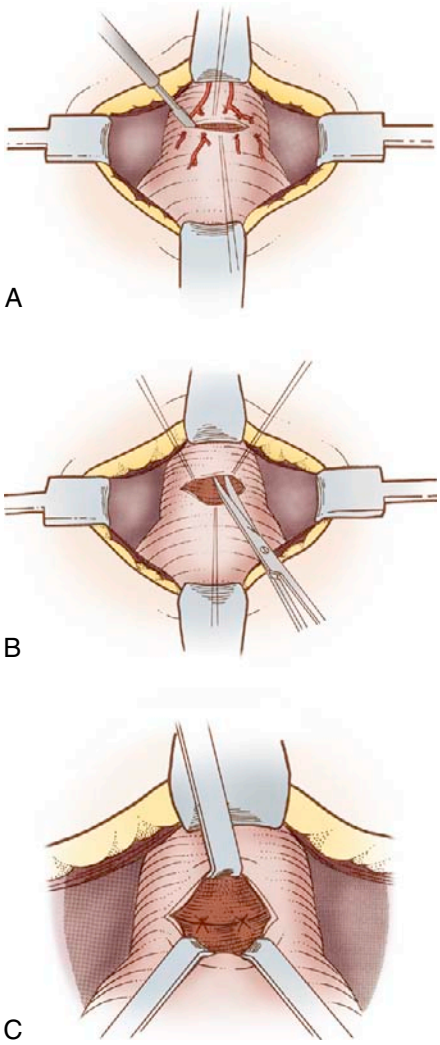


FIGURE 14-42 Retropubic prostatectomy.

9. After enucleation is completed, attention is directed to maintaining good hemostasis by suture ligation of the vesical neck at the 5 and 7 o'clock positions. Other significant bleeding points may also be ligated.
10. A suprapubic catheter is placed into the bladder lumen through a small stab incision.
11. A 22F or 24F, two-way or three-way Foley catheter with a 30-ml balloon is inserted into the urethra in place of the original one, and the balloon is inflated to a size that prevents the catheter from falling or being pulled into the prostatic fossa (Figure 14-43, *C*).
12. The surgeon closes the cystotomy incision with interrupted 2-0 absorbable sutures.
13. A drain is left along the cystotomy incision, exteriorized through a separate stab wound, and secured to the skin with a silk suture.
14. The muscles, fascia, and subcutaneous tissues are closed in layers, and a dressing is applied.
15. To reduce clot formation and maintain catheter patency, normal saline irrigation solution may be connected to the Foley catheter to provide continuous irrigation to the bladder. Continuous irrigation may be initiated during closure.

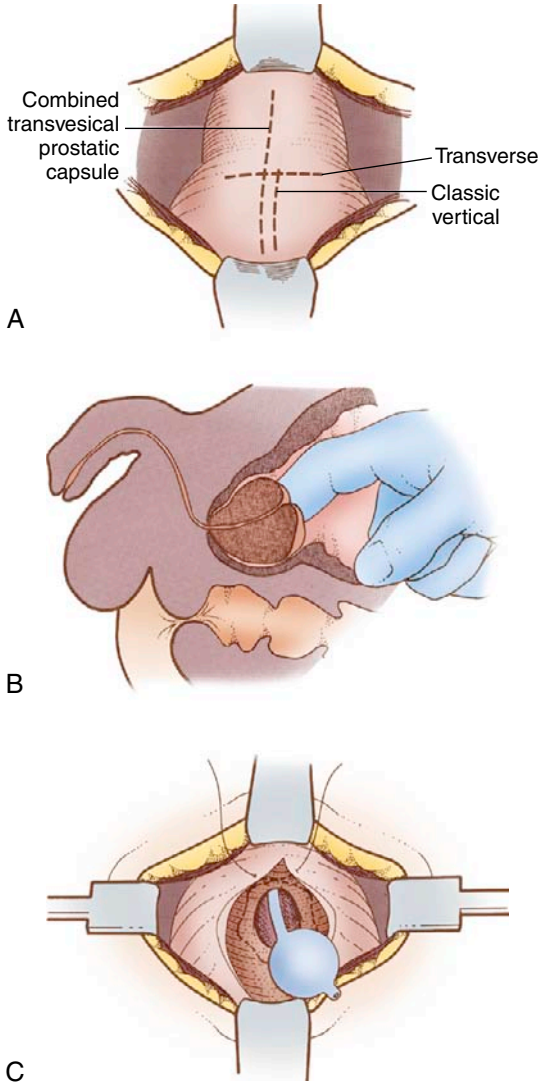


FIGURE 14-43 Suprapubic prostatectomy.

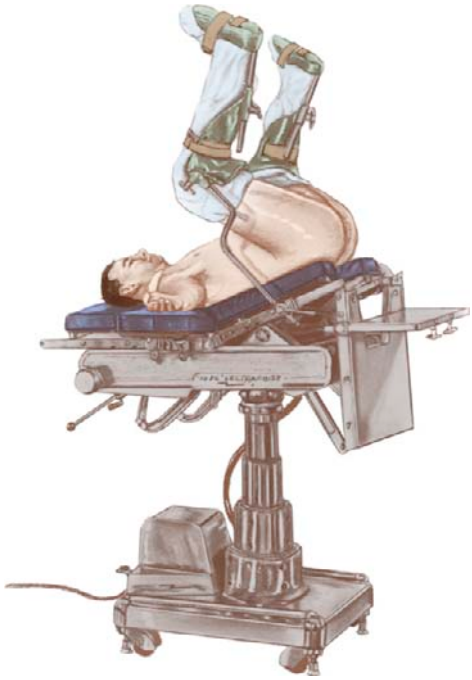


FIGURE 14-44 Exaggerated lithotomy position for perineal prostatectomy.

Simple Perineal Prostatectomy

Simple perineal prostatectomy is the removal of a prostatic adenoma through a perineal approach. A perineal approach to the prostate gland is most suitable when open prostatic biopsy is desired and, after receipt of pathologic confirmation, radical excision is to follow. Other advantages include preservation of the bladder neck, improved urethrovesical anastomosis, and easier control of bleeding. Some surgical disadvantages are (1) inability to perform biopsy of the iliac and obturator nodes for determining extension of disease and (2) possible formation of urethrorectal fistulas.

Procedural Considerations. The patient is placed in an exaggerated lithotomy position with the legs above the level of the pelvis (Figure 14-44). The perioperative nurse places a bolster beneath the sacrum to allow the perineum to be as parallel to the OR bed as possible, with the buttocks extending several inches over the bed edge. Stirrups should be well padded to protect the popliteal fossa. Sequential compression stockings are recommended to assist peripheral vascular flow. The patient is often placed in a steep Trendelenburg position. Well-padded shoulder braces, placed over the acromial processes in a manner to prevent stretch or pressure injury, may be required to prevent the patient from sliding upward on the bed. Routine skin preparation is carried out and includes an interior rectal prep. Special draping is as follows:

1. A towel folded in half is placed over the pubic area.
2. Two towels with a cuff are placed on either side of the perineum.
3. Two leggings, with points down, are placed over the legs.
4. One impervious drape is placed over the anus.
5. A large sheet fully opened with a large cuff is placed across from one stirrup to the other and secured by towel clamps.
6. A laparotomy sheet follows, with the short end to the floor.

The instrument setup is as described for suprapubic prostatectomy, omitting abdominal self-retaining retractors and adding straight and curved Lowsley tractors (Figure 14-45), Roux retractors, Jackson retractors with short and long blades, Doyen vaginal retractors, Young retractor, perineal prostatic retractors (Figure 14-46), Sauerbruch retractors, and a narrow and wide self-retaining perineal retractor, such as the Thompson retractor or the Omni-Tract Surgical UO100 Pelvic Retractor System (Figure 14-47).

Operative Procedure

1. A curved Lowsley tractor is placed through the urethra into the bladder and held back by the surgical assistant, causing the prostate to be pushed down toward the perineum.
2. An inverted U-shaped incision is made from one ischial tuberosity to another, curving just anteriorly to the anus (Figure 14-48, *A*).

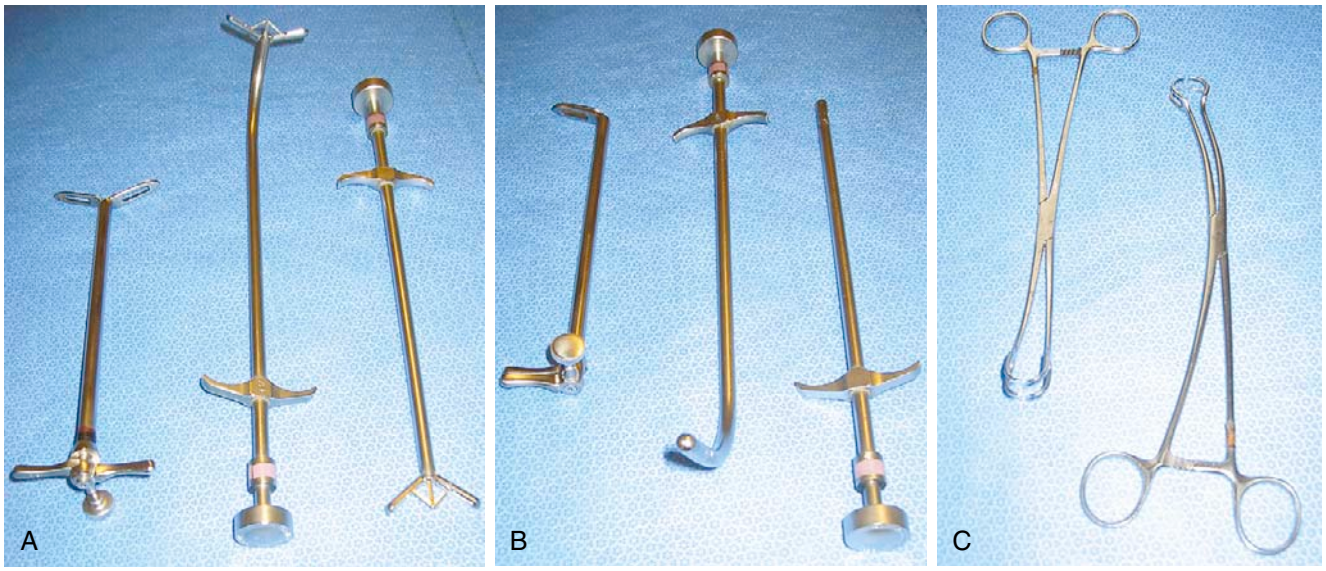


FIGURE 14-45 Young, curved Lowsley, and straight Lowsley tractors in open (**A**) and closed (**B**) positions. **C**, Curved double-prong prostate clamps.

FIGURE 14-46 Lateral, bulb, and anterior perineal prostatectomy retractors.

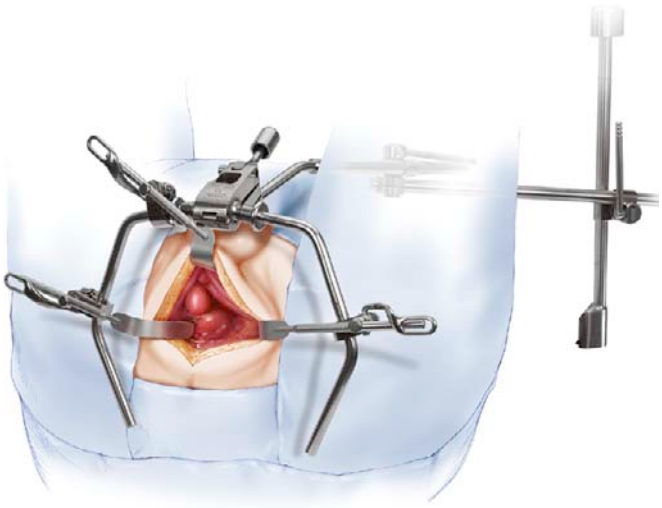


FIGURE 14-47 Adjustable Omni-Tract Surgical UO100 Pelvic Retractor System.

3. Three Martius or Allis clamps are secured to the posterior edge of the incision and retracted downward, over the anal drape.
4. The surgeon clamps any subcutaneous bleeders with straight mosquito hemostats and electrocoagulates or ties them with 3-0 absorbable ligatures.
5. The central tendon is isolated, clamped, and cut distally to the external anal sphincter (Figure 14-48, *B*).
6. The rectourethral muscle is incised and pushed downward from the central tendon.
7. The levator ani muscle is exposed and retracted laterally (Figure 14-48, *C*).
8. The prostate gland is exposed. The surgeon may send biopsies of the prostate for pathologic confirmation. If the results are negative, the prostatic adenoma is removed. If the frozen section reveals malignancy, a radical prostatectomy may be done at this time.
9. If simple enucleation is to be performed, the prostatic capsule is incised and the Lowsley tractor is removed (Figure 14-48, *D*).
10. The urethra is divided, and the Young prostatic retractor is inserted.
11. The blades are opened, drawing the prostate down, and the adenoma is manually enucleated from the surgical capsule.
12. A 22F Foley catheter with a 30-ml balloon is inserted through the urethra into the bladder.

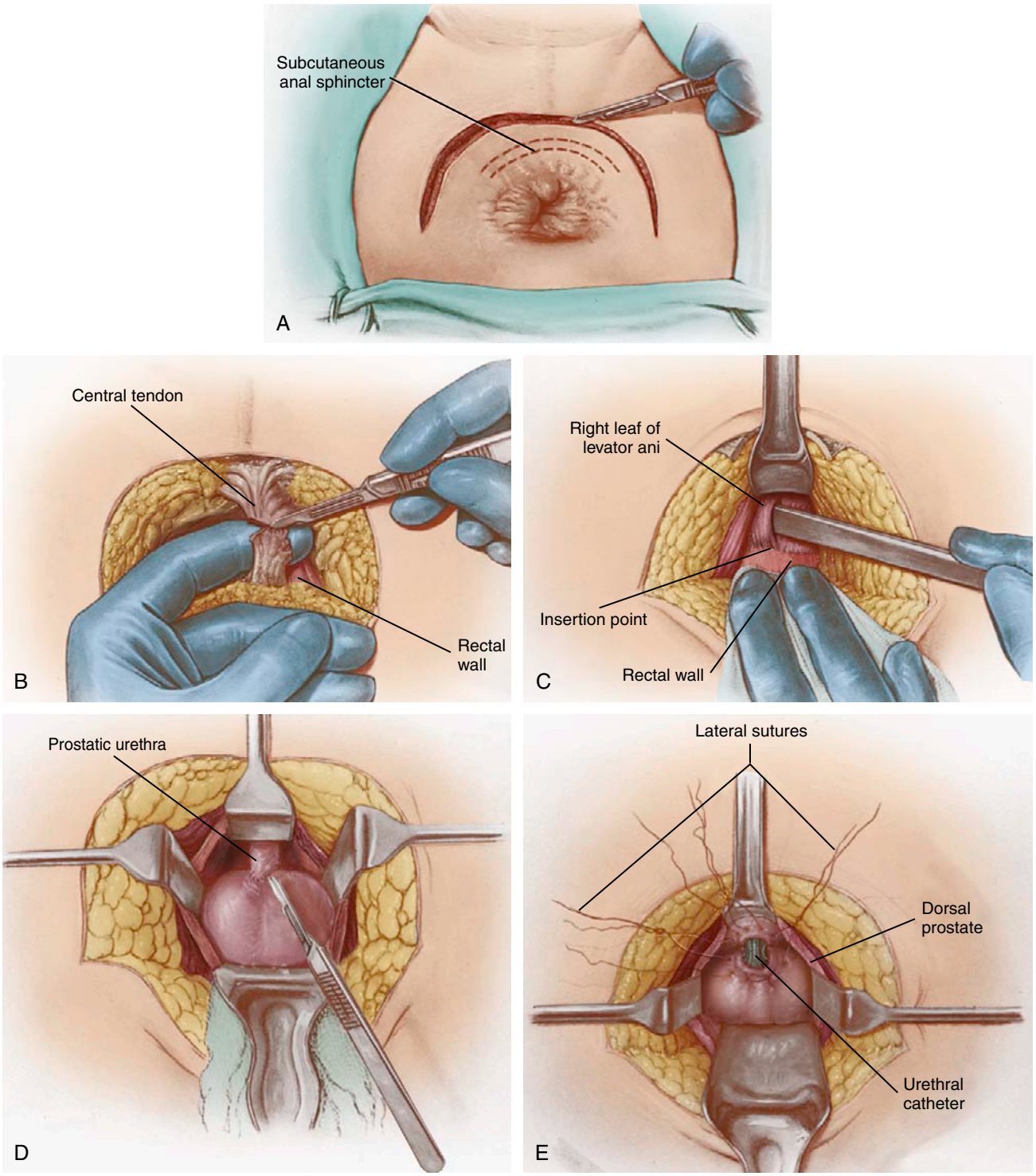


FIGURE 14-48 Simple perineal prostatectomy.

13. Bleeding is controlled at the 5 and 7 o'clock positions.
14. The capsulotomy incision is repaired with a continuous 2-0 absorbable suture (Figure 14-48, *E*).
15. A drain is left in place at the level of the capsulotomy incision.
16. The surgeon reapproximates the subcutaneous tissue with 3-0 absorbable suture.
17. The skin incision is reapproximated with 4-0 absorbable subcutaneous sutures.
18. The wound is dressed according to the surgeon's preference and taped or held with a supportive device, such as mesh pants.

Transrectal Seed Implantation (Interstitial Radiotherapy with Brachytherapy)

Brachytherapy of the prostate gland is a procedure that requires a collaborative, multidisciplinary approach to patient care. The radiation oncologist and medical physicist, in addition to the

surgeon, are vital to an optimum outcome from the initial planning stage throughout the postoperative surveillance. Preplanning is required to determine the size of the prostate, dose of each seed, the spacing necessary between each seed, and the number of seeds required. A template plan is developed preoperatively by using the ultrasound and the probe-anchoring equipment to measure and map the appropriate seed sites within the prostate. This may be accomplished in the surgeon's office, radiology department, or oncology clinic. The implant plan is finalized at the time of surgery.

The facility that offers this treatment must be licensed for "Group 6" with the radioactive materials licensing department of their respective state. If seed implantation is indicated as an adjunct to radiation therapy, it should be performed 3 to 4 weeks after the radiation treatment.

During percutaneous implantation of iodine-125 or palladium-103 seeds, the patient is positioned in the lithotomy position. The surgeon visualizes the prostate with transrectal ultrasonic imaging, and locates the midportion of the prostate on a transverse image. This location becomes an index for positioning the axial ultrasound plane at the base of the prostate. Approximately 2 to 3 hours should be allowed from start to completion. The procedure is amenable to outpatient management using a regional or general anesthetic.

Iodine seeds are commercially available in titanium-encased rods called magazines that absorb the electrons. The magazines can be sterilized in the OR at the beginning of the procedure. These seeds may also be obtained embedded in an absorbable suture that allows them to remain positioned appropriately in relation to themselves and their location within the prostate and minimizes the risk of seed migration. Palladium seeds, not presently available prethreaded, are plated onto a graphite pellet. The pellets are loaded into titanium tubes with a lead marker. The half-life of iodine-125 (60 days) is longer than that of palladium-103 (17 days) and allows the therapy to be delivered over the duration of tumor cell replication, altering the ability of the tumor cells to multiply. Compared to iodine-125, palladium-103 affords a larger dose of radiation in a shorter time interval to more rapidly growing tumors.

Procedural Considerations. Percutaneous implantation of radioactive seeds allows the delivery of significantly higher doses of radiotherapy to the prostate than provided by external beam therapy. The radius of penetration around each seed is only 5 mm, thus sparing adjacent organs. The typical radiation dose that can be delivered by external beam may be 6500 centigrays (cGy), whereas the dose that can be delivered with implantation of seeds alone is in the range of 12,000 to 16,000 cGy. Some patients may receive hormone therapy, to shrink the prostate gland, for 3 months before implantation, and some will undergo radiation therapy before implantation. Patients with stage A or stage B prostate cancer are appropriate candidates, and selection is not influenced by a rise in the PSA level, biopsy specimens indicative of further involvement, or age. Ideal patients for brachytherapy treatment as monotherapy are those with low-risk parameters (PSA ≤10, Gleason score 6 or less, low-volume disease on biopsy).

Possible complications include the risk of intraoperative seed displacement into the bladder; implantation too close to the urethra, resulting in postoperative urethral stricture or prolonged dysuria; and implantation into the perineum if the needles are withdrawn too quickly. There is also the chance of migration of seeds, placed just outside the periphery of the gland and in the periprostatic plexus, to the lung. The nurse instructs the patient to avoid extended contact with children and pregnant females and to keep a 6-foot distance from this population group for 6 to 8 weeks. The patient must strain his urine, and any seeds expelled should be retrieved and returned to the oncologist. Body wastes are not considered hazardous, however.

Bleeding from the percutaneous sites is minimal, but postoperative ecchymosis of the perineum is to be expected. Other postoperative complications that may occur in the first 12 months include acute cystitis, prostatitis, and urinary retention. Late complications may include chronic prostatitis with cystitis, urethral stricture with contracture, stress with urge or total incontinence, proctitis, and impotence. Some patients have required posttreatment TURP, bladder-neck incision, suprapubic catheter insertion, or urethral dilation to alleviate the aforementioned conditions. Much less commonly, rectovesical or rectoprostatic fistula can occur, requiring interventions such as laparotomy, colostomy, and urinary diversion. Patients are generally able to void 24 to 48 hours after implantation. The perioperative nurse positions the patient in the lithotomy position with assistance. The scrotum must be secured cephalad to allow a clear operating field. The surgeon places a traction stitch through the lateral edges of the scrotum and anchors it to the groin region.

With an experienced team, seeding is done with real-time ultrasound imaging. Throughout the procedure, random room checks with the Geiger counter will be performed to determine radiation levels. All personnel, surgical equipment, and trash (including disposable drapes) are scanned before leaving the room at the end of the procedure.

Operative Procedure

Before seeding is begun, the surgeon positions the ultrasound transducer so that the posterior margin of the prostate is parallel to the axis of the ultrasound transducer. The direction of seed insertion and the transverse images of the prostate must have a similar appearance to those on the preoperative volume study. The volume study and implant worksheet are used for continual verification of coordinates. The surgeon attaches a stabilizer bar to the OR bed. This secures the "stepping unit," which allows a 5-mm incremental forward-and-backward motion of the probe. The sled that holds the transducer is attached to the stepping unit. The probe must be securely anchored so that the position of the prostate relative to the needles used to implant the seeds remains unaltered throughout the procedure. For the needles to be positioned appropriately, the template with labeled grid is attached to the transrectal transducer so that the needles placed through the probe grid match the grid locations on the plan. The grid is labeled alphabetically *Aa, Bb, Cc,* and so on, with the center of the prostate corresponding to *D* on the grid. The plan is designed to avoid the urethra, bladder neck, and rectum to prevent urethrorectal fistula formation, irradiation of the bladder, and scarring at the bladder neck level.

1. At the beginning of the procedure the surgeon inserts a urethral catheter, drains the bladder, and then refills it with 150 ml of sterile water. The bladder then provides an "acoustic void" to better visualize the prostate. If fluoroscopy is used, contrast medium can be instilled into the bladder to delineate the position of the bladder neck.

2. The surgeon removes the urethral catheter during implantation of seeds to avoid placement of seeds close to the urethra. The catheter causes the tissue surrounding the urethra to be compressed, and if attempts are made to implant seeds into this compressed tissue, penetration of the catheter and urethra may occur. The catheter also causes an acoustic shadow that prevents visualization of the anterior prostate gland.
3. The surgical technologist covers the ultrasound probe with a sterile probe cover filled with 15 ml of sterile water to remove the artifact. Alternatively, a gel-filled probe cover can be placed on the end of the ultrasound probe. Filling with too much fluid will change the configuration of the prostate and alter the anatomic presentation. The transducer will be aimed with the tip upwards at a 10- to 20-degree angle (Figure 14-49). The posterior wall of the prostate must be far enough away from the probe so that the posterior row of seeds is placed just inside the posterior capsule. Seeds are implanted by means of loaded needles placed into the prostate according to the template plan, with the midline seeds placed slightly off center to avoid the urethra. Alternatively, individual seeds can be placed through the hollow needles using a mick applicator that utilizes a long plunger.
4. Stabilization of the prostate may be achieved with stabilization needles placed laterally to the center into the right and left lobes and then removed once the anterior seeds are in place. Another method is to use a Foley catheter as a retractor for implantation of the periphery and until implantation near the urethra occurs. The best method may be to overcompensate for the rotation of the prostate by angling or turning the needle slightly opposite to the direction desired.
5. The most anterior seeds are placed first so that imaging of the anterior portion of the gland is not obscured by the ultrasonic shadows created by seeds placed posteriorly. If strands are used, Anusol-HC (hydrocortisone) is used to seal the bevel before implantation. Strands should be cut cleanly with electrosurgery to seal the ends and avoid frayed ends, which may be split further when the stylet is inserted into the needle, adversely affecting seed placement.
6. Contrary to normal needle insertion with the bevel up, these needles are placed into the prostate with the solid, or back, side up. Every effort is extended to avoid implanting seeds into the bladder or too close to the urethra, which causes significant postoperative irritative symptoms.
7. When placing the anterior needles, passage of the needle may be prevented by the inferior arch of the pubic bone. The needle tip is visualized as a bright echo, and the angle may be altered to compensate for the bone. Alternatively, the placement of the anterior seeds may be postponed until the end when the template may be dropped down, the probe positioned parallel to the pubic arch, and the needles inserted past the anterior portion into the prostate. Rarely, the template may need to be removed from the ultrasound probe at the conclusion of the procedure to allow "free-hand" placement of anterior needles.
8. The needle is inserted beyond the desired site and then retracted. The first seed will then determine where the balance will lie because the seeds will fall into a plane that follows the first seed in a specific needle. The target volume is greater than the actual volume of the prostate so the capsular edge of the prostate and just beyond are also subjected to seed penetration (Figure 14-50). These peripherally placed seeds have a higher energy and may also have a greater tendency for migration if the tissue is not dense enough to hold the seed in place.
9. The distribution of seeds is generally 80% peripheral and 20% central.
10. The surgeon performs a cystoscopy at the end of the treatment so that seeds protruding into the urethra or left in the bladder may be removed.
11. A Foley catheter is placed and left for 24 to 48 hours.

Transrectal Cryosurgical Ablation of the Prostate Gland

Cryoablation of the prostate is a feasible, minimally invasive option for patients with localized or locally advanced prostate cancer. This method of treating the prostate gland can be used either as primary therapy or as a salvage procedure for local recurrence of prostate adenocarcinoma after previous external radiation therapy, brachytherapy, or even previous cryoablation. Cryoablation causes cell death through crystallization within the intercellular and extracellular spaces that exert mechanical shear forces on the cell membranes, osmotic changes, and cellular hypoxia. Complications related to the procedure include urinary incontinence, urethral slough,

FIGURE 14-49 Transducer on stepping unit and slide, angled upward to "get under" the pubic bone.

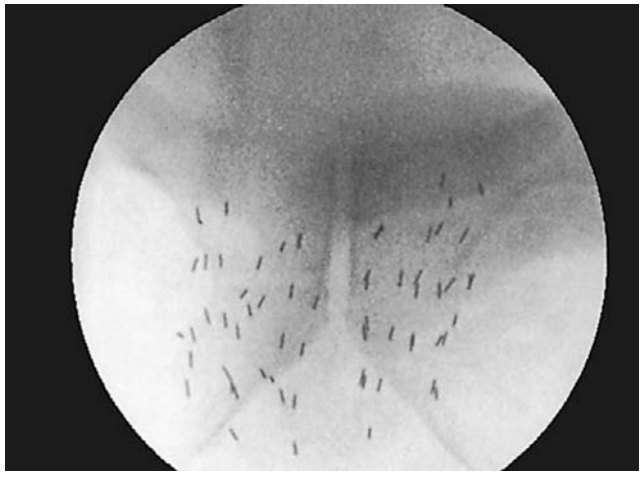


FIGURE 14-50 C-arm view of completed seed implant.

rectourethral fistula, UTI, and post-cryoablation erectile dysfunction (Langenhuijsen et al, 2009).

Procedural Considerations. The perioperative nurse assists with positioning the patient in a dorsal lithotomy position with the legs raised high enough to allow placement of a stabilizer bar that is affixed directly to the operating table. The ultrasound probe can then be placed on a sled with the use of brachytherapy. Because of the positioning required for the procedure and the length of the procedure (e.g., average 2 hours), the patient is at increased risk for developing deep vein thrombosis (DVT). The perioperative nurse initiates DVT precautions (e.g., elastic stockings, sequential compression device sleeves) as part of the plan of care. Patients treated with cryosurgery are generally admitted to the hospital after the procedure and discharged the following morning, unless bleeding, fever, or anesthetic complications prevent their discharge.

Operative Procedure

1. The surgeon performs a cystoscopy to assess the external sphincter, prosthetic urethra, bladder neck, and location of the ureteric orifices on the bladder trigone.
2. At the conclusion of the cystoscopy the surgeon fills the bladder with sterile irrigant to facilitate percutaneous insertion of a suprapubic cystotomy tube.
3. A guidewire is then introduced into the bladder upon removal of the cystoscope, to facilitate later passage of the urethral warming device.
4. The surgeon tacks the scrotum away from the perineum with suture.
5. The transrectal ultrasound probe is then affixed to the table and inserted for visualization of the prostate gland. Volume and length measurements of the prostate are made at this time.
6. The perioperative nurse attaches the needles to the cryosurgery machine to allow circulation of the argon and helium gases through the device tubing. Before insertion of the needles into the perineum, the perioperative nurse and surgical technologist test the needles in the saline to ensure production of an ice ball.
7. Once all needles are in place, the surgeon advances the urethral warming device over the guidewire previously placed in the urethra. This warming catheter remains for the duration of the procedure, and is often left in place for up to 1 hour following the cryoablation treatment. The use of the urethral warming catheter is crucial to the safety of this procedure, and cryoablation of the prostate should not be done without its use.
8. Using ultrasound guidance in the transverse and longitudinal planes, the surgeon inserts the cryosurgery treatment needles and thermocouple needles for temperature monitoring. The needles are positioned according to a template that allows for uniform freezing of the prostate gland. Alternatively, needle placement can be tailored by the surgeon to allow for focal cryoablation as clinically indicated. The needle probes are placed at least 1 cm from the location of the urethra, to minimize risk of damage to this structure and to the urinary sphincter.
9. Freezing is initiated in the anterior portion of the prostate (upper needles), and progress of the ice ball is monitored with ultrasound as the ice front progresses to the posterior aspect and apex of the prostate gland.
10. After all tissue has been frozen using a double-freeze technique, the surgeon removes the cryoprobes. Active warming of the prostate can be achieved with circulation of helium through the hollow needles, and this also facilitates removal of the needles at the conclusion of the procedure.
11. If the urethral warming catheter is to remain in place, the patient is transferred to the recovery room with the urethral warmer and circulating machine, which can be transported on an IV pole. One hour following the procedure, the warming catheter is removed and replaced with a Foley catheter, which is usually removed the morning after surgery.
12. The suprapubic catheter allows for urinary drainage for the first 1 to 2 weeks. The tube can then be clamped for a voiding trial after prostate swelling has subsided enough to allow micturition to occur.

Nerve-Sparing Radical Retropubic Prostatectomy with Pelvic Lymphadenectomy

Radical prostatectomy is the treatment preferred for patients with organ-confined carcinoma of the prostate. This procedure involves removal of the entire gland, its capsule, and the seminal vesicles. Important anatomic structures that impact erectile function are within the surgical field. Whenever possible, the surgeon attempts to spare the posterolateral neurovascular bundles, supplying the corpora cavernosa, to preserve potency. Those with tumors confined in the prostatic capsule are the best candidates for nerve-sparing procedures. In the presence of more advanced tumor extension, the surgeon attempts to spare one of the bundles, allowing the chance for potency.

Procedural Considerations. Patient preparation and basic surgical instrumentation are as for the simple retropubic approach. Additional supplies include long-tipped, right-angled clamps; urethral suture guides; a Bookwalter or Wishbone (UO400) self-retaining retractor; long Martius clamps; straight and right-angled clip appliers and clips; and right-angled scissors.

Operative Procedure

1. The surgeon creates a vertical midline lower abdominal extraperitoneal incision.
2. A bilateral pelvic lymphadenectomy is performed, removing the external iliac, obturator, and hypogastric nodes en bloc. Lymphadenectomy is done primarily for tumor staging.
3. The surgeon exposes the puboprostatic ligaments, and incises the endopelvic fascia on each side of the gland to the puboprostatic ligaments (Figure 14-51, *A*). Right-angled scissors are employed to divide the puboprostatic ligaments. The dorsal vein complex is easily subject to injury, and excessive venous bleeding may occur during this phase of the procedure. The surgical technologist and the perioperative nurse need to be alert to this potential complication.
4. A plane is developed between the lateral prostatic border and the levator ani muscles with sharp and blunt dissection. Once visualized, the muscle is dissected laterally to the urogenital diaphragm.
5. The surgeon ligates and divides the collateral veins originating from the levator ani muscle and running laterally to the puboprostatic ligaments to free the apex of the prostate.

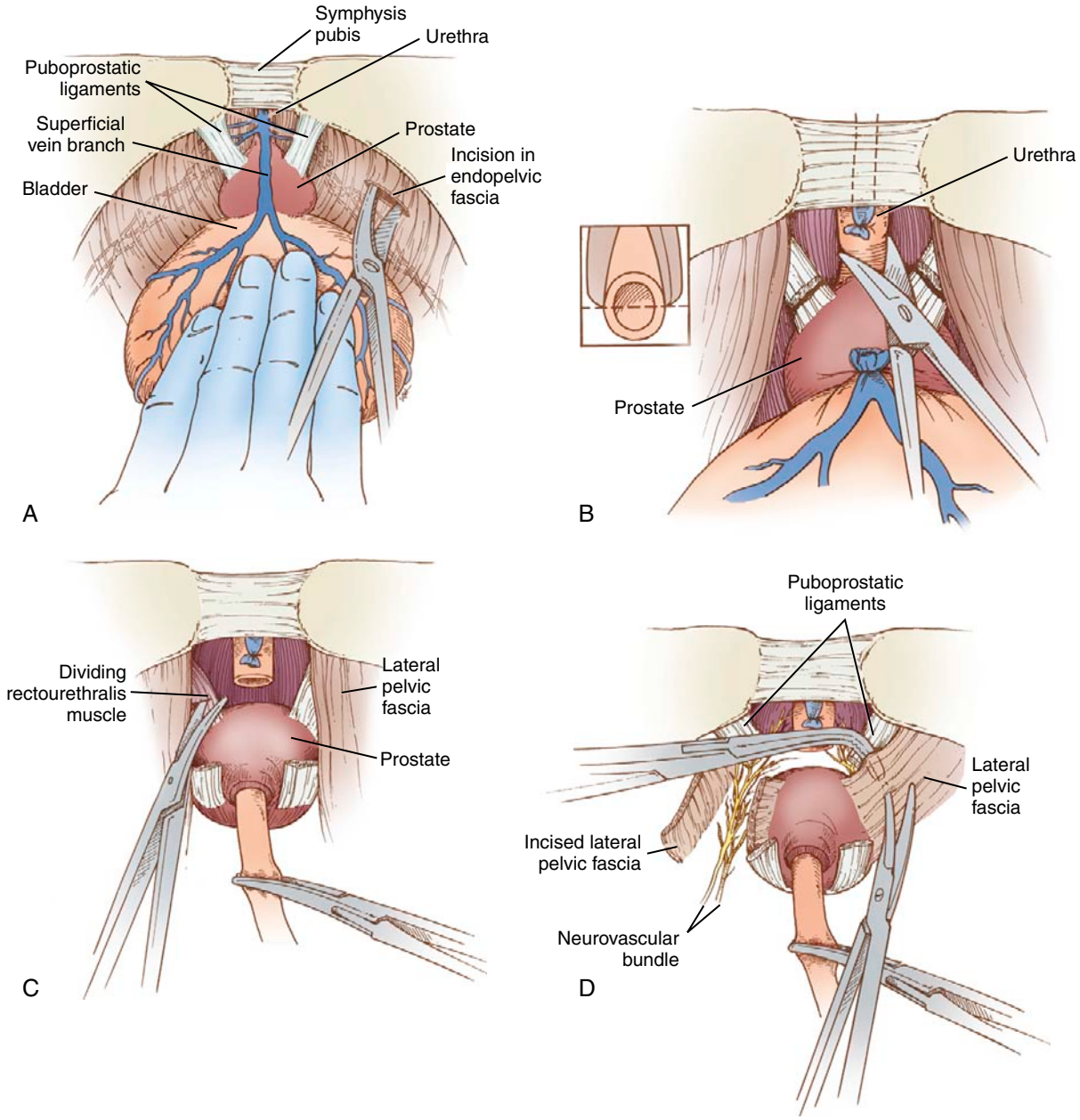


FIGURE 14-51 Radical retropubic prostatectomy.

6. The dorsal venous complex, supplying the penis, is carefully retracted medially. Once a plane is developed, the venous complex is separated from the urethra with a long-tipped, right-angled clamp. The venous complex is ligated with 0 or 2-0 absorbable ligatures. Some surgeons opt to use a stapler designed for this purpose. The complex is then transected with a #15 scalpel. Backbleeding, from the vessels onto the anterior surface of the prostate, is suture-ligated.
7. The surgeon uses a right-angled clamp to mobilize the urethra from the rectourethralis muscle between the two neurovascular bundles, avoiding damage to them.
8. A Penrose drain or vessel loop is passed around the urethra. The surgeon elevates and divides the urethra with a long-handled scissors or scalpel (Figure 14-51, *B*). The catheter is clamped proximally and pulled upward through the urethral incision, where it is cut and held cephalad.
9. The posterior urethra is transected (Figure 14-51, *B*).
10. The surgeon dissects the rectourethralis fibers free from and medial to the neurovascular bundles (Figure 14-51, *C* and *D*).
11. Next, the surgeon enucleates the prostate, divides the bladder neck, and clip-ligates the seminal vesicles (Figure 14-51, *E* and *F*).
12. Once bleeding is controlled, the urethral suture guide is inserted in place of the Foley and six 2-0 absorbable sutures on a ⅝-inch curved needle are placed inside to outside on the distal urethral segment. These are tagged and left uncut to be anastomosed to the bladder neck (Figure 14-51, *G*).

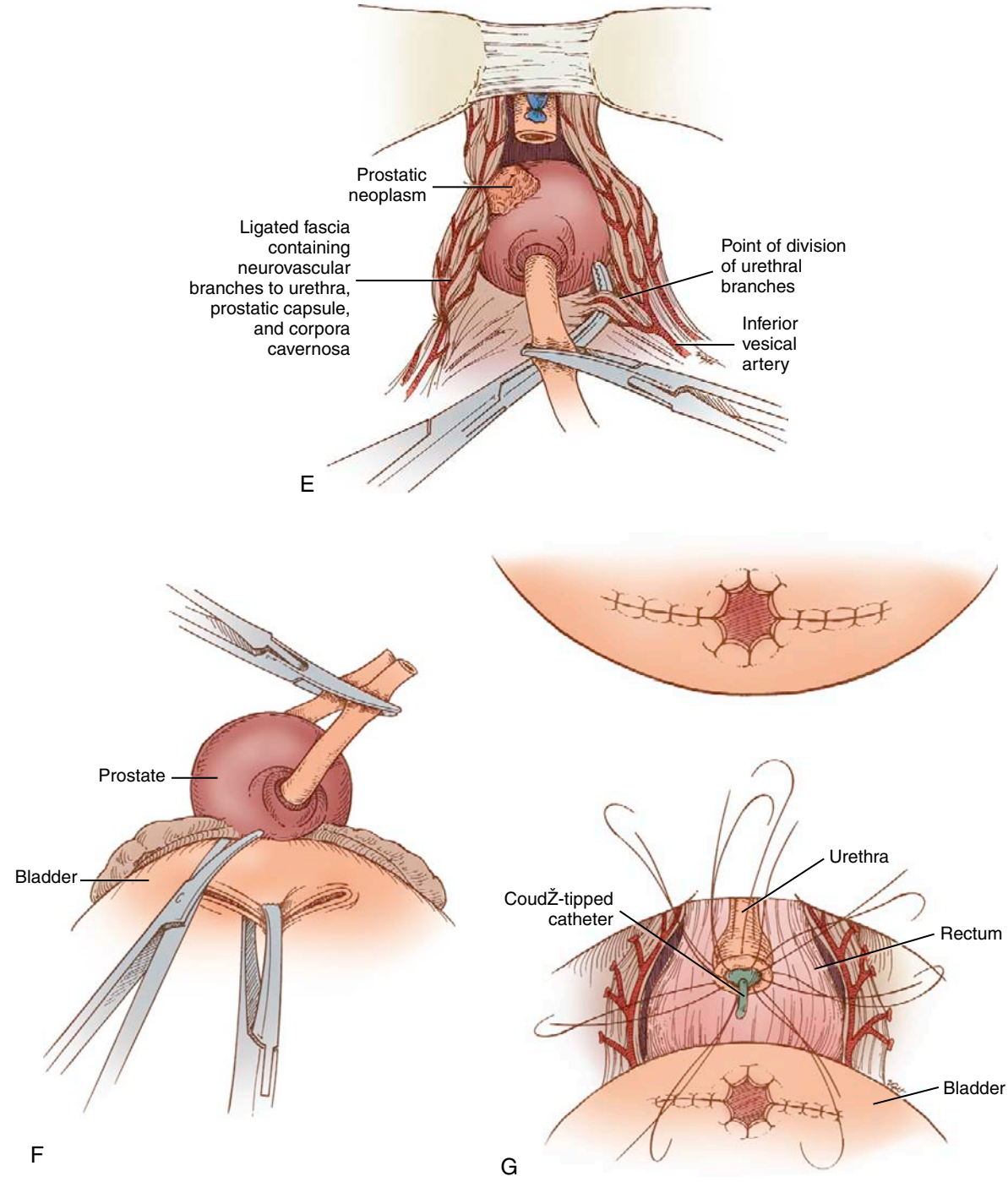


FIGURE 14-51, cont'd. Radical retropubic prostatectomy.

13. The surgeon trims and everts the bladder neck and creates a rosebud stoma. The sutures are placed from the urethra to a corresponding position on the bladder neck. When all are placed, they are brought together in single fashion and tied.
14. Closure is as for simple retropubic prostatectomy. Continuous postoperative irrigation is rarely used. A 22F, 30-ml Foley catheter is inserted and placed to gentle traction, and dressings are applied.

Radical (Total) Perineal Prostatectomy

Patient preparation and instrumentation are the same as for simple perineal prostatectomy. The radical approach is accompanied by laparoscopic or low abdominal lymph node dissection, if not previously performed as a separate procedure. Currently, laparoscopy is performed more frequently than the standard incisional approach. Supplies needed for laparoscopy include standard laparoscopic instrumentation, three 10-mm

trocars, one 5-mm trocar, an insufflation needle, a video camera unit, and CO_2 insufflation supplies.

Procedural Considerations. Two operative setups are necessary. Most commonly, laparoscopy precedes prostatectomy. The patient is in the supine position for the laparoscopy, with the area of the umbilicus slightly elevated. Sequential compressive stockings and preoperative Foley catheterization are necessary. Instruments should be available in the OR to convert to an open procedure if necessary. Lymph nodes may be sent for frozen section, primarily for tumor staging.

Operative Procedure

LAPAROSCOPIC LYMPH NODE DISSECTION

1. The surgeon inserts the Veress needle and insufflates the abdomen.
2. Trocars are placed as follows: 10-mm trocars at the 12 o'clock (umbilicus), 3 o'clock, and 9 o'clock positions; a 5-mm trocar at the 6 o'clock position.
3. The surgeon grasps the peritoneum over the vas deferens, and incises it with scissors. The vas is identified, clipped or electrocoagulated, and divided.
4. The peritoneal dissection is continued laterally and cephalad to the sigmoid colon on the left and the ascending colon on the right.
5. After identification of the spermatic cord structures, iliac vessels, ureters, and psoas muscle, the surgeon extends the incision to the pubic ramus.
6. The Cloquet node is identified and freed from under the external iliac vein.
7. Dissection continues until the obturator nerve is isolated.
8. At the level of the bifurcation of the common iliac vein, the large lymph channel is located and removed. Endoclips or scissor-coagulation may be employed. Clips offer a lower risk of postoperative lymphocele.
9. In a similar fashion, the tissue overlying the external iliac artery is removed.
10. The procedure is repeated on the opposite side.
11. Hemostasis is achieved and the trocars are removed. Each trocar is removed under direct observation with the laparoscope, to allow for identification of inner abdominal wall bleeding sites.
12. After evacuation of the gas from the abdomen, the fascia layers are closed at the 12, 3, and 9 o'clock positions.
13. The surgeon closes the skin with 4-0 absorbable subcuticular sutures and dresses the wound.
14. The patient is then repositioned and prepared for radical perineal prostatectomy.

RADICAL PERINEAL PROSTATECTOMY. Surgical approach is as for simple perineal prostatectomy (Figure 14-52).

1. The surgeon incises a layer of subcutaneous fascia and uses blunt dissection to create a space within the ischial rectal fossa (Figure 14-53, *A*).
2. The central tendon is incised, permitting dissection to be carried out beneath the triangle formed by the superficial external anal sphincter (Figure 14-53, *B*).
3. The assistant retracts the sphincter to provide visualization of the rectourethralis (Figure 14-53, *C*).
4. The true prostatic capsule is exposed by incision of the overlying fascia (Figure 14-53, *D*).
5. After dissection of the periprostatic fascia unilaterally, the surgeon passes a right-angled clamp around the membranous urethra and incises it (Figure 14-53, *E*).
6. Using a knife, the surgeon severs the posterior bladder neck and retracts the bladder superiorly (Figure 14-53, *F*).
7. Blunt dissection is used to develop a plane between the anterior bladder and the posterior prostate and seminal vesicles (Figure 14-53, *G*).
8. The surgeon identifies the vascular pedicles at the 5 and 7 o'clock positions, and incises and divides them (Figure 14-53, *H*).
9. Before closure of the bladder neck, the surgeon may place vest sutures of 0 or 2-0 absorbable material in a mattress fashion in the open bladder neck at the 2 and 10 o'clock positions and left long for later lateral perineal placement (Figure 14-53, *I*).

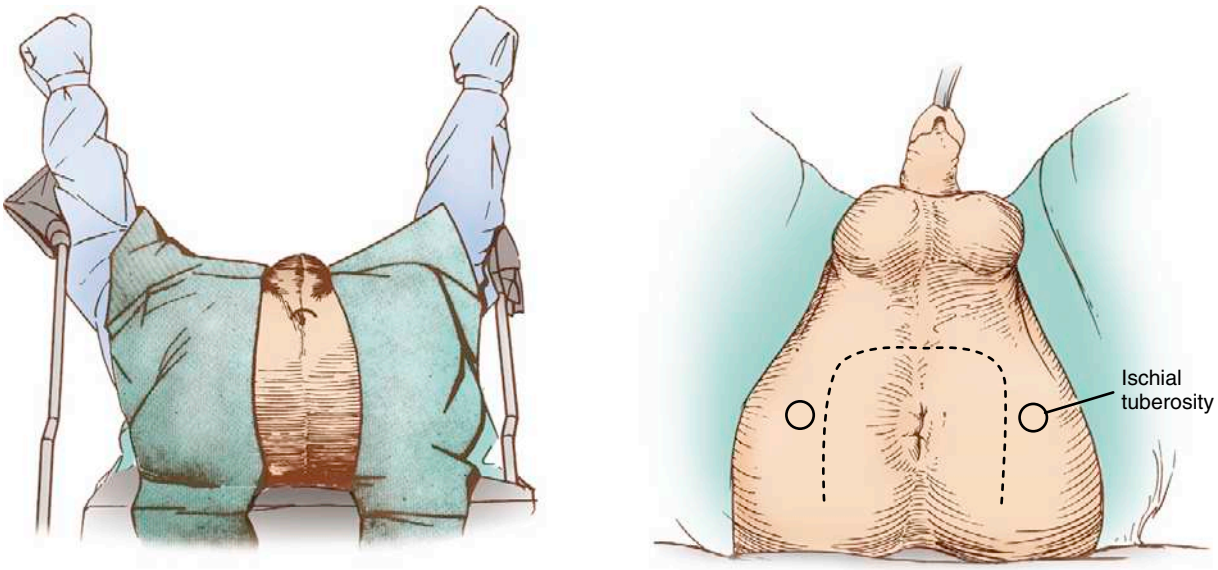


FIGURE 14-52 Radical perineal prostatectomy, draping and incision.

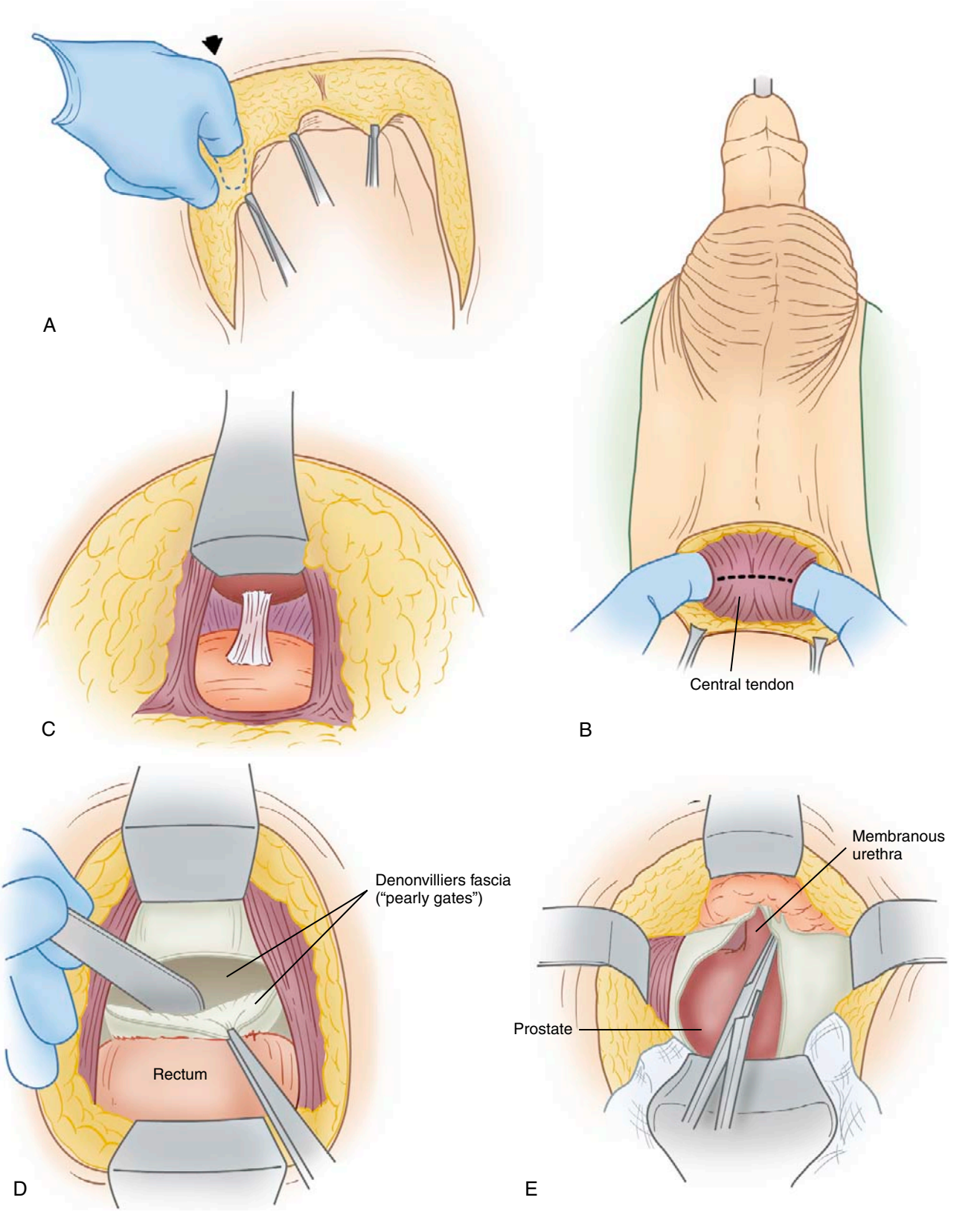


FIGURE 14-53 Radical perineal prostatectomy.

Continued

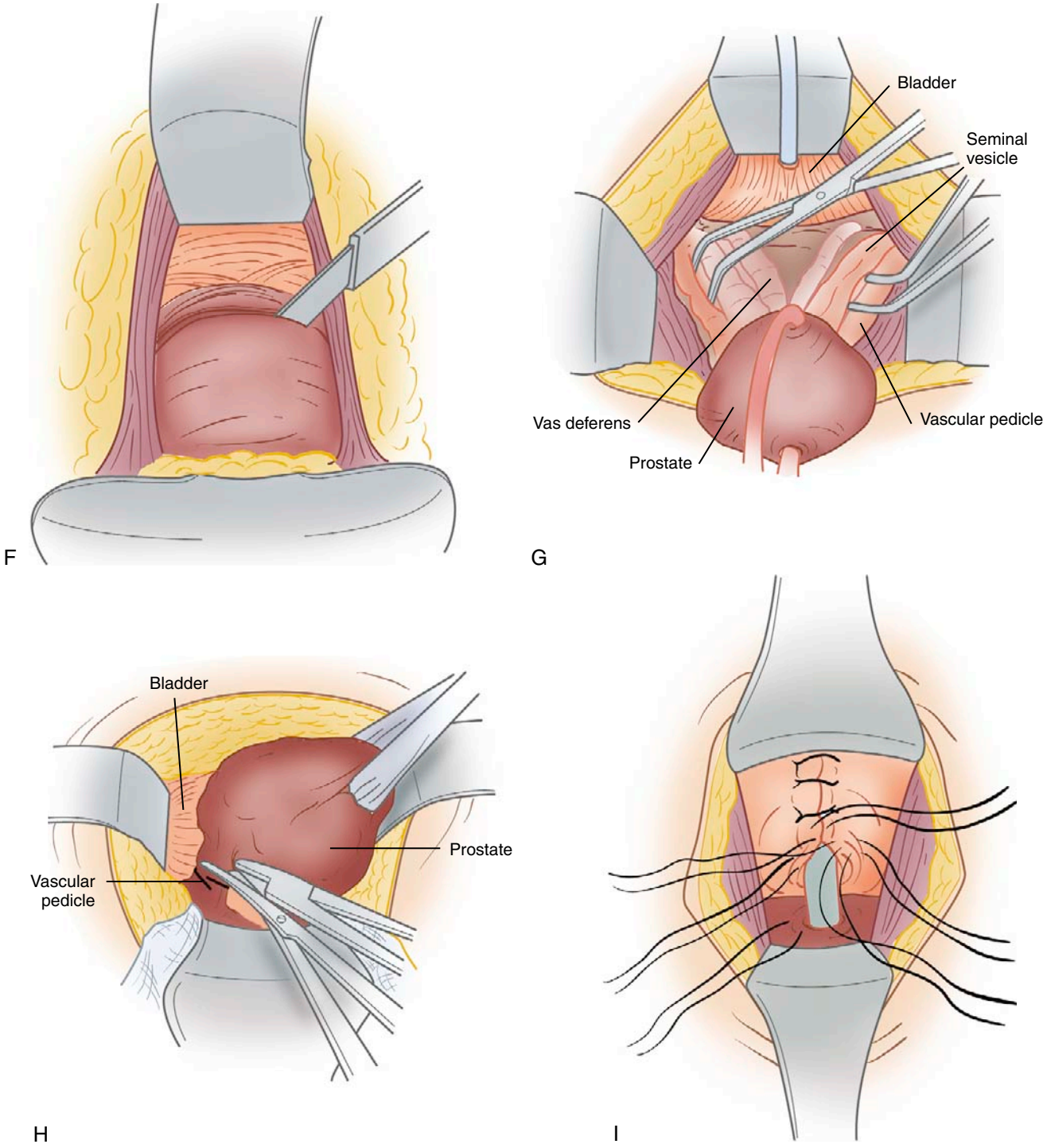


FIGURE 14-53, cont'd Radical perineal prostatectomy.

10. Once the reanastomosis is accomplished, the vest sutures are crossed, passed through the perineal body laterally and parallel to the urethra (anterior to the incision), and secured either just beneath the skin or to the skin with suture buttons.
11. After placement of the Foley catheter, the surgeon reanastomoses the urethra to the bladder neck with four to six 2-0 absorbable sutures placed at the 2, 4, 8, and 10 o'clock positions. Some surgeons opt to place sutures at the 6 and 12 o'clock positions as well.
12. A drain is placed anteriorly to the rectal surface and exteriorized through the incision line or through a separate stab wound.
13. The wound is closed as described in the simple procedure.

Laparoscopic Radical Prostatectomy

Laparoscopic radical prostatectomy (LRP) is a minimally invasive approach that may be offered to some patients in centers where practitioners are skilled in the technique. Patient

selection is the same as that for radical retropubic or perineal prostatectomy. Those patients who have undergone androgen deprivation, radiation, or perineal surgery may not be good candidates for the procedure, however. Advantages to an LRP over an open procedure are decreased intraoperative blood loss (attributable to the tamponade effect of the pneumoperitoneum on the venous sinuses, and improved access to and visualization of vascular structures), shorter hospital stays, and decreased postoperative pain. The return to continence and sexual potency is reported to be comparable with other approaches. Some practitioners suggest that retaining sexual potency is more likely because the neurovascular bundles may be visualized under magnification and therefore are more readily preserved (Gonzalgo, 2008). Because of the high cost of the numerous disposable items needed, many institutions may opt to not offer this approach to their patients.

Procedural Considerations. Generally no bowel prep is performed preoperatively. Intravenous administration of a third-generation cephalosporin and 2500 units of low–molecular weight subcutaneous heparin on the morning of surgery is standard treatment.

With the assistance of at least one additional person, the perioperative nurse positions the patient in low lithotomy position with his arms at the sides. The abdomen, entire perineal area, and the upper and inner thigh region are prepped. This entire area is draped open, and separate leggings are employed. The anesthesia provider places the patient in the Trendelenburg position. The perioperative nurse positions the video monitor between the patient's legs. A Foley catheter is inserted into the urethra and attached to drainage. After the procedure, heparin is given once daily for 2 weeks postoperatively. The drain and Foley catheter are generally removed on the third postoperative day, and the patient is discharged.

Operative Procedure

1. The surgeon inserts the Veress needle and insufflates the abdomen. Once an internal pressure of 15 mm Hg of CO_2 is achieved the needle is removed and replaced with a 10-mm trocar.
2. The laparoscope is used to inspect the interior of the abdominal wall. A second incision is then created at McBurney point, a 10-mm trocar is inserted, and the CO_2 line is moved and reattached to this port to prevent fogging of the lens.
3. Three small incisions are made for 5-mm trocar placement: one inferolateral to McBurney point, one in the left iliac fossa, and the third midline between the umbilicus and pubis.
4. If a lymph node dissection is to be performed, this is accomplished first as described in laparoscopic lymph node dissection.
5. The surgeon incises the peritoneal reflection to expose the vas deferens and seminal vesicles. The vasal artery is coagulated, and the vas is transected bilaterally. The seminal vesicles are transected bilaterally and well mobilized.
6. Denonvilliers' fascia is incised longitudinally close to the ampulla of the vas and seminal vesicles and placed on mild traction. Once the prerectal fat is visible, the surgeon begins inferior blunt dissection to the posterior surface of the prostate. Dissection is carried to the rectourethralis muscle.
7. The bladder is filled through the Foley catheter with approximately 120 ml of sterile saline to pull it posteriorly and help identify the bladder contours.
8. An incision is made medial to the medial umbilical ligament for the initiation of bladder dissection. This is carried to the vas and up the abdominal wall anteriorly and caudally until contact is made with the pubic ramus.
9. The urachus is divided in the midline and dissected to the level of the symphysis pubis, across the space of Retzius. A bipolar or monopolar dissector is often employed for this purpose.
10. After the bladder is freed anteriorly and laterally, the surgeon manually empties it with a suction or syringe device.
11. The surgeon coagulates and incises the dorsal vein. The fascia of Zuckerkandl (fat) covering the prostate is resected or pushed laterally cephalad. The periprostatic space is entered, and the endopelvic fascia is incised on its line of reflection.
12. The puboprostatic ligaments are incised to allow dissection of the dorsal venous complex. This is accomplished with a curved monopolar or bipolar scissors. The vessels surrounding the dorsal venous complex are electrocoagulated with bipolar forceps and then ligated with 2-0 absorbable ligature passed from one side to the other.
13. Using sharp and blunt dissection, the surgeon develops a plane between the bladder neck and prostate. The anterior wall of the urethra is incised, and the Foley catheter is deflated and pulled into the operative field. The lateral and posterior urethral walls are then incised.
14. The posterior bladder neck is finally incised and the retrovesical space entered. The prostatic pedicles are bilaterally electrocoagulated with bipolar forceps.
15. A lateral incision is made to expose and preserve the neurovascular bundles on each side. They are dissected free of the prostatic base to the entrance of the pelvic floor and posterolateral to the urethra.
16. The surgeon transects the dorsal vein complex and retracts it anteriorly to expose the anterior urethral wall. A knife is used to cut across the anterior urethra, and a urethral suture guide is pushed through the urethrotomy into the pelvis. The posterior wall is then transected.
17. The prostate is retracted superiorly and the remaining attachments freed.
18. The surgeon creates the urethrovesical anastomosis with interrupted 3-0 absorbable sutures using two needle holders. Once all sutures are placed and tied, the Foley is reinserted and the bladder filled to check the patency of the anastomosis.
19. A specimen collection bag is passed through the second port at McBurney point and opened. The prostate is placed in the sac, the sac is closed, and the string is cut. The port is removed and the string to the sac is placed on the abdomen outside the port, a mosquito clamp is attached to the end, and the port is reinserted.
20. Abdominal pressure is lowered to 5 mm Hg, and peritoneal incisions are left open. A drain is placed in the pelvis through the lower left port and sutured to the skin. The abdominal muscles are split, and the specimen is extracted after removal of the trocar. All trocars are then removed and the incisions closed in a routine manner.

Robotic-Assisted Laparoscopic Radical Prostatectomy

Robotic-assisted surgery uses robotic equipment to imitate the surgeon's movements, allowing for operative access through five small portal incisions rather than large incisions, which results in shorter recovery times. The robotic system enhances the surgeon's range of motion and precision and allows surgeons to preserve nerves crucial to urinary continence and erectile function. Benefits of robotic-assisted prostatectomy are similar to benefits of laparoscopic surgery. Patients have only five to six small incisions, a shorter hospital stay, decreased blood loss, and a shorter time period before the catheter is removed. Men who have undergone the procedure also have decreased incidence of postoperative urinary incontinence and improved sexual function compared to patients who undergo open prostatectomy (Gonzalgo, 2008).

The robotic surgical system consists of a surgeon console, a cart with interactive robotic arms, jointed instruments that mimic the dexterity of the human hand and wrist, and a high-resolution three-dimensional endoscope and image processing equipment. The system provides a three-dimensional stereoscopic display as the surgeon uses the master arms to make surgical movements that are translated into real-time movements of the instrument tips (Figure 14-54). The surgeon's movements are transferred to the robot 13,000 times per second (Rigdon, 2006).

The role of the perioperative nurse during robotic laparoscopic radical prostatectomy procedures begins with competency in the OR. Because use of this technology requires special skills, nurses should become familiar and proficient with all aspects of the procedure.

Procedural Considerations. Before the patient's arrival to the OR the perioperative nurse and surgical technologist collaborate to ensure all the necessary instrumentation and equipment is available for the procedure. Depending on the robotic system used, a standard laparoscopic setup is utilized with the addition of the robotic instrumentation and equipment, including the control station, the surgeon's console that provides the interface to the robot, and the robotic arms.

Patients undergoing robotic prostatectomy receive a general anesthetic. The perioperative nurse assists with positioning the patient in the supine position with his legs in Allen stirrups. Once the procedure begins, the anesthesia provider will place the patient in the Trendelenburg position to displace the viscera from the pelvis into the upper abdomen to improve visualization. Surgeons may use a transperitoneal or extraperitoneal approach to the prostatectomy. The transperitoneal approach is described in the next section.

Operative Procedure

1. The surgeon inserts a 22F Foley catheter and maintains it within the sterile field.
2. Pneumoperitoneum is established using either a Veress needle placed at the base of the umbilicus or an open trocar placement with a Hasson technique, depending on the surgeon's preference.
3. The surgeon inserts the 0-degree endoscope through the 12-mm cannula and places the remaining ports as described under direct vision: Two ports are inserted on each side of the pararectus and two additional ports are placed two to three fingerbreadths medial to the patient's right and left anterior superior iliac spine.
4. The sterile team docks the robot and the perioperative nurse transfers the cart with the robotic arms to the field and assists the surgical technologist with draping. The surgical technologist assists with connecting the robotic manipulators and other system components.
5. The surgeon moves to the console and the assistant remains in the sterile field to operate the clip applicator and suction devices.
6. From the remote location at the console, the surgeon incises the peritoneum over the vas deferens and divides them.
7. The seminal vesicles are dissected and the surgeon incises Denonvillier's fascia.
8. Using blunt dissection, the surgeon develops a plane between Denonvillier's fascia and the rectum. The surgeon identifies the endopelvic fascia, dissects it, and makes a bilateral incision.
9. The Foley catheter is removed and the assistant replaces it with a metal sound. Using a figure-of-eight 2-0 polyglactin suture, the surgeon suture-ligates the deep dorsal venous complex. The sound ensures that the urethra is not incorporated into the ligature (Figure 14-55).
10. Using ultrasonic shears or the monopolar ESU, the surgeon incises the anterior and posterior bladder neck. EndoClips are placed along the lateral pedicles as necessary for hemostasis.
11. Dissection continues along the lateral surface of the prostate and the neurovascular bundles are identified.
12. The surgeon divides the dorsal vein and divides the urethra distal to the apex of the prostate.
13. The gland is freed and placed in an entrapment bag.
14. Using a running or interrupted 2-0 polyglactin suture, the surgeon performs the urethrovesical anastomosis (Figure 14-56). The assistant fills the bladder with 100 to 150 ml of irrigant to test the anastomosis. Any visible leaks are repaired with additional suture.
15. A closed-suction drain is placed in the prevesical space.
16. The assistant extends the incision at the umbilical port site and removes the specimen.
17. The surgeon closes the port incisions.

FIGURE 14-54 Minimally invasive robotic surgery system.

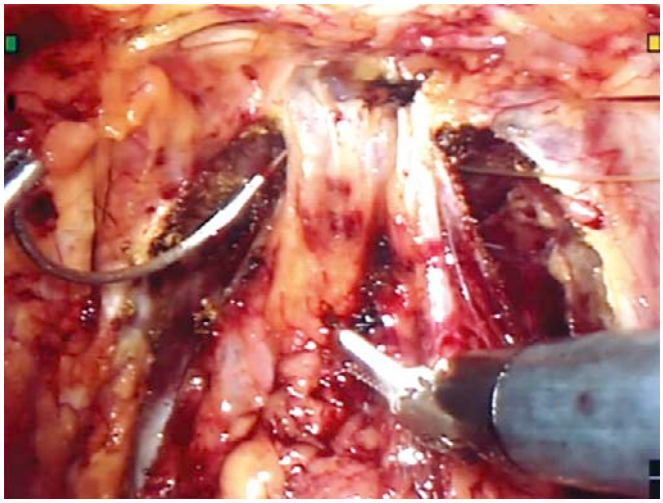


FIGURE 14-55 Intraoperative view demonstrating passage of a suture incorporating the deep dorsal vein complex during robotic-assisted laparoscopic radical prostatectomy.

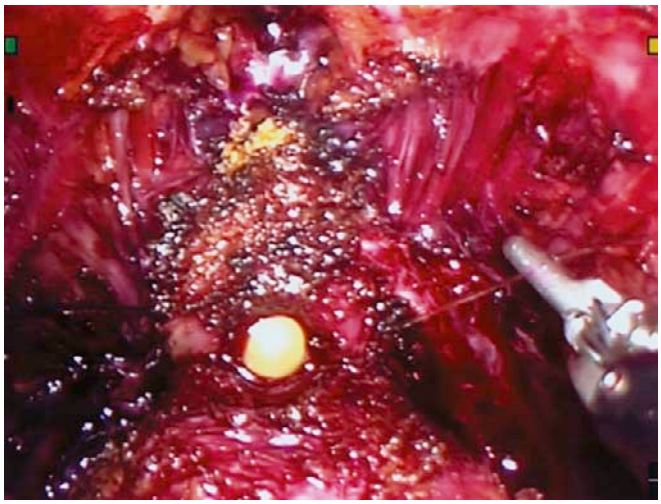


FIGURE 14-56 Intraoperative view demonstrating the use of a running continuous suture for the vesicourethral anastomosis.

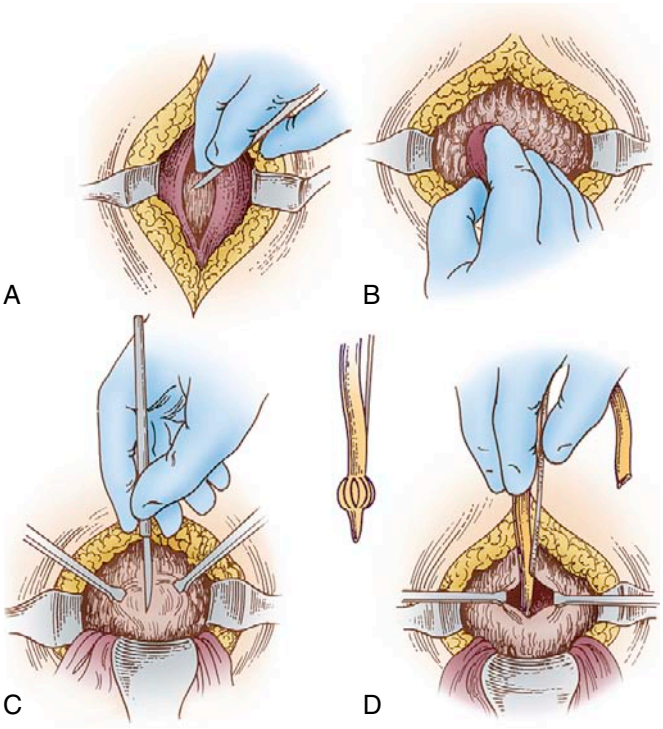


FIGURE 14-57 Suprapubic cystostomy.

SURGERY OF THE BLADDER

Operations on the urinary bladder may be performed through an open abdominal incision or a transurethral route. Diagnostic procedures are often undertaken via the transurethral route. Bladder tumors, diverticula, congenital defects, or trauma may necessitate an open abdominal approach. A thorough diagnostic workup and endoscopic examination help to determine the appropriate surgical approach to be employed. Radical procedures, such as total cystectomy, are performed for the treatment of invasive carcinoma of the bladder and require permanent urinary diversion.

For most open-bladder surgery the patient is placed in the supine position with a bolster under the pelvis. The Trendelenburg position may be desired because this position tilts the head down and allows the viscera to fall cephalad. This allows excellent exposure of the pelvic organs, including the bladder. The patient is draped as described for routine suprapubic prostatectomy, using a disposable impermeable drape that is placed immediately below the bladder incision. A catheter may be inserted into the urethra and the bladder distended with sterile saline at the start of surgery for easy identification. The ESU is required. The instrument setup for open-bladder operations requires a basic laparotomy set, plus Mason-Judd bladder retractors, long and short thyroid traction forceps, retropubic needle holders (or other long needle holders), one trocar, vessel loops, a catheter stylet, a closed-wound suction system, and assorted Foley, Pezzer, and Malecot catheters.

Suprapubic Cystostomy

Cystotomy is an opening made into the urinary bladder through a low abdominal incision. When a drainage tube is inserted into the bladder through an abdominal incision, the procedure is a cystostomy.

Procedural Considerations. The patient is in the supine position. Anesthesia may be general, spinal, or local with sedation. A basic laparotomy set is generally sufficient for the procedure. Foley catheters ranging from 22F to 30F should be available, as well as Malecot suprapubic catheters and a drainage bag. Frequently, a flexible cystoscopy is incorporated as part of the procedure.

Operative Procedure

1. After making a vertical or Pfannenstiel incision the surgeon divides the rectus fascia along the midline (Figure 14-57, *A*).
2. The bladder is distended with saline solution that is instilled with an Asepto syringe through a catheter.
3. The surgeon uses sharp and blunt dissection to dissect free the dome of the bladder (Figure 14-57, *B*).

4. Using a pair of Martius forceps, the surgeon grasps the walls of the bladder on either side of the midline (Figure 14-57, *C*).
5. Two traction sutures may be placed through the bladder wall and held with straight hemostats.
6. The surgeon incises the bladder downward with a scalpel. Bleeding vessels in the bladder wall are clamped and ligated.
7. The bladder contents are aspirated with a suction device.
8. The bladder opening may be extended if the bladder is to be explored for diverticula or calculi.
9. The surgeon inserts a large-size Malecot or Pezzer catheter into the bladder (Figure 14-57, *D*).
10. The incision is closed snugly about the catheter with absorbable sutures to render the closure watertight around the cystostomy tube.
11. The muscle, fascia, and subcutaneous tissue are closed with absorbable suture.
12. The surgeon closes the skin with staples or suture.
13. The cystostomy tube is secured to the skin with a 0 or 2-0 nonabsorbable suture to prevent it from being inadvertently dislodged from the bladder. A drain such as a Jackson-Pratt may be left in the prevesical space.
14. The wound is dressed, and the cystostomy tube is connected to a straight urinary drainage system.

Transurethral Resection of Bladder Tumors

Bladder lesions may be removed using a standard resectoscope, working element, loop, and a Foroblique telescope, which is passed through the urethra into the bladder. A 24F cystoscope sheath with a catheterizing bridge and biopsy forceps may be used to remove bladder tumors located at the very top or dome of the bladder (Figure 14-58). Transitional cell carcinoma of the bladder is one of the most difficult lesions to track because it can occur wherever there is transitional cell lining of the urinary tract. Bladder cancer has a tendency to recur in other areas of the bladder, even after complete resection of the original lesion.

Usually the surgeon removes not only the bladder lesion but also a portion of the bladder muscle underlying the lesion so that the pathologist can determine if any tumor has invaded the muscle. Random biopsy specimens of the normal bladder lining are also taken to ascertain if microscopic transitional cell carcinoma in situ is present. Lesions that deeply invade the muscle must be treated with an open surgical procedure, such as a partial cystectomy or total cystectomy.

The resection technique, setup, and preparation of the patient are virtually the same as those for TURP. The anesthesia provider administers a general, spinal, or regional anesthetic. A retrograde pyelogram may be done to check for lesions existing in the upper urinary tract.

Sterile water is recommended as an irrigating solution in transurethral resection of bladder tumors. Because few vessels are uncovered during this short resection procedure, water absorption with hemolysis and systemic complications such as hyponatremia do not occur. In addition, cancer cells released during the procedure tend to absorb water, causing them to rupture and lyse rather than remain viable and capable of implanting themselves into the raw surface of the bladder created by the surgery. When the procedure is completed, the

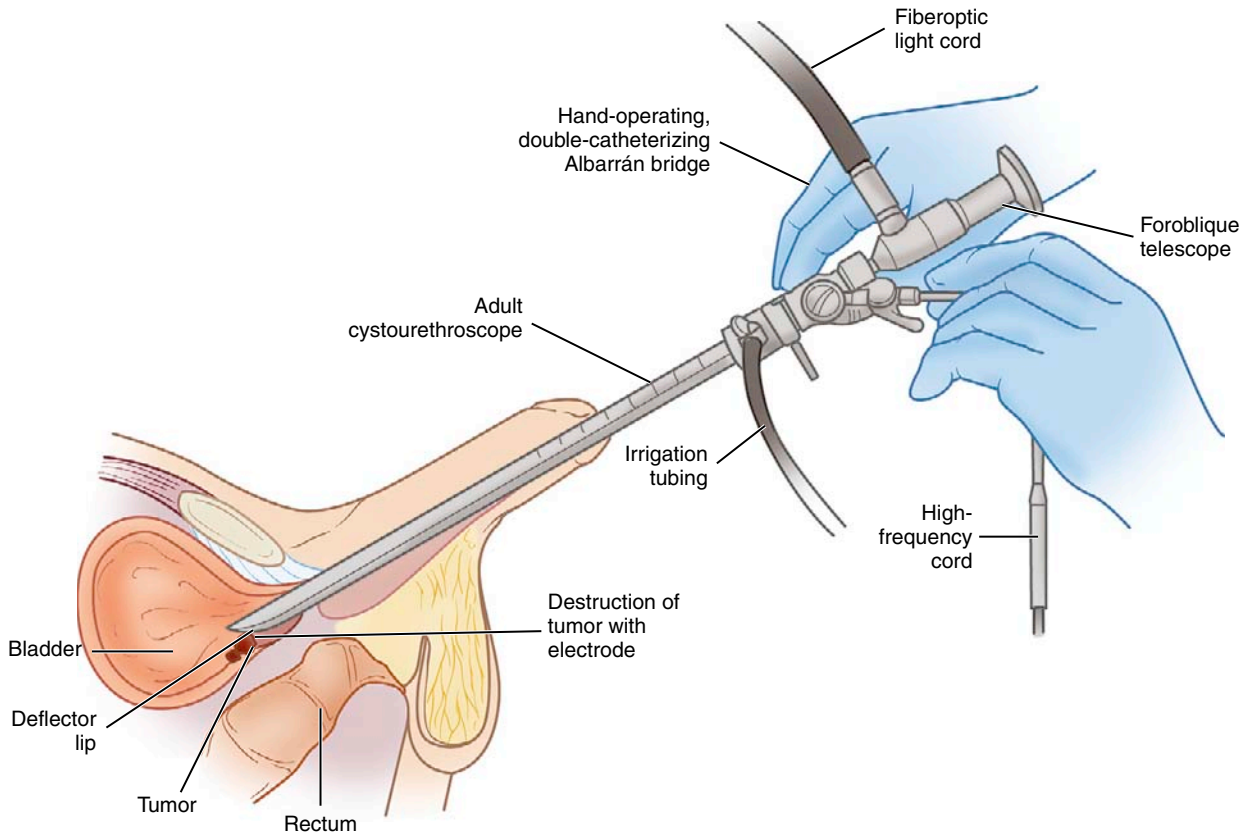


FIGURE 14-58 Laser fulguration.

surgeon passes a large catheter, usually a 24F, into the bladder and connects it to drainage.

Transurethral Laser Ablation of Bladder Tumors

The neodymium (Nd):YAG or holmium (Ho):YAG laser may be used to destroy small recurrent bladder tumors and to coagulate the tumor bed of larger bladder tumors resected with an electrosurgical loop. A powerful, highly focused beam of light in the near-infrared range is transmitted to the tumor site through a flexible glass fiber. This laser fiber is passed through the catheter channel of a cystoscope, and the fiber is directed by a deflecting laser bridge (Figure 14-59). The advantages of a laser in the eradication of bladder tumors are as follows: (1) bleeding is minimized, (2) only sedation is required, (3) the operating time is shortened, (4) there is minimal damage to healthy tissue, and (5) postoperative drainage of the bladder by a urethral catheter is not needed.

Alternatives to Surgery for Superficial Bladder Cancer

Patients with various types of cancer may be treated in the urology office setting with various therapeutic modalities including the instillation of chemotherapeutic solutions. These measures may be initiated instead of surgery or as an adjunct to surgery. Instillations are aimed at eradicating existing disease, reducing tumor recurrence and progression, and improving overall patient survival (Lamm et al, 2005).

Patients with bladder cancer that has been staged as Ta, carcinoma in situ (CIS), and T1 may be treated with intravesical, antineoplastic chemotherapy agents such as *thiotepa* (Thioplax), *mitomycin C* (Mutamycin), *doxorubicin* (Adriamycin), and *etoglucid* (Epodyl). Chemotherapy has become the treatment of choice for low-risk patients.

Immunotherapy with TheraCys or Tice *bacille Calmette-Guérin (BCG)* is used to treat patients considered to have high-risk tumors. BCG, through an unknown mechanism, strengthens the body's immune reaction to cancer and is considered the most effective therapy for recurrent and residual bladder cancer.

Combination chemotherapy and immunotherapy have become standard treatment for patients with metastatic transitional cell carcinoma. BCG has been combined with *mitomycin C* and with *interferon alfa-2b*. The latter combination has been highly effective, rescuing approximately 60% of those who failed with BCG alone (Lamm et al, 2005).

Trocar Cystostomy

Trocar cystostomy consists of draining the bladder by puncture with a needle or trocar and inserting a catheter.

Procedural Considerations. A minor instrument set along with a metal probe and grooved director, an Anthony suction tube and tubing, and trocar catheters or a prepackaged cystostomy kit is required. A local anesthetic may be used.

FIGURE 14-59 Rectoscope with bridge.

Operative Procedure

1. The surgeon nicks the skin at the site of the puncture with a scalpel and inserts the trocar into the bladder.
2. The trocar obturator is withdrawn, the bladder is drained through the trocar by suction, and a catheter is passed through the trocar cannula into the bladder.
3. The surgeon removes the cannula and sutures the catheter to the wound edges. The wound is dressed.

Suprapubic Cystolithotomy

Suprapubic cystolithotomy is the removal of calculi from the bladder. Obstructions, such as prostatic enlargement or foreign bodies, are common causes of bladder calculi and may be corrected at the time of surgery. In the past, special transurethral instruments such as the lithotrite were commonly used to crush vesical calculi manually. Bladder stones are often eradicated via the electrohydraulic lithotripter, which fragments the stone within the bladder by using an electric current to initiate shock waves (Figure 14-60, *A*), or by ultrasonic lithotripsy.

During ultrasonic lithotripsy ultrasound waves are transmitted through a hollow metal probe, which creates vibration at the tip. When applied to the surface of a calculus, the vibrating tip drills and fragments the calculus. This mechanical disintegration is continued until the stone is reduced to small fragments that are evacuated by suction through the hollow center of the probe (Figure 14-60, *B*). The holmium:YAG laser (Ho:YAG) may also be used for fragmentation of bladder calculi (Figure 14-61).

Procedural Considerations. Instruments for open-bladder operations along with Millin T-shaped stone forceps, Millin capsule forceps, and Lewkowitz lithotomy forceps are required.

Operative Procedure. The surgical approach is similar to that described for suprapubic cystotomy. When the bladder is opened, calculi are identified and extracted. If indicated, bladder outlet obstruction is repaired.

Repair of Vesical Fistulas

Vesical fistulas occurring between the bladder and the intestines or vagina may be repaired surgically. *Vesicointestinal fistulas* may be caused by ulcerative colitis, diverticulitis, or neoplasms of the colon or rectum. *Vesicovaginal fistulas* may be a complication of radiotherapy for cervical cancer, endoscopic procedures involving surgery of the trigone or vesical neck, obstetric injuries, and hysterectomies.

Procedural Considerations. The instrument setup is as described for open-bladder operations. Intestinal instruments (Chapter 10) are necessary for vesicointestinal fistulas. For vesicovaginal fistulas, vaginal preparation and a colporrhaphy set (Chapter 13) with colostomy or ileostomy instruments are used.

Vesicointestinal fistulas are more common than vesicovaginal fistulas. Of the intestinal fistulas, the sigmoid colon is most often involved (Figure 14-62). A colostomy proximal to the fistula may be performed to protect the repaired segment of bowel. The communicating area of bladder and bowel is totally resected. Generally, an end-to-end bowel resection is performed

FIGURE 14-60 **A**, Electrohydraulic lithotripter. **B**, Ultrasonic lithotripter.

FIGURE 14-61 Holmium laser unit.

after excision of the involved intestinal segment. The bladder is then repaired in three layers.

If the fistula is at the dome of the bladder, the approach will be transperitoneal, transvesical, or a combination of the two. If the fistula is in the trigone of the bladder, a vaginal approach may be employed. A suprapubic tube is usually left in the bladder.

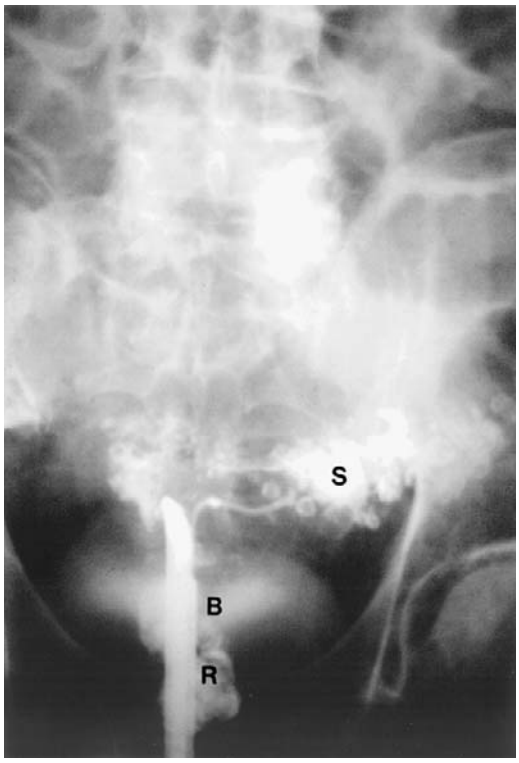


FIGURE 14-62 Vesicoenteric fistulogram (cystogram) showing contrast material in bladder *(B)*, sigmoid colon *(S)*, and rectum *(R)*.

Operative Procedure

VESICOVAGINAL FISTULA REPAIR—VAGINAL APPROACH

1. Before placing the patient in the hyperflexed lithotomy or Kraske position (jackknife), the surgeon inserts a suprapubic catheter, clamps it, and connects it to closed drainage. If the intended position is Kraske, separate draping material and instrumentation are set up for the suprapubic catheter insertion with the patient supine. The catheter is secured, and the patient is turned for the procedure.
2. The area is draped with a lithotomy or laparotomy sheet as indicated per the patient's position.
3. The surgeon sutures the labia to the outer groin or inner thigh for retraction and visualization.
4. A weighted vaginal retractor is placed posteriorly, and the defect is examined. A relaxing vaginal incision may be necessary at the 5 or 7 o'clock position.
5. The surgeon inserts a 4F ureteral catheter through the fistula, and dilates the tract to admit an 8F balloon catheter. The balloon is inflated, and the catheter is used as a retractor.
6. The area is infiltrated with vasopressin (Pitressin) solution.
7. The surgeon incises the vaginal mucosa and perivesical fascia around the defect outside of the scarred tissue.
8. Two planes are developed—one between the mucosa and fascia and one between the fascia and the bladder wall—with fine scissors, forceps, and gauze (Kittner) dissectors.
9. The bladder wall is freed from the vaginal wall.
10. The vesical defect is grasped with Martius clamps, the scarred edges are everted, and the defect is closed vertically with interrupted 3-0 absorbable sutures after removal of the catheter previously placed. In some instances,

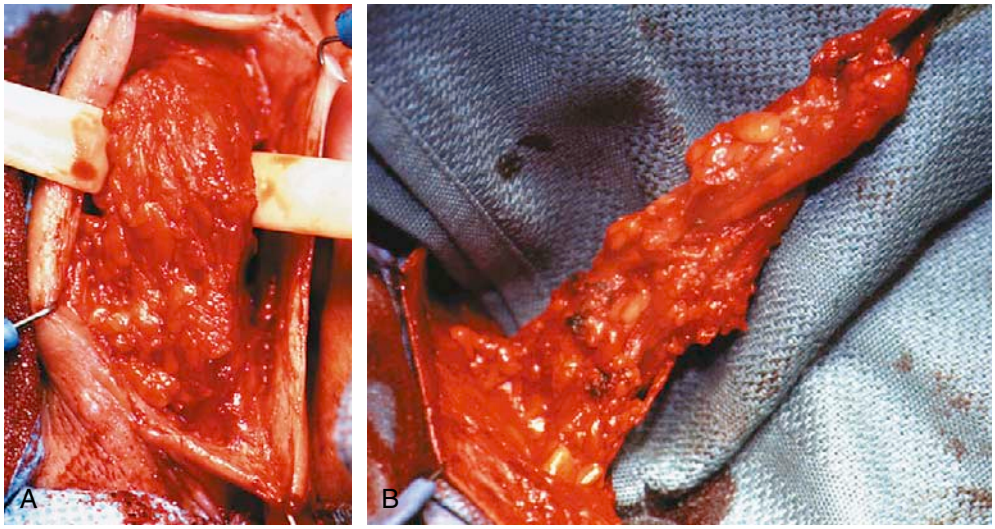


FIGURE 14-63 Creation of Martius flap.

a labial pedicle or full-thickness flap (Martius flap) may be placed between the vesical closure and the vaginal closure (Figure 14-63). This prevents suture-line stress and overlay and removes the need for a relaxing incision. Larger fistulas that do not adequately reapproximate may necessitate a vascularized muscle flap to reinforce closure.

11. The surgeon approximates the perivesical fascia and vaginal mucosa separately with transverse interrupted 3-0 absorbable sutures. A one-sided ellipse of vaginal mucosa may be excised to offset the closure.
12. Alternatively, an inverted-U incision may provide more exposure than other incisions and result in a posterior flap that completely covers the site of the defect.
13. The surgeon unclamps the suprapubic catheter, removes the labial stitches, and loosely packs the vagina.

VESICOVAGINAL FISTULA—TRANSPERITONEAL (TRANSVESICAL) APPROACH

1. The patient is placed in the low lithotomy and moderate Trendelenburg's position. Both the perineum and the abdomen are prepped and draped appropriately. A laparoscopy pack works well for this approach.
2. The surgeon inserts ureteral catheters and places a 16F Foley catheter in the bladder and clamps it.
3. A tight gauze pack or vaginal ball is placed into the vagina.
4. The surgeon makes a vertical midline or Pfannenstiel incision.
5. The peritoneum is incised and bluntly dissected from the dome of the bladder.
6. The small bowel is packed cephalad.
7. Stay sutures of 2-0 absorbable material are placed in the bladder dome, and the bladder is opened.
8. The surgeon divides the bladder wall and overlying peritoneum down to the fistula. Stay sutures are placed periodically to serve as retractors for bladder elevation.
9. The peritoneum is incised transversely at the level of the fistula, forming a pedicle flap.
10. The vagina and bladder are separated widely on each side of the fistula. An assistant places upward pressure on the vaginal ball or pack to facilitate dissection.
11. As the fistula is exposed, the surgeon excises it until it is completely removed. A probe may be used to localize it, if small, or an 8F balloon catheter may be inserted and used for traction during dissection.
12. The bladder and vagina are freed from each other until there is enough mobility for separate closures.
13. The surgeon closes the vagina, without tension, with inverting 2-0 or 3-0 interrupted sutures in two layers.
14. The peritoneal flap is swung into the defect and sutured in place for reperitonealization. A long, attached peritoneal or free peritoneal pedicle flap may be needed for reperitonealization. Alternatively, the omentum may be manipulated from behind the right side of the colon for an omental graft. A vascularized muscle flap may be placed for fistulas resulting from radiation necrosis.
15. A 22F Malecot catheter and a wound drain are inserted and pulled through separate stab wounds in the abdomen.
16. The ureteral catheters are removed, and the bladder mucosa and submucosa are closed in separate layers with 2-0 or 3-0 absorbable suture in a running fashion.
17. The muscularis and adventitia are externally approximated with interrupted 3-0 sutures.
18. The wound is closed in layers.
19. Dressings are applied, the Foley is unclamped, the vaginal ball or gauze pack is removed, and the vagina is loosely repacked.

VESICOSIGMOID FISTULA REPAIR—ABDOMINAL APPROACH

1. With the patient in the Trendelenburg position, a 20F or 22F, 5-ml Foley catheter is inserted and the bladder filled with 100 ml of sterile water. Once the patient is prepped and draped as described for laparotomy, a midline, or paramedian, and transperitoneal incisions are made.
2. The surgeon explores the abdomen.
3. The descending colon and sigmoid colon are mobilized by incising along the fascia fusion line of Toldt.
4. The involved loop of colon is identified. If a walled-off inflammatory mass is found, a transverse colostomy may be performed and a two-stage intervention considered.
5. Using blunt dissection, the surgeon separates the fistulous tract.
6. A probe is inserted to determine the extent of involvement.

7. The defects in the bladder and bowel are debrided to obtain healthy tissue. Large inflammatory masses require a colon resection.
8. The surgeon closes the bladder in two layers with a 3-0 absorbable submucosal running stitch and a 2-0 absorbable interrupted muscularis and adventitial stitch.
9. The edges of the bowel defect are trimmed to reach normal tissue, and stay sutures are placed on each side.
10. The cavity is pulled transversely, and the mucosa and submucosa are closed in one pass with a Connell stitch of 3-0 chromic catgut.
11. The surgeon approximates and closes the muscularis and serosa in one pass with 4-0 silk Lembert sutures.
12. The abdomen is irrigated with 2000 ml of sterile saline with an attempt to reach all areas.
13. A sump-style drain is placed intraperitoneally, and a Penrose or small Jackson-Pratt drain is placed suprapubically, exiting through separate stab wounds.
14. The surgeon closes the abdomen in layers in the conventional manner. If a colostomy was performed, it is opened for fecal diversion and the appropriate appliance applied.
15. Gauze and bulky absorbable dressings are applied and secured; Montgomery straps may be used.

Vesicourethral (Marshall-Marchetti-Krantz) Suspension

A Marshall-Marchetti-Krantz suspension is performed for the correction of stress incontinence caused by an abnormal urethrovesical angle. The intent of the Marshall-Marchetti-Krantz operation is to bring the bladder and urethra into the pelvis by suturing paraurethral vaginal tissue to the back of the symphysis pubis. A modification of this technique is the Burch procedure. The approach mimics the Marshall-Marchetti-Krantz until placement of the buttressing sutures. Instead of attempting difficult periosteal sutures, the surgeon places nonabsorbable size 0 sutures into the Cooper ligament from each side of the bladder neck. The Burch procedure is technically easier, and long-term results are fairly equivalent.

A large percentage of patients with stress incontinence are obese and have diabetes. It is important to evaluate for these conditions and prepare for proper patient management (i.e., positioning concerns relating to peripheral vascular circulation and pressure points, skin breakdown, risk for infection, wound healing).

Procedural Considerations. The patient is usually placed in a moderate Trendelenburg's position, frog-legged, with supports under each knee to allow for intraoperative vaginal manipulation. Abdominal and vaginal preps are required. A Foley catheter is inserted at the beginning of surgery. Both the surgeon and assistant double-glove for vaginal manipulation. Basic laparotomy and abdominal hysterectomy instruments (see Chapter 13), if needed, are used. Postoperatively, the patient commonly has a vaginal pack, a urethral catheter with or without a suprapubic catheter, and possibly a wound drain.

Operative Procedure

1. The surgeon makes a suprapubic transverse incision and exposes the prevesical space of Retzius.
2. The bladder retractor is positioned with small, moist laparotomy packs in place.
3. Using blunt dissection, the surgeon frees the bladder and urethra from the posterior surface of the rectus muscle and symphysis pubis.
4. The assistant places two fingers into the vagina, lifting the urethra upward against the symphysis pubis to facilitate ease of repair of the periurethral musculofascial structures.
5. A heavy, nonabsorbable atraumatic suture on a Heaney needle holder is placed through the supporting fascia of the vaginal wall on each side of the urethra. The suture is passed through the symphysis pubis, providing support to the urethra and bladder neck. Generally, a row of three heavy, nonabsorbable sutures is placed on each side of the urethra, the most proximal being located just at the vesical neck.
6. The surgeon closes the wound in layers.
7. The vagina may be packed with 2-inch packing, which is removed after 24 to 36 hours.

TVT Sling (Tension-Free Vaginal Tape)

A TVT sling is indicated for women diagnosed with urethral hypermobility, intrinsic sphincter deficiency, and pure stress incontinence caused by pelvic floor relaxation. It will not correct urge incontinence, although it may be used in women with combination stress and urge incontinence. This patient will need to have her urge incontinence controlled in another manner. It appears to be a viable option for the overweight and older female and for women who have had previous corrective measures that failed. It is not recommended for younger women who are pregnant or intend to become pregnant. Other contraindications include patients with intrinsic bleeding problems or who are receiving anticoagulant therapy. Risks include bladder perforation, perforation of pelvic viscera adherent to the pubis, retropubic hemorrhage and hematoma formation, infection, and urinary retention.

The tape is composed of polypropylene mesh (Figure 14-64) encased in a plastic sleeve that has a center slit and is secured to a large, curved trocar needle at each end. A T-shaped introducer is attached to these needles for passage of the sling material. The mesh is passed through the pelvic tissue and positioned under the urethra, creating a supportive sling. Unlike other corrective procedures for incontinence, no screws, anchors, or internal sutures are required.

Procedural Considerations. The procedure may be performed using a local anesthetic with monitored sedation. After the sedation is administered, the perioperative nurse places the patient in the lithotomy position.

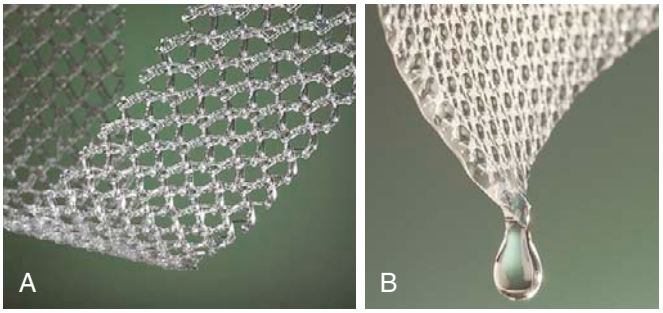


FIGURE 14-64 **A**, Uretex self-anchoring urethral support system. **B**, Pelvitex polypropylene mesh.

Operative Procedure

1. A 16F or 18F Foley catheter is inserted to drain the bladder.
2. The surgeon injects local anesthetic through the skin and into the muscle and fascia lateral to the midline and just above the symphysis pubis, bilaterally. Vasopressin (Pitressin) is commonly added to the anesthetic to help control bleeding.
3. Additional local anesthetic is injected suburethrally into the anterior vaginal mucosa to the retropubic space, bilaterally.
4. The surgeon performs a cystoscopy to confirm integrity of the bladder wall, urethral patency and length, and location of the ureters.
5. Two incisions, 0.5 to 1 cm in length, are made in the abdominal skin over each injection site.
6. The surgeon places a weighted speculum in the vagina, and grasps the anterior vaginal mucosa with two Allis clamps.
7. Using a #10 or #15 scalpel the surgeon makes a 1.5-cm incision into the anterior vaginal mucosa, 1 cm to the right of the external meatus.
8. Blunt Metzenbaum scissors are used to dissect suburethrally and periurethrally to the level of the endopelvic fascia.
9. The surgeon inserts a rigid stylet into the Foley catheter, and inserts the catheter into the bladder.
10. The bladder neck and urethra are deflected away to allow passage of the first needle by holding the Foley with its stylet against the inner ipsilateral thigh. An Allis clamp or hemostat may be placed in the center of the sling material to prevent twisting of the mesh or its sleeve.
11. After attaching the introducer, the first needle is passed 1 cm lateral to the urethra with the curve of the needle in the palm of the surgeon's hand. The needle penetrates the urogenital diaphragm behind the symphysis pubis.
12. Two fingers of the other hand are placed over the skin incision, the needle is pushed through the retropubic space, and the introducer is removed. The needle is guided up to partially protrude through the abdominal wall.
13. Before the trocar needle is extracted and removed, the surgeon removes the Foley and performs a cystoscopy. When bladder integrity has been confirmed, the first needle may be brought out through the abdominal wall and cut from the sling material, and a hemostat is attached to the mesh and sleeve.
14. The procedure is then repeated on the other side with the Foley directed toward the ipsilateral inner thigh during insertion and passage of the needle.
15. Once the tape is in place, the surgeon positions an 8F Hegar dilator between the tape and the urethra for tension testing. The patient is asked to cough, and the tape is adjusted until there is no leak or only a few drops of fluid are lost during coughing. The plastic sleeves are then removed by pulling them up through the abdominal incisions. The excess mesh that protrudes is cut at the skin surface.
16. The surgeon closes the vaginal mucosa with a running stitch of 2-0 chromic suture. Wound closure strips or skin sutures are used to close the abdominal incisions.
17. A perineal pad may be placed to absorb any vaginal bleeding. Abdominal dressings are applied at the surgeon's discretion. Vaginal packing and a postoperative Foley catheter are usually not necessary.

Transvaginal Sling with Bone Anchor

Indications and contraindications for this procedure are the same as those for the TVT sling procedure. In addition, the patient with severe osteoporosis may not be a good candidate for this technique because the bone anchors may not integrate into the pubic bone properly.

Risks with this technique include bladder perforation, inadequate fixation of the bone anchor (this generally requires abandoning the method and using a different type of sling approach), urinary retention, pain, osteitis pubis or osteomyelitis of the pubic bone, and recurrent incontinence.

Procedural Considerations. The procedure may be performed using a local anesthetic with monitored sedation. After the sedation is administered, the perioperative nurse places the patient in the lithotomy position. A formal incision may not be necessary for this procedure.

Operative Procedure

1. Before the procedure the surgical technologist loads a bone screw with preloaded #1 polypropylene suture onto the bone drill. A plastic cover fits over the screw, protecting the patient during insertion.
2. A Foley catheter is inserted, the bladder drained, and the catheter clamped.
3. The surgeon places Allis clamps on the mucosa and pulls gently upward to expose the anterior vaginal wall.
4. Tension is put on the polypropylene stitch that protrudes through the handle of the bone drill. The surgeon inserts the drill into the vagina in a line parallel to the plane of the symphysis pubis, and holds the drill head against the pubic bone (Figure 14-65).
5. Insertion is complete when the polypropylene stitch stops rotating. Fixation of the screw is tested with a gentle downward tug on the suture. The bone screws should lie lateral to the symphysis pubis in the posterior midthird of the pubic bone.
6. The Foley is opened and drained. If the urine is bloody a cystoscopy is performed. Some surgeons choose to routinely perform cystoscopy after each screw insertion to evaluate bladder patency.
7. A right-angle clamp is employed to follow the tunnel of the polypropylene suture upward. A small puncture is created in the urethropelvic ligament to allow passage of the sling material into the retropubic space. The sling material may be cadaveric fascia or polypropylene mesh.
8. The surgeon creates a 2-cm tunnel between the midurethra and bladder neck, behind the vaginal wall.
9. The sling material is perforated with a Keith needle, and the polypropylene suture is passed through the eye of the needle. The suture is then transferred to the sling material. This is done twice on each end of the material.
10. The material is passed through the tunnel (Figure 14-66).
11. Following cystoscopy, steps 4 through 6 are repeated on the contralateral vaginal wall. The polypropylene sutures are tied individually so that the material lies in close proximity to the pubic bone.
12. The vagina is sutured on each side with a single stitch of absorbable 2-0 sutures.

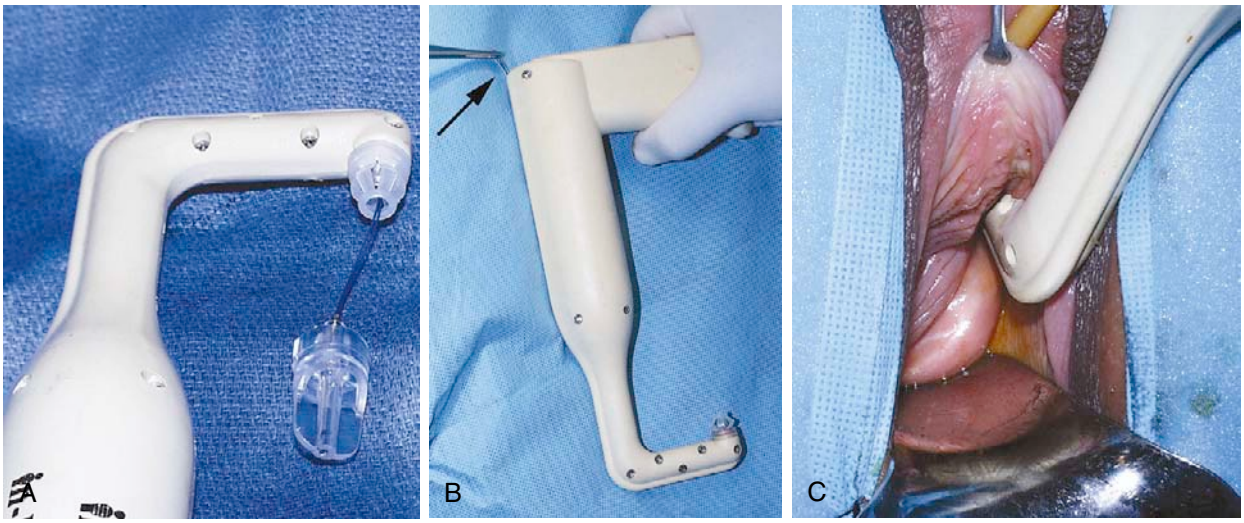


FIGURE 14-65 A, Bone anchor on bone drill with #1 polypropylene. B, Bone drill ready; polypropylene extends out handle. C, Bone drill in place.

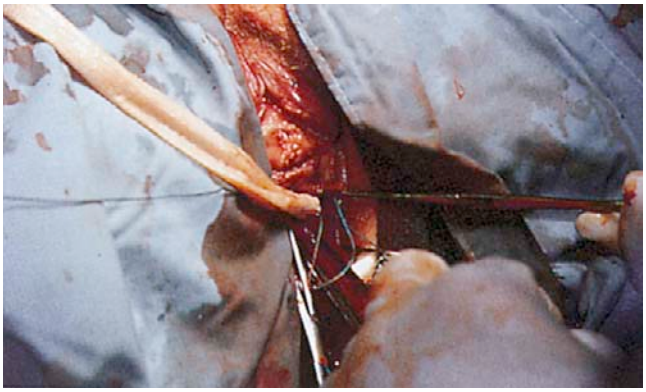


FIGURE 14-66 Fascia lata graft being placed for suburethral sling procedure.

13. A vaginal pack soaked in antibiotic or estrogen cream is inserted. The Foley catheter is drained and attached to a closed drainage system.

Implantation of InterStim Sacral Nerve Stimulator (Neuromodulator)

The InterStim System is indicated for the treatment of urinary urge incontinence, urinary retention, and significant urgency-frequency in patients who have failed or could not tolerate other measures (Sherman and Amundsen, 2007). The procedure is performed in two stages. During the first stage, a lead is implanted and connected to an external stimulator. The patient is discharged and undergoes a trial period that lasts from 2 to 4 weeks to determine if the device will be effective. During this trial period, the patient maintains a diary to track symptoms and post void residuals. If the trial is successful, the patient will return for the subcutaneous implantation of a pulse generator.

Some precautions must be taken by the patient who has had this device implanted. MRI studies are not recommended. Caution should be taken and the device turned off if electrocoagulation will be employed during any future surgery the patient might undergo. Female patients should be instructed to carry their purses on the opposite side of the implant.

Procedural Considerations. The perioperative nurse assists with positioning the patient in the prone position with a 30-degree flexion at the hips. Pillows may be placed under the patient's abdomen to support the lumbar area and decrease lordosis. Pillows are also placed under the ankles to elevate the feet and prevent pressure on the toes.

C-arm fluoroscopy is employed to visualize sacral landmarks and verify lead position intraoperatively. Although general anesthesia may be employed, monitored sedation with a local anesthetic is preferable so that the patient may verbally respond to nerve stimuli during the procedure. It is suggested that no IV muscle relaxants be administered, because this will affect the physiologic response to the stimulator. If electrocoagulation is needed, a bipolar system should be employed, because unipolar current could potentially travel into the sacral foramen. The patient is typically discharged from the hospital on the same day.

The nurse preps the patient's sacral area, buttocks, and perineum and applies the test stimulation ground pad to the patient's heel. An alternative to this placement is the calf or skin below the rib cage or iliac crest. The pad is approximately 5 to 8 cm in size. The pad will be attached by a test stimulation cable to the external stimulator. The patient is draped to expose the entire buttock area so that responses to nerve stimulation may be assessed. The feet and lower legs are also exposed to allow visualization of muscle response.

The surgeon locates and marks the sacral outline, S3 foramen, posterior iliac spine, coccygeal tip, and midline. To locate these landmarks, the surgeon palpates the upper border of the greater sciatic notch. The S3 sacral foramen is approximately one fingerbreadth from the midline whereas the S2 and S4 foramina are one fingerbreadth above and below S3. The sacral crest corresponds to S4, and the S3 foramen is 9 cm above the coccygeal tip and 2 cm from the midline.

Operative Procedure

1. The surgeon inserts the needle into the S3 foramen. The external stimulator is activated to confirm correct placement of the needle. A bellows response (flattening of the perineum) and flexion of the great toe indicate the needle is in the S3 foramen.
2. The guidewire is inserted into the foramen needle.
3. A 5-mm stab wound is created for the lead introducer.
4. The surgeon slides the lead introducer, consisting of dilator and sheath, over the guidewire and advances it into the foramen. The depth marker on the directional guide is aligned with the top of the dilator.
5. The dilator is then removed, and the sheath remains in place.
6. The surgeon inserts the tined lead, with its stylet (Figure 14-67), and passes it through the sheath until the second white marker is aligned with the back of the sheath. The four electrodes on the lead are now exposed and visible on fluoroscopy.
7. Nerve responses are again assessed at this time by connecting the mini-J hook on the patient cable to the uninsulated section of the foramen needle. The electrodes are numbered zero to three, and the connector contacts on the needle correspond to these numbers. Beginning at the distal tip of the needle, all four electrodes are tested. The lead is repositioned according to the verbalized and visualized responses of the patient. The foramen producing the best results is chosen.
8. Once the electrodes are in optimal position the lead body proximal to the sheath is held in place and the sheath is slowly backed out of the wound. This is often accomplished under live fluoroscopy.
9. As the sheath is withdrawn the tines on the lead open, anchoring it in place.
10. The surgeon creates a tunnel for the subcutaneous neurostimulator generator pocket by means of the same incision. Placement is in the upper buttock below the beltline.
11. A pocket is created with the bipolar ESU. The pocket depth should not be greater than 4 cm to avoid interference with programming and shifting of the neurostimulator. The ideal pocket is 3 to 5 cm below the superior iliac crest and lateral to the outer sacral edge.
12. The surgeon uses the tunneling tool with its metal tip and plastic tube to develop the tunnel from the lead to the intended pocket. Once tunneling is achieved the metal tip is removed and the tool is withdrawn, leaving the plastic tubing in place. The proximal lead end is then fed through the tubing to the pocket, and the tubing is removed. The protective boot is placed over the end of the lead. Leads may be placed bilaterally at the surgeon's discretion.
13. The percutaneous extension is then tunneled from the eventual generator site to the opposite posterior iliac side and exits the skin. This is then attached to the external device.
14. The incisions at all wound sites are closed. The wounds are dressed with small gauze and an occlusive dressing.

If the patient has a good response (50% or greater decrease in symptoms), then the area of generator site is extended in a second stage and the generator is connected to the lead (Figures 14-68 and 14-69). The percutaneous extension is pulled out through the other side and taken away from the field.

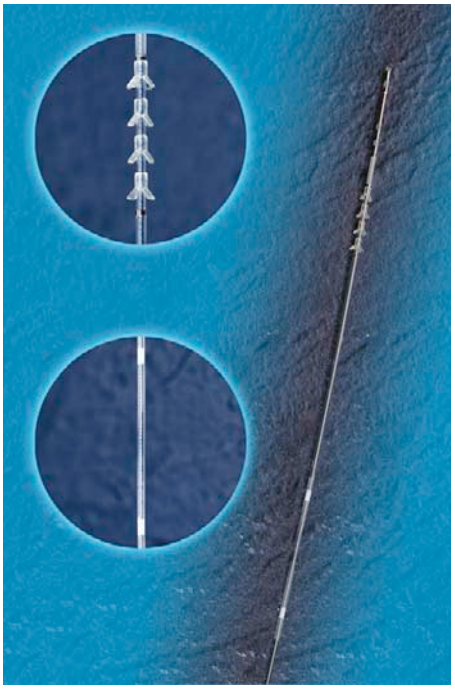


FIGURE 14-67 InterStim tined lead.

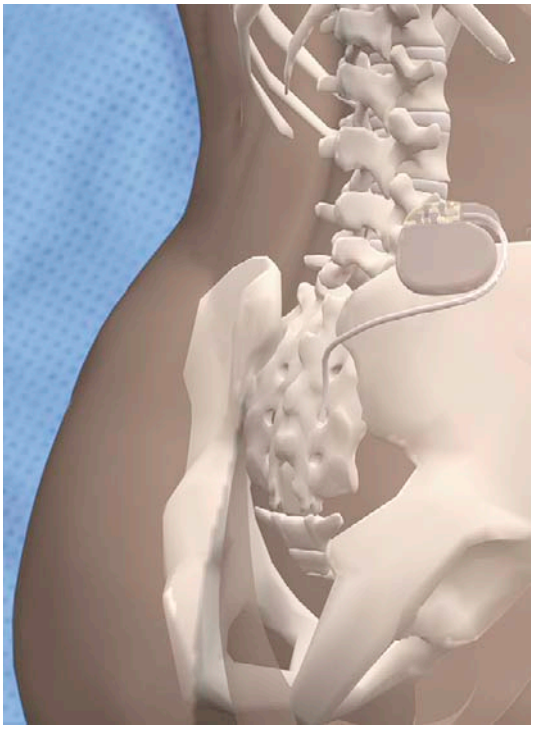


FIGURE 14-68 Graphic placement of InterStim.

Male Sling

The male perineal sling is designed to improve male incontinence by increasing outlet resistance. Using cadaveric dermis, fascia lata, or pericardium, the surgeon places a triangular sling under the bulbous urethra and anchors it with six screws that are placed into the inner portion of the descending ramus just below the symphysis pubis. Other treatments for incontinence,

FIGURE 14-69 InterStim implant.

including the use of botulinum A toxin, are being investigated (Research Highlight).

RESEARCH HIGHLIGHT

Botox Treatment for Urinary Incontinence

Researchers evaluated the use of Botox in the treatment of idiopathic overactive bladder in a two-stage, randomized, double-blinded study comparing Botox to a placebo. The toxin, which is more commonly used in cosmetic treatments, works by paralyzing one of the muscles that controls the bladder, preventing it from emptying involuntarily. Stage 1 of the study consisted of a 6-week randomized, placebo-controlled trial, and stage 2 was a 9-month randomized trial of two doses of Botox without a placebo control.

A total of 22 patients participated in stage 1 of this two-stage study. Criteria for the study were overactive bladder refractory to anticholinergic medications, multiple daily incontinence episodes, and a 24-hour incontinence pad weight of 100 g or greater. Researchers injected the detrusor muscle in 8 to 10 locations above the trigone.

In analyzing the study results, the researchers reported improvements in daily incontinence episodes, number of incontinence pads used per day, and quality-of-life questionnaires in the botulinum-A toxin group with no changes in the placebo group. Complications experienced during the study were minor, and included urinary tract infection in 13% of the botulinum-A toxin group and 28% in the placebo group. One participant required intermittent catheterization.

Modified from Flynn MK et al: Outcome of a randomized, double-blind, placebo controlled trial of botulinum A toxin for refractory overactive bladder, *J Urol* 181:2608-2615, 2009.

Bladder Augmentation

Augmentation enterocystoplasty is a procedure performed to surgically enlarge the bladder capacity. A wide range of conditions that were previously treated with urinary diversion may now be successfully managed with this technique. Indications include reflex incontinence unresponsive to medical management, detrusor hyperactivity with compromised bladder function, chronically contracted bladder resulting from radiation or repeated infections, and neuropathic bladder combined with recurrent urinary tract infections or compromised renal function. A segment of bowel is used to augment the bladder. The bowel is re-formed into a semispheric shape to decrease peristaltic contractions and anastomosed to the opened bladder dome. The result is a low-pressure reservoir that provides improved bladder capacity and urinary compliance. Almost all segments of bowel as well as the stomach have been employed for bladder augmentation. Selection depends on anatomic factors, functional characteristics, and the surgeon's preference. In some cases, ureteral reimplantation or associated bladder-outlet procedures are incorporated in a one-stage procedure.

Postoperatively, intermittent catheterization and bladder irrigations may be necessary. The patient must be able and willing to learn and perform these procedures and must be accepting of this alteration in lifestyle.

Procedural Considerations. The nurse assists with positioning the patient in the supine position after the anesthesia provider administers a general or regional anesthetic. The female patient may be in a frog-leg or lithotomy position, particularly if access to the perineum is necessary. The entire abdomen and genitalia are prepped and draped. The surgeon inserts a Foley catheter after the patient has been prepped and draped so that the bladder can be filled to capacity for visualization during the procedure. Basic laparotomy and intestinal instruments are required.

Operative Procedure

1. The surgeon makes a supraumbilical to symphysis midline abdominal incision.
2. The peritoneal cavity is exposed using a Bookwalter or similar retractor.
3. The surgeon examines the intestines and stomach, and chooses the appropriate segment for reconstruction (Figure 14-70, *A*).
4. A sagittal bladder incision is made from 2 cm cephalad to the bladder neck anteriorly across the anterior bladder wall, the peritonealized dome surface, and the posterior bladder wall to 2 cm above the posterior interureteric ridge. This causes the bladder to be bivalved in a clam-shaped design.
5. The surgeon places bilateral traction sutures along the bladder incision.
6. The length of the incision is measured to correlate with the corresponding segment of bowel or stomach. Average length required is 25 cm.
7. The surgeon mobilizes the segment of bowel and closes the mesentery cephalad so that the segment is on the retroperitoneum. The segment is left attached to its mesentery to maintain blood supply (Figure 14-70, *B*).
8. The isolated segment is opened, trimmed, and detubularized. The surgeon then folds it double and sutures it to form a cup patch (Figure 14-70, *C*).
9. Anastomosis is accomplished with a running, intermittent locking, absorbable suture, beginning at the posterior apex and running up each side.

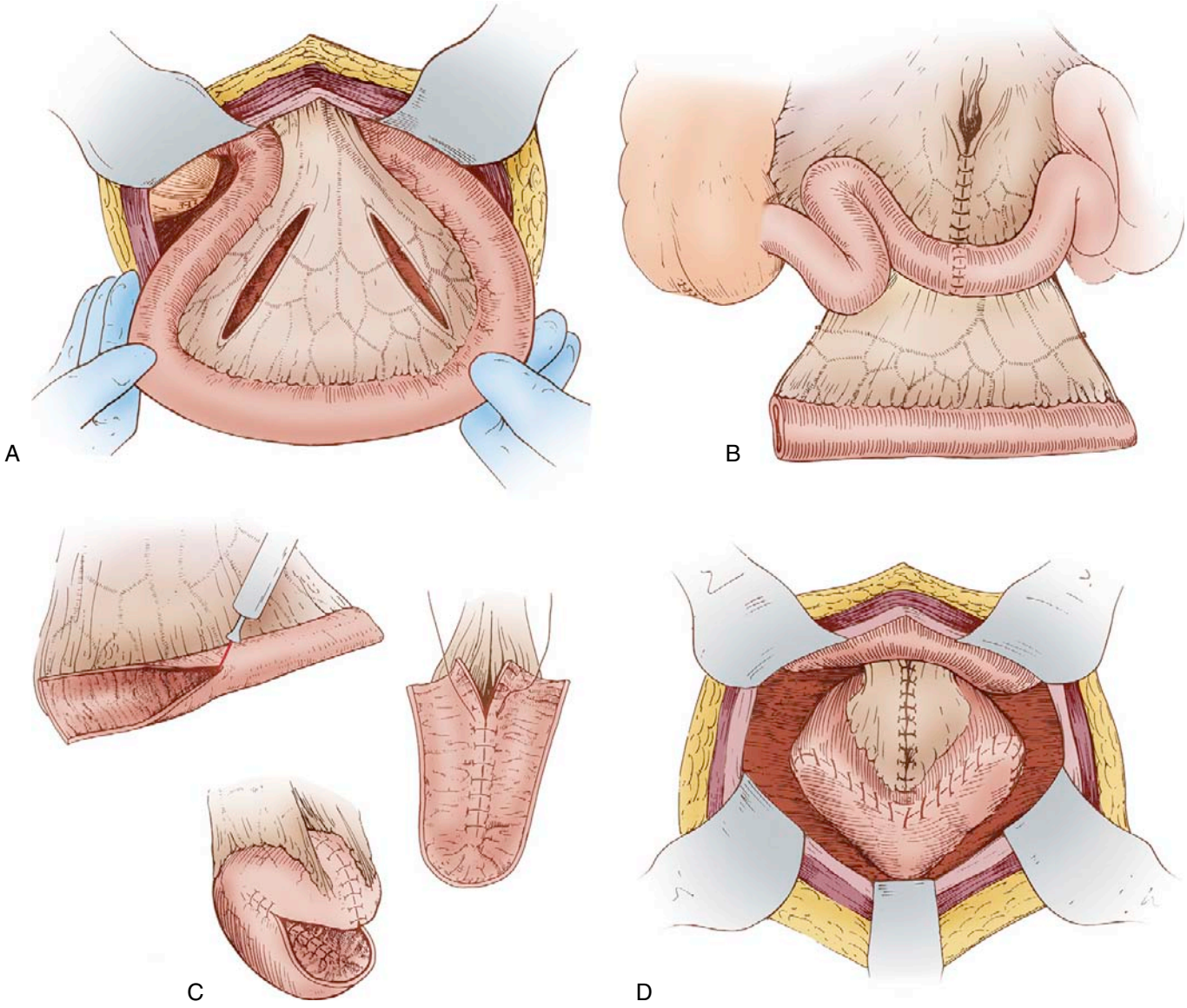


FIGURE 14-70 Ileocystoplasty for bladder augmentation.

10. With one third of the attachment complete, the surgeon places sutures at the anterior apex and runs them bilaterally to meet cephalad (Figure 14-70, *D*).
11. The surgeon fills the bladder to check the integrity of the anastomosis.
12. Abdominal closure is performed, and dressings are applied. The Foley catheter will remain for 7 to 14 days. Some surgeons may choose to place a suprapubic catheter instead of a Foley.

Implantation of Prosthetic Urethral Sphincter

Implantation of a prosthetic urethral sphincter is usually done as a last measure for patients with stress incontinence for which other modalities have failed. Problems with the device have included foreign-body reaction, persistent urethral pressure causing urethral erosion, and fluid hydraulic failure. The artificial sphincter unit has an abdominally placed, pressure-regulated reservoir that maintains a constant predetermined pressure on the periurethral cuff. Because of the connection between the reservoir and cuff, any increase in intraabdominal pressure transmits more fluid into the cuff. This connection allows for a compensatory increase in urethral resistance during coughing or straining.

The scrotal or labial pump shifts the fluid into the cuff to the reservoir to allow bladder emptying. The fluid reenters the cuff through a resistor in about 60 to 120 seconds. The locking button in the AMS Sphincter 800 artificial sphincter unit traps fluid in the reservoir to allow activation of the cuff. The sphincter is available in a single-cuff and double-cuff model.

Procedural Considerations. Standard laparotomy and lithotomy setups are required, as well as the sphincter components, contrast material diluted according to the manufacturer's recommendations, and an antibiotic solution. The patient is placed in a modified lithotomy position.

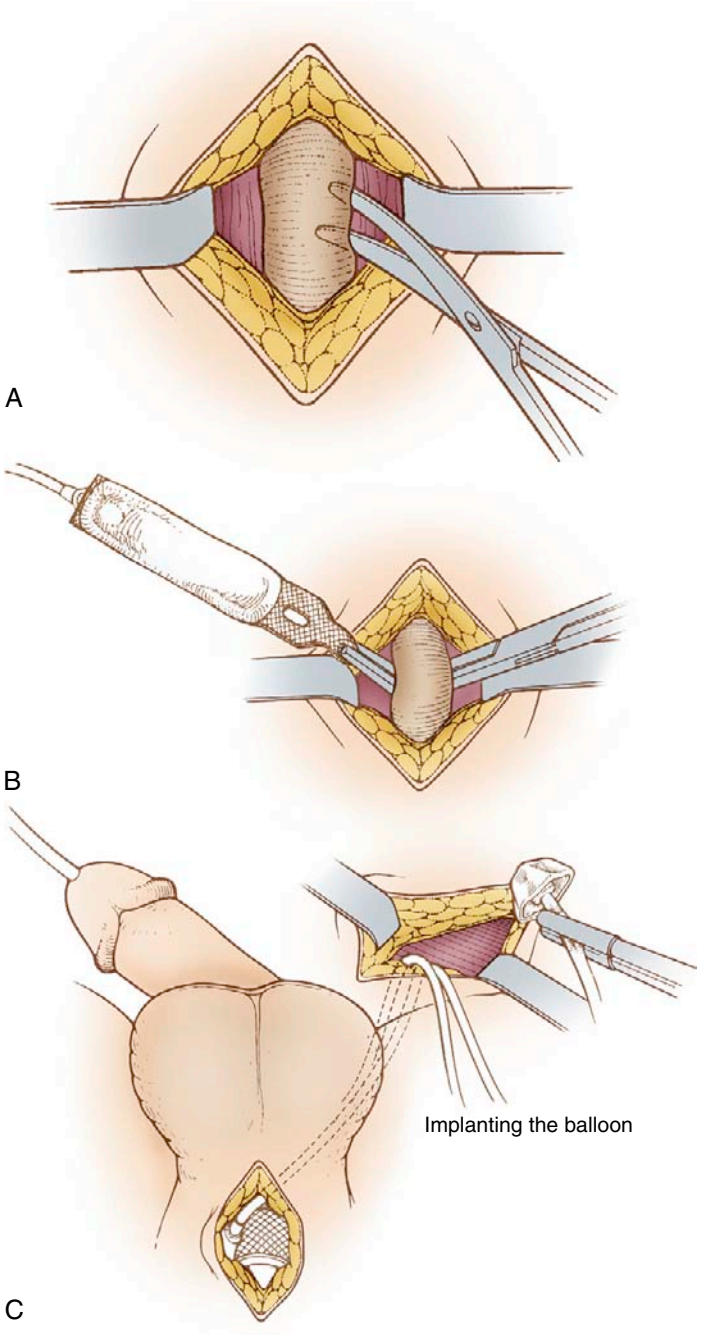


FIGURE 14-71 Implantation of artificial urinary sphincter.

Stricture disease is more commonly found in the male population, and the most common cuff placement is around the bulbous urethra. Bladder neck placement of the cuff is generally reserved only for females.

Operative Procedure

BULBOUS URETHRAL CUFF

1. Perineal and transverse suprapubic incisions are made.
2. The surgeon mobilizes the bulbous urethra through a midline perineal incision (Figure 14-71, *A*).
3. A 2-cm space is created beneath the bulbocavernous muscle and around the bulbous urethra.
4. The surgeon places the cuff, tab end first, around the bulbous urethra (Figure 14-71, *B*).
5. The reservoir is placed beneath the rectus muscle through the suprapubic incision (Figure 14-71, *C*).
6. The surgeon attaches the pump to the tubing passer, introduces it through the suprapubic incision, and transfers it to the scrotum through a subcutaneous tunnel created between the two incisions. The reservoir, cuff, and pump are connected and filled with contrast material or injectable saline to the appropriate volume (Figure 14-72).
7. The wound is closed and dressed with gauze sponges. A urethral catheter is usually not inserted.

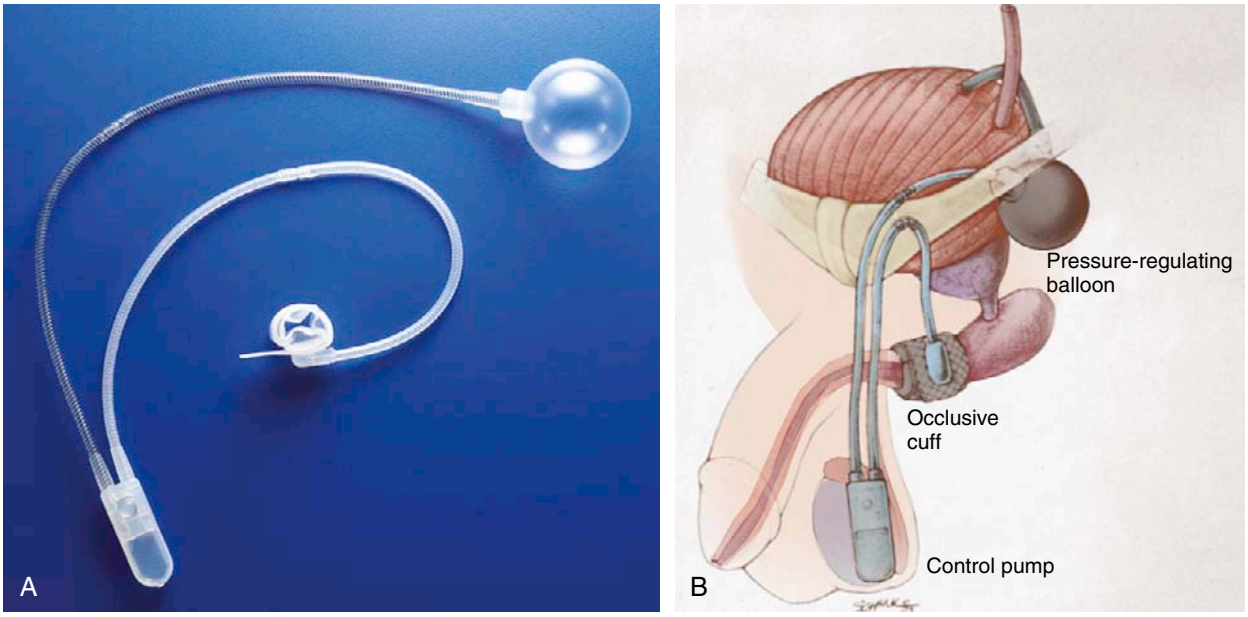


FIGURE 14-72 **A**, AMS 800 single-cuff artificial urinary sphincter. **B**, Final placement of artificial urinary sphincter.

Radical Cystectomy with Pelvic Lymphadenectomy

Cystectomy is the total excision of the urinary bladder and adjacent structures along with pelvic lymph nodes. Cystectomy is a surgical consideration when a vesical malignancy has invaded the muscular wall of the bladder or when frequent recurrences of widespread papillary tumors do not respond to endoscopic or chemotherapeutic management. The patient should be medically able to withstand surgery with the expectation of reasonable longevity. Total cystectomy necessitates permanent urinary diversion into an ileal or colonic conduit. In a male patient, the prostate gland, seminal vesicles, and distal ureters are removed with the bladder and its peritoneal surface. In a female patient, the bladder, urethra, distal ureters, uterus, cervix, and proximal third of the vagina are removed.

Procedural Considerations. The perioperative nurse places the patient in the supine position. Instruments are as described for major abdominal procedures. For a male patient, if the prostate and seminal vesicles are to be removed, prostatectomy instruments should be added. For a female patient, vaginal and abdominal hysterectomy as well as plastic surgery instruments should be added (see Chapters 13 and 21).

Operative Procedure. A midline incision from the epigastrium to the symphysis pubis, curving to the left of the umbilicus, is generally used.

1. The surgeon enters the peritoneal cavity above the umbilicus. The entire urachal remnant is clamped, divided, and ligated with heavy silk ligatures (Figure 14-73, *A*). It will be removed en bloc with the bladder.
2. The bladder dome is lifted at its peritoneal surface, and dissection proceeds laterally on either side with ligation of the major vesical arteries to the level of the vas deferens or round ligament (Figure 14-73, *B*).
3. The surgeon divides the vas deferens and cuts the urethra at the level of the pelvic diaphragm.
4. The ureters are identified and traced to the bladder. Care is taken to preserve the adventitial tissue (Figure 14-73, *C*).
5. Abdominal exploration and pelvic lymphadenectomy with frozen sections are performed to rule out metastatic disease.
6. In the male patient, the bladder is then retracted to expose the endopelvic fascia and puboprostatic ligaments. The prostate, dorsal venous complex, and seminal vesicles are dissected free, as described for a radical retropubic prostatectomy (Figure 14-73, *D*). These will be removed in continuity with the bladder.
7. In the female patient, the broad ligament is bilaterally incised posterior to the fallopian tube and ovary to the level of the posterior vagina to be removed en bloc with the bladder (Figure 14-73, *E*). The endopelvic fascia is incised at the bladder neck to expose the proximal urethra. The vagina is then incised along the lateral walls to the level of the proximal urethra and bladder neck. The anterior vaginal wall is incised in a U fashion to circumscribe the urethra (Figure 14-73, *F*). The vagina is reconstructed.
8. The surgical specimen consists of the bladder, distal ureters, prostate, seminal vesicles, and distal vas in the male and the uterus, fallopian tubes, and ovaries in the female and is removed en bloc.
9. The surgeon ligates the urethra with absorbable suture. If urethrectomy is indicated, this is done en bloc with the bladder.
10. Lap pads are placed in the denuded pelvis, and pressure is applied to reduce blood loss from oozing.
11. Urinary diversion is accomplished by means of an isolated ileal or colonic conduit, an orthotopic diversion, or a continent urinary diversion.

Bladder Substitution (Substitution Cystoplasty)

The ideal candidate for a bladder replacement after cystectomy for carcinoma is a patient with a normal urethra; a proximally located, well-differentiated bladder tumor; absence of carcinoma in situ; and proof, in the male patient, that the prostatic urethra is free of disease. High-dose radiation offers appreciable

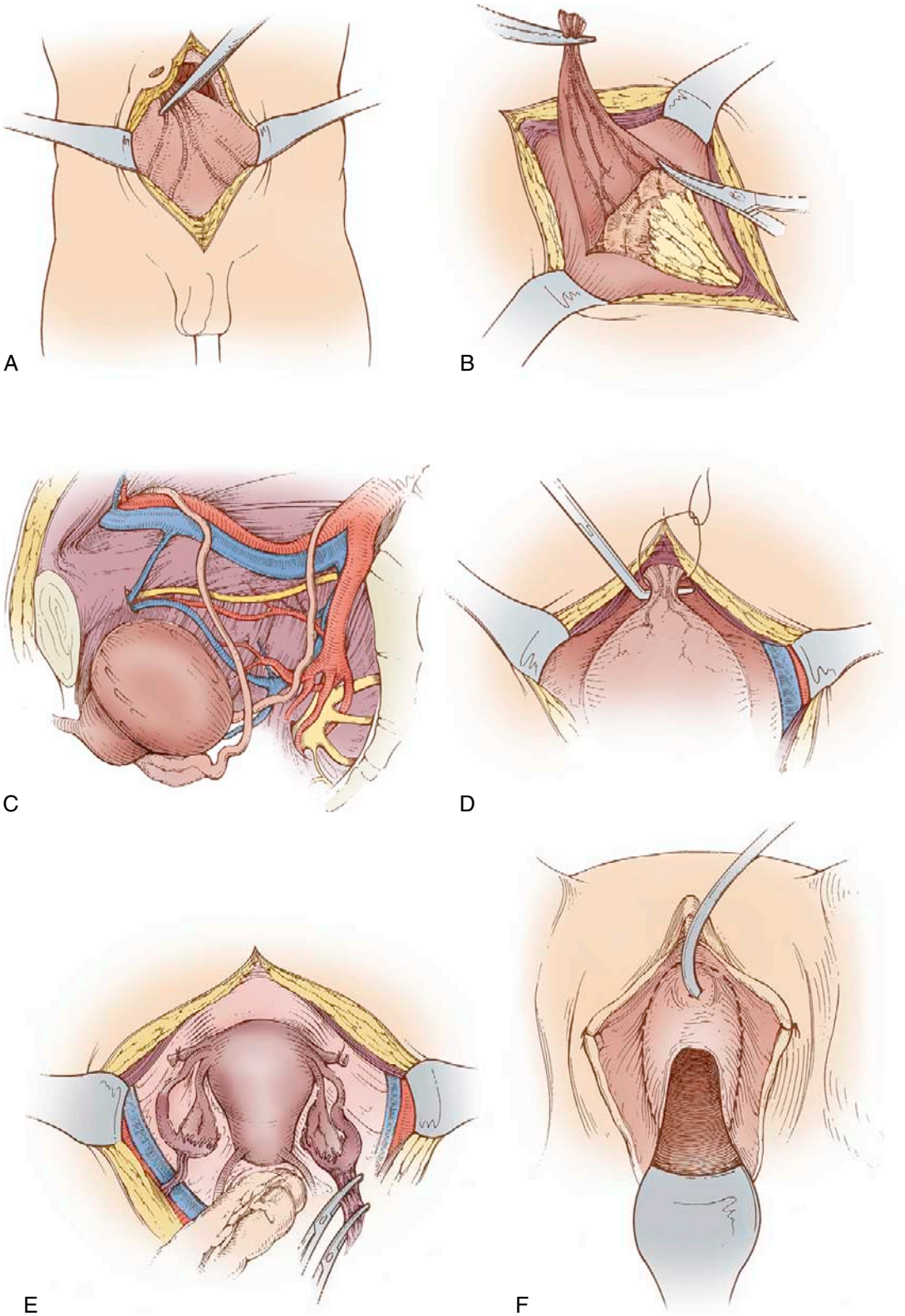


FIGURE 14-73 **A**, The urachal remnant is identified and divided just below the umbilicus. **B**, The peritoneum is divided laterally to the umbilical ligaments to the level of the vas deferens or round ligament. **C**, The ureter crossing the bifurcation of the iliac vessels is identified. **D**, Right-angled clamp is passed beneath the dorsal venous complex, anterior to the membranous urethra. **E**, In female patients the ovaries, fallopian tubes, and uterus are removed en bloc with the bladder and anterior vaginal wall. **F**, U-shaped incision is made on the anterior vagina to circumscribe the urethra.

risks for postoperative complications and is contraindicated with enterourethral anastomosis. A discussion of techniques to create a neobladder follows.

Right Colocystoplasty. Depending on the extent of involvement, the right side of the colon may be used to replace the bladder, the bladder and prostatic urethra, or the bladder and prostate with a direct enteric-to-proximal bulbar urethral anastomosis. This procedure has become more functionally effective with the use of intermittent self-catheterization and selective implantation of a prosthetic urinary sphincter.

Ileocecal Bladder Substitution. The ileum has been used as a reservoir to restore urinary continuity because it possesses a low intraluminal pressure. However, the short mesentery does not always permit the bowel to reach the urethra and results are not consistently successful. There have been significant incidences of recurrent carcinoma, renal damage, incontinence, postoperative strictures, fistula, hypokalemia, anemia, suture-line breakdown, and stone formation. Although most patients attain daytime urinary control, a small percentage still have problems with enuresis. Deterioration of the upper urinary tract as a result of infection and obstruction has historically been a significant risk with this procedure, and therefore ileocecal substitution is met with mixed reactions and recommendations.

Sigmoidocystoplasty. Because of the sigmoid colon's ease of construction, bladder proximity, decreased obstruction from mucus, and large capacity, it has been more appealing to many surgeons in their attempt to create a new bladder. More efficient emptying with a larger reservoir capacity seems to occur with a sigmoid replacement. Results yield higher intraluminal pressures, more effective urinary flow rates, and less nocturnal incontinence than with ileal segments.

Ileoascending Bladder Substitution. In an effort to improve the intestinal reservoir's capacity and antirefluxing effectiveness, the use of the ascending colon as a continent reservoir was introduced. This technique has several anatomic advantages over other methods of bladder replacement. The segment used can include the hepatic flexure and proximal transverse colon. A large-capacity reservoir is obtained, and colonic incision or tailoring is not required to achieve an appropriate shape. It easily reaches any site within the pelvis and can be anastomosed directly to the urethra without tension.

Orthotopic Ileocolic Neobladder. The Le Bag continent diversion technique utilizes the right colon and ileum as an orthotopic bladder replacement. Bladder substitution relies on meticulous dissection of the prostatic apex with preservation of the urinary sphincter and neurovascular bundles, as well as a watertight urethral anastomosis. Most patients have achieved a high degree of daytime continence and a minimum of nocturnal enuresis. Short-term complications encountered include bleeding, infection, urinary extravasation, bladder perforation, urethral stricture, fistula formation, urinoma, and small-bowel obstruction. Long-term problems include chronic constipation or diarrhea, compromised enterohepatic circulation, vitamin B_{12} deficiency, and urinary incontinence in a small percentage of patients.

Considerations influencing patient selection include age, general health, and fitness for extensive, complicated surgery. Contraindications include previous radiation therapy, bowel disease (diverticulosis, Crohn's disease, colitis), and other major medical problems. Preoperative urethral biopsy specimens are frequently taken to rule out tumor or cellular atypia in the urethra, which would prevent this particular intervention.

PROCEDURAL CONSIDERATIONS. The patient is placed in the supine position. SCDs are applied before the induction of anesthesia. A cystectomy and prostatectomy or hysterectomy are performed. Major deep intestinal, bladder, and prostate or hysterectomy instruments, as well as a large self-retaining retractor, are needed.

OPERATIVE PROCEDURE

1. After cystoprostatectomy, the right side of the colon is reflected medially along the mesentery to the hepatic flexure. The distal ileum that is to be used in the neobladder is inspected.
2. The surgeon divides the small bowel, positions it in an S shape, and places stay sutures of 2-0 or 3-0 absorbable material.
3. The posterior walls are sewn from inside to outside with running 3-0 absorbable suture.
4. A seromuscular wedge of the dependent cecum is excised, and the mucosa is everted with 4-0 absorbable sutures to form a bladder neck.
5. The left ureter is brought retroperitoneally under the sigmoid mesentery, a submucosal tunnel is created, and the ureters are reimplanted through the colonic wall. Anastomosis is done from the interior of the pouch.
6. The surgeon places anchor sutures of 3-0 or 4-0 silk at the outer entry point. The wall of the colon is anchored to the psoas muscle with 3-0 or 4-0 silk to prevent migration of the neobladder.
7. Ureteral stents are placed and exteriorized through the colonic segment and a separate abdominal stab wound, along with a catheter, to serve as a suprapubic tube.
8. Sutures of 2-0 absorbable material are placed around the urethral stump and tagged.
9. The surgeon inserts a Foley catheter into the urethra in a retrograde manner, and the urethra is anastomosed to the neobladder at the point of the new bladder neck.
10. The neobladder is closed in an intestinal fashion or with a GI stapler in a side-to-side anastomosis. Wound drains are placed, the bladder filled to test for leaks, and the wound closed.

Cutaneous Urinary Diversions

Ileal Conduit. The ileal conduit is the classic method by which the urine flow is diverted to an isolated loop of bowel. One end of the isolated loop is exteriorized through the skin so that the urine can be collected in a drainage bag, which is intermittently emptied. The surgeon consults with the enterostomal therapist preoperatively to determine the stoma site. The selected site, usually in the right lower quadrant of the abdomen, above the beltline, is marked with a fine needle dipped in methylene blue to prevent erasure during skin preparation. The goal is to create a round, protruding stoma without wrinkles in the skin, to prevent urine leakage under the collecting device. The candidate for ileal diversion must have a retrievable ureter at least 1 cm in diameter with a thick, well-vascularized wall. The patient must

be able to care for the appliance. Conditions amenable to diversion include neurogenic bladder, interstitial cystitis, and bladder carcinoma. Cystectomy may be performed before or after this procedure, depending on the patient's diagnosis. In cases that do not involve bladder cancer, the surgeon may choose to leave the bladder in situ rather than subject a debilitated patient to further surgery. In certain cases of extensive bladder carcinoma, the surgeon may elect to treat the patient with radiation in an attempt to decrease the size of the tumor and neutralize the regional lymph nodes before performing cystectomy.

PROCEDURAL CONSIDERATIONS. The perioperative nurse assists with positioning the patient in the supine position. Abdominal and GI instruments are required. A cystectomy, prostatectomy, or hysterectomy may also be done at the time of the surgery. Endostapling devices, with absorbable staples, should be available.

OPERATIVE PROCEDURE

1. The bladder is decompressed with a catheter.
2. The surgeon enters the abdomen through a midline abdominal incision and places a self-retaining abdominal retractor to exclude the viscera from the region of dissection.
3. The ureters are identified and severed approximately 2.5 cm from the bladder.
4. The surgeon creates a retroperitoneal tunnel so that the left ureter lies close to the right ureter.
5. The distal ileum and mesentery are inspected to identify the bowel's blood supply.
6. A drain is passed through the mesentery, midway between the two main arterial arcades adjacent to the ileum at the proximal and distal ends of the selected segment. This segment usually makes up 15 to 20 cm of the terminal ileum, a few centimeters from the ileocecal valve. The ileocecal artery is preserved to maintain adequate circulation to the isolated ileal segment.
7. The surgeon incises the peritoneum over the proposed line of division of the mesentery.
8. Intestinal clamps are placed across the ileum, and the bowel is divided flush with the clamps.
9. Using GI technique (also referred to as bowel technique; see Chapter 10), the surgeon closes the proximal end of the isolated ileal segment first with a layer of absorbable sutures and then with a second layer of interrupted 2-0 nonabsorbable sutures.
10. The proximal and distal segments of ileum are reanastomosed end-to-end in two layers.
11. The surgeon closes the mesenteric incision with interrupted nonabsorbable sutures.
12. The closed proximal end of the conduit segment is fixed to the posterior peritoneum.
13. The ureters are implanted in the ileal segment, using fine instruments and 4-0 absorbable ureteral sutures on atraumatic needles.
14. The surgeon separates the peritoneum and muscle of the abdominal wall lateral to the original incision with blunt dissection.
15. The abdominal opening for the stoma is made, and the distal opening of the ileal conduit is then drawn through a fenestration in the muscle, fascia, and skin.
16. The ileum is fixed to the fascia with 2-0 sutures. A rosebud stoma is constructed as the ileum is sutured to the skin using subcuticular stitches (Figure 14-74).
17. Ureteral stents are usually left in the stoma, and a urinary collecting pouch is placed over the rosebud stoma to collect urine.
18. The surgeon inserts closed-suction wound drains and closes the abdominal incision. The skin is reapproximated.

Continent Urinary Diversions

The Kock pouch, the right colocystoplasty, and the Camey version of the ileocystoplasty have been modified for anastomosis to a urethral stump or the prostatic capsule, resulting in effective continent bladder replacement. All continent urinary diversions create an easily catheterized stoma and a nonrefluxing ureteral anastomosis. Different parts of the bowel and the stomach have been used as continent reservoirs. The choice of the antireflux mechanism depends on the implantation site. The stoma does not require an appliance; therefore the site may be placed below the beltline or bikini line, permitting it to be catheterized when the patient is sitting. It may be anastomosed to the proximal urethra, thus forming an orthotopic bladder.

Ileal Reservoir (Kock Pouch)

PROCEDURAL CONSIDERATIONS. A continent reservoir formed into a U configuration is constructed from a section of ileum proximal to the ileocecal valve. The legs of the U are sewn together at the antimesenteric border. The intestine is opened adjacent to the antimesenteric border, and the back wall of the pouch is reinforced with absorbable suture.

Continence is achieved by the valve mechanism with the nipple valve attached to the skin. Nipple valves are created proximally and distally by intussusception of the bowel into the reservoir cavity. Once the nipples are fixed to the sidewall of the reservoir with absorbable suture or polyglycolic staples, the anterior wall is closed. The ureters are anastomosed to the afferent limb of the pouch, preventing reflux. The efferent limb is drawn through the stoma site and anchored to the abdominal wall fascia.

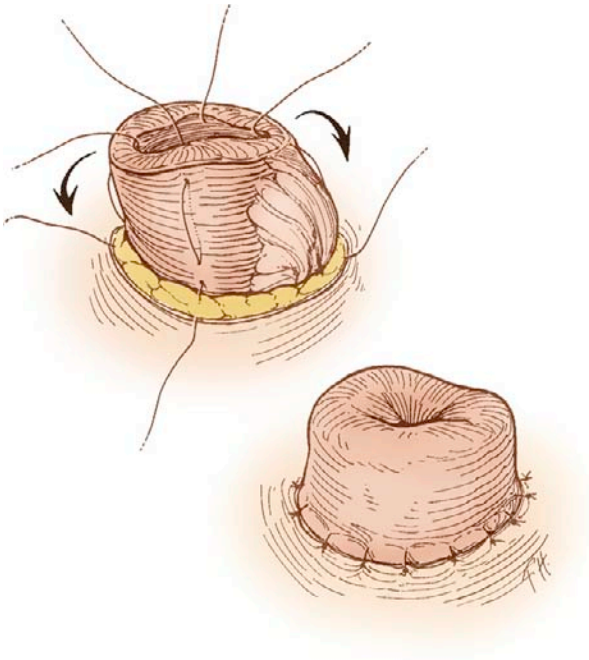


FIGURE 14-74 Rosebud suture technique for stoma.

OPERATIVE PROCEDURE

1. The mesentery is divided and suture-ligated or staple-ligated along the avascular plane between the superior mesenteric artery and the ileocolic artery.
2. The surgeon divides the bowel, and four segments are measured and marked with silk suture tags. These segments will serve as the efferent conduit, the pouch, and the afferent limb.
3. A portion of the proximal ileum is resected and discarded along with a wedge of mesentery. Suction is passed down the lumen to clear any fecal material or mucus.
4. The surgeon closes the proximal end of the bowel with suture or staples.
5. The segment to be employed is spread out in a U-shaped fashion. The sides are sewn together with 3-0 absorbable suture in a running stitch or connected using a GI endostapler.
6. The surgeon uses the ESU to incise the bowel laterally to the suture in the two loops. The medial edges are oversewn with 3-0 or 4-0 silk.
7. The mesentery is cleared on the limb segments, and the lumens are intussuscepted into the open pouch.
8. Synthetic mesh is used to serve as a strut to prevent peristomal herniation and to fix the base of the efferent nipple to the abdominal wall, facilitating catheterization. The TA or similar endostapler is used to form each nipple and to attach the nipples to the back wall of the pouch.
9. An 8F stenting catheter is placed inside the nipple of the efferent conduit to prevent the formation of a collar that is too tight.
10. The surgeon secures the limbs with 3-0 or 4-0 silk suture.
11. The pouch is closed with sutures or the endostapler.
12. The ureters are anastomosed, as described in the "Ileal Conduit" discussion, to the afferent limb.
13. A small stoma site is prepared, as described in the "Ileal Conduit" discussion. A catheter of choice is placed in the stoma for postoperative care. Stents may be placed in the ureters for the immediate postoperative period. This will necessitate initial placement of an ileostomy appliance until all systems are functioning.
14. A drain is placed, which exits through a separate stab wound.
15. The surgeon closes the wound. Retention sutures may be employed. Bulky absorbent dressings are applied; Montgomery straps may be used.

Indiana Pouch

PROCEDURAL CONSIDERATIONS. The Indiana pouch technique is a modification of the original ileocecal diversion. The surgeon constructs a continent reservoir from the right side of the colon, which may include the ileum and cecum, the ileocecal valve, and ascending colon. Surgery proceeds as for any diversionary procedure. The ileocecal valve is reinforced with nonabsorbable suture. Two rows of nonabsorbable suture are used to then imbricate the ileal segment, which serves as a limb that can be catheterized once it is exteriorized to the skin level as a stoma. The cecal segment is detubularized by incising along the taenia and anastomosing the distal edge horizontally to the proximal portion. Intussusception of the ileocecal valve into the cecum and narrowing of the ileal segment attached to the skin allow for continence.

OPERATIVE PROCEDURE

1. The large bowel is split down the antimesenteric border for approximately three fourths of its length.
2. The U-shaped defect is closed.
3. The surgeon sutures the terminal ileum along its length over a small Robinson catheter in an intestinal fashion.
4. The pouch is filled with 400 ml of saline, and a larger catheter is placed to determine ability to be catheterized.
5. The ureters are tunneled into the cecum through its taenia and then tacked to the outer bowel wall. The cecum is secured to the pelvic wall. Ureteral stents may be placed.
6. The pouch is secured to the abdominal wall.
7. The surgeon prepares the stomal site as described in the "Ileal Conduit" discussion.
8. A 22F Malecot drain is placed in the reservoir to drain the cecostomy, exiting through a separate stab wound.

SURGERY OF THE URETERS AND KIDNEYS

Stones, infections, and tumors are the most common causes of urinary tract obstruction, necessitating surgery to prevent renal obstruction and subsequent renal failure. Obstruction may also result from congenital malformations or previous operations on the urinary tract (Figure 14-75).

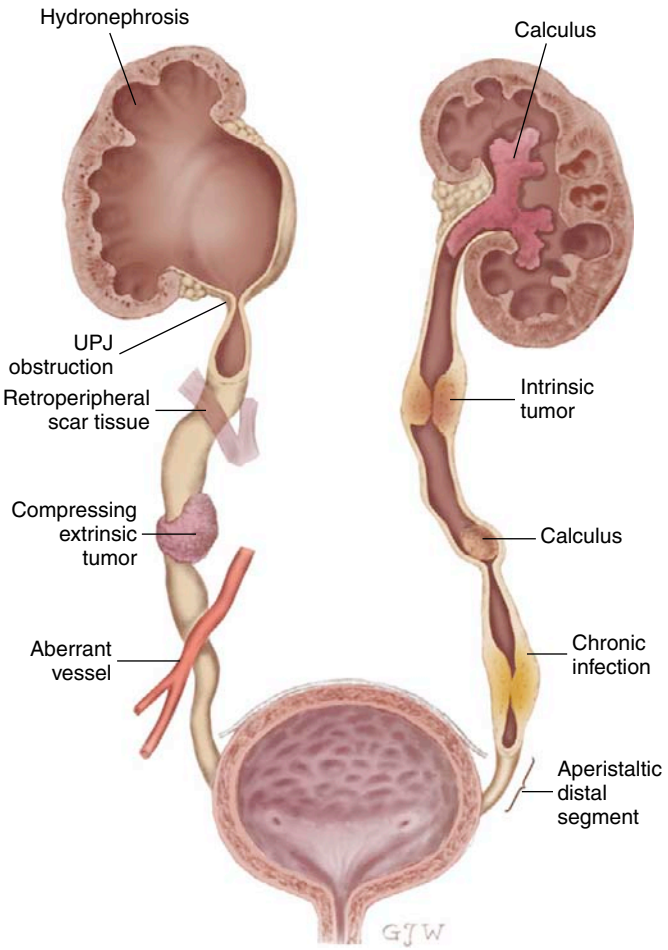


FIGURE 14-75 Some common causes of urinary tract obstruction. *UPJ,* ureteropelvic junction.

The ureter has three areas of narrowing where calculi may become lodged and pose a potential problem with pain and obstruction: (1) the ureteropelvic junction (UPJ), (2) the crossing of the ureter over the external iliac vessels, and (3) the ureterovesical junction (UVJ). Urine may sometimes cause calculi to be washed down the ureter to produce severe ureteral colic. The majority of renal calculi are spontaneously passed into the bladder. However, if they become lodged in the ureter, surgical intervention may be indicated.

Although the causes of many kidney stones are obscure, certain conditions, such as obstruction, stasis, and imbalance of metabolism, predispose to their formation. Stones consist of various elements: calcium oxalate, calcium phosphate, magnesium ammonium phosphate, uric acid, calcium carbonate, and cystine. An increase in the concentration of any of these compounds can cause tiny crystals to form; as these clump together, they begin to form a stone. Stones removed during surgery are subjected to chemical analysis and should be submitted in a dry jar. Fixative agents such as formalin should not be used.

Stones in the renal pelvis may fall into the ureteropelvic junction and obstruct the flow of urine. However, stones less than 3 cm in diameter may also pass down the ureter and lodge at a more distal location. A stone may remain in a renal calyx and continue to enlarge, eventually filling the entire renal collecting system (staghorn calculus). Diverticula may form and harbor stones that can be difficult to reach and treat. Hydroureteronephrosis, infection, and destruction of renal parenchyma frequently result from unrelieved obstruction.

Hypothermia may be used as an adjunct to renal stone surgery as a means of prolonging the safe period of renal ischemia. Several methods enable renal cooling: ice slush or cold saline solution, surface cooling coils, perfusion of cold solutions through the renal artery, or a variation of these basic techniques, such as perfusion of the renal pelvis with saline that has been cooled by a coil immersed in ice slush.

A refrigeration unit "slush machine" that produces sterile slush provides a cost-effective, time-saving alternative to the other methods of slush preparation. Commercially synthesized ultrafiltrate of sterile plasma in liter bottles is also available for use as the slush. Alternatively, a rigid plastic container of 1000 ml of normal saline or lactated Ringer's solution may be placed on its side in a freezer several hours before surgery. To prevent the solution from solidifying, the container should be rotated one-half turn every 20 to 30 minutes. Sterile slush may then be poured directly into a sterile basin as required.

The surgical approach in renal surgery depends on the patient's condition, the amount of exposure needed, and the surgical procedure to be performed. There are three principal surgical approaches to the kidney. The simple *flank,* or *transabdominal,* incision is most frequently used and may include removal of the eleventh or twelfth rib. The incision begins at the posterior axillary line and parallels the course of the twelfth rib. It extends forward and slightly downward between the iliac crest and the thorax. For the *lumbar* incision, the patient may be initially positioned supine and then rotated to lateral and slightly forward over protective bolsters with the operative side up. This effectively places the flank in an oblique position, causing the abdominal viscera to fall away from the operative incision, and affords an excellent approach to the renal pedicle. Alternatively, the patient may be placed prone with bolsters under the affected side to provide elevation. The *thoracoabdominal* exposure is employed primarily for large upper-pole renal neoplasms. The tenth and eleventh ribs are usually removed, and the chest cavity is opened, collapsing the lung. The leaves of the diaphragm are separated to expose the kidney.

Ureteral Surgery

Ureterostomy (ureterotomy) is opening the ureter for continued drainage from it into another body part. Cutaneous ureterostomy is diversion of the flow of urine from the kidney, through the ureter, away from the bladder, and onto the skin of the lower abdomen. A suitable urinary collecting device is then placed over the ureteral stoma.

Ureterectomy is complete removal of the ureter. This procedure is generally employed in collecting system tumors and includes nephrectomy and the excision of a cuff of bladder.

Ureteroureterostomy is segmental resection of a diseased portion of the ureter and reconstruction in continuity of the two normal segments.

Ureteroenterostomy is diversion of the ureter into a segment of the ileum (ureteroileostomy, or more commonly, ileal urinary conduit) or into the sigmoid colon (ureterosigmoidostomy). Ureteroneocystostomy (ureterovesical anastomosis) is division of the distal ureter from the bladder and reimplantation of the ureter into the bladder with a submucosal tunnel.

Reconstructive operations may be indicated because of a pathologic condition of the bladder or lower ureter that interferes with normal drainage. Conditions requiring urinary diversion or reconstruction of the urinary tract include malignancy, cystitis, stricture, trauma, and congenital ureterovesical reflux. Invasive vesical malignancy requiring surgical removal of the bladder necessitates urinary diversion.

Ureterocutaneous transplant, ureterosigmoid anastomosis, and ileal conduit are urinary diversionary procedures performed when the bladder is no longer functioning as a proper urine reservoir. Etiologic factors causing irreparable vesical dysfunction are chronic inflammation, interstitial cystitis, neurogenic bladder, exstrophy, trauma, tumor, and infiltrative disease (amyloidosis). Ureterolithotomy is incision into the ureter and removal of an obstructing calculus.

Procedural Considerations. The site of the incision and position of the patient depend on the nature of the proposed surgery. The patient may be placed in the supine position for abdominal surgery, in the modified Trendelenburg's position for low abdominal or pelvic surgery, or in the lateral position for high- or mid-ureteral obstructing calculi. The perioperative nurse ensures that the patient's arms are supinated when on armboards; in lateral position the upper arm is placed on an overbed armboard such as the Allen lateral arm support and the lower arm is supinated on a padded armboard. The kidney rest should lie just under the dependent iliac crest.

Instruments include the nephrectomy set, plus plastic instrumentation for pyeloplasty. Additional instruments may be required, depending on the type of operation and the surgical approach used.

Operative Procedure

URETERAL REIMPLANTATION

1. The surgeon exposes the ureter through an incision determined by the location of the pathologic condition. A ureteral catheter, passed retrograde, may be used to facilitate identification and isolation of the ureter.

2. The ureter is dissected free with long forceps and scissors, picked up with fine traction sutures, freed from the surrounding tissues, and severed at the desired level.
3. The surgeon ligates the distal end of the ureter and transfers the proximal stoma to the site of anastomosis. The anastomosis is accomplished with fine dissection instruments and fine atraumatic sutures.
4. A soft splinting stent is usually left in place until healing has taken place and free drainage is ensured. The wound is closed in layers and dressings applied.

URETEROCUTANEOUS TRANSPLANT (ANASTOMOSIS). The surgical approach is the same as that for a low ureterolithotomy.

1. The ureter is divided as far distally as possible.
2. The surgeon passes the severed ureter retroperitoneally through the lower abdominal wall and sutures it to the skin with an absorbable everting suture of 4-0 on an atraumatic needle to form a stoma. The ureter is handled gently with plastic instruments, fixation forceps, and iris scissors.
3. A small Silastic stenting catheter is passed up into the ureter and left in place for 48 to 72 hours, as ureteral edema subsides. The patient requires a urine-collecting device after surgery.

URETEROSIGMOID ANASTOMOSIS

1. The surgeon enters the peritoneal cavity through a lower left paramedian incision.
2. The major portion of the large bowel is protected with moist laparotomy packs.
3. Deep retractors are placed, and the surgeon uses long forceps and scissors to incise the posterior peritoneum.
4. The ureters are identified, divided close to the bladder, mobilized, and brought through the posterior peritoneal incision to lie near the sigmoid. Traction sutures and smooth tissue forceps are used to handle the ureters.
5. The sigmoid colon is mobilized to prevent tension on the ureteroenteric anastomosis.
6. Using 3-0 nonabsorbable suture material, the surgeon sutures the sigmoid colon to the pelvic peritoneum at a point where the ureter falls easily on the bowel.
7. Using a scalpel with a #15 blade, the surgeon makes an incision into the taenia of the sigmoid down to the mucosal layer. The edges of the taenia are undermined to create two parallel flaps.
8. The ureter is laid on the bowel mucosa, and a small slit is made through the mucosa into the lumen of the colon.
9. With fixation forceps and iris scissors, the surgeon bevels the ureter to lie flat in the tunica incision.
10. The distal ureter is anchored to the bowel mucosa with 4-0 absorbable ureteral sutures on atraumatic needles. The other ureter is anastomosed in the same manner in a position slightly above the first.
11. The tunicae are then loosely reapproximated over the ureter with 4-0 absorbable sutures, creating an antireflux anastomosis.
12. The surgeon closes the posterior peritoneum with absorbable sutures. Drains are exteriorized retroperitoneally. The incision is closed and dressings applied.

Ureterolithotomy

PROCEDURAL CONSIDERATIONS. A KUB x-ray examination should be done immediately before surgery to determine the exact location of the stone. The surgeon may also schedule a cystoscopic examination preoperatively and may attempt to remove the stone endoscopically. The location of the stone determines the surgical approach. A stone high in the ureter requires a flank incision with possible removal of the twelfth rib; a more distal ureteral stone requires a lower abdominal incision.

OPERATIVE PROCEDURE

1. After exposure of the ureter, the stone may be kept stationary with Babcock clamps or vessel loops applied above and below it.
2. With a #15 blade, the surgeon makes an incision in the ureter directly over the stone, which may be easily removed with Randall stone forceps.
3. A 10F catheter is passed proximally up and distally down the ureter while irrigating with saline to check for ureteral patency and to dislodge any remaining stone fragments.
4. The surgeon closes the ureter with 4-0 or 5-0 absorbable sutures. All stones should be placed in dry receptacles and sent to the chemistry laboratory for analysis.

Kidney Surgery

See Box 14-3 for terms pertaining to kidney surgery.

Procedural Considerations. Patient preparation and instrument setup are as described for ureteral surgery.

Operative Procedure

PYELOTOMY AND PYELOSTOMY

1. The surgeon incises the pelvis of the kidney with a small scalpel blade. Fine traction sutures may be placed at the edges of the incision for gentle retraction while the pelvis and calyces are explored.
2. In pyelostomy a small Malecot or Foley catheter is placed through the incision into the renal pelvis. Pyelotomy is used only for very short periods of renal drainage because tubes tend to be dislodged easily from the renal pelvis.

BOX 14-3

Terms Pertaining to Kidney Surgery

Term	Definition
Nephrostomy	Creation of an opening into the kidney to maintain temporary or permanent urinary drainage. A nephrostomy is used to correct an obstruction of the urinary tract and to conserve and permit physiologic functioning of renal tissue. It is also used to provide permanent urinary drainage when a ureter is obstructed or for temporary urinary drainage immediately after a plastic repair on the kidney.
Nephrotomy	Incision into the kidney, usually over a collecting system containing a calculus
Pyelolithotomy	Removal of a calculus through an opening in the renal pelvis
Pyelostomy	Making an opening in the renal pelvis for temporarily or permanently diverting the flow of urine
Pyelotomy	Incision into the renal pelvis used as an access to stones in the renal pelvis or collecting system

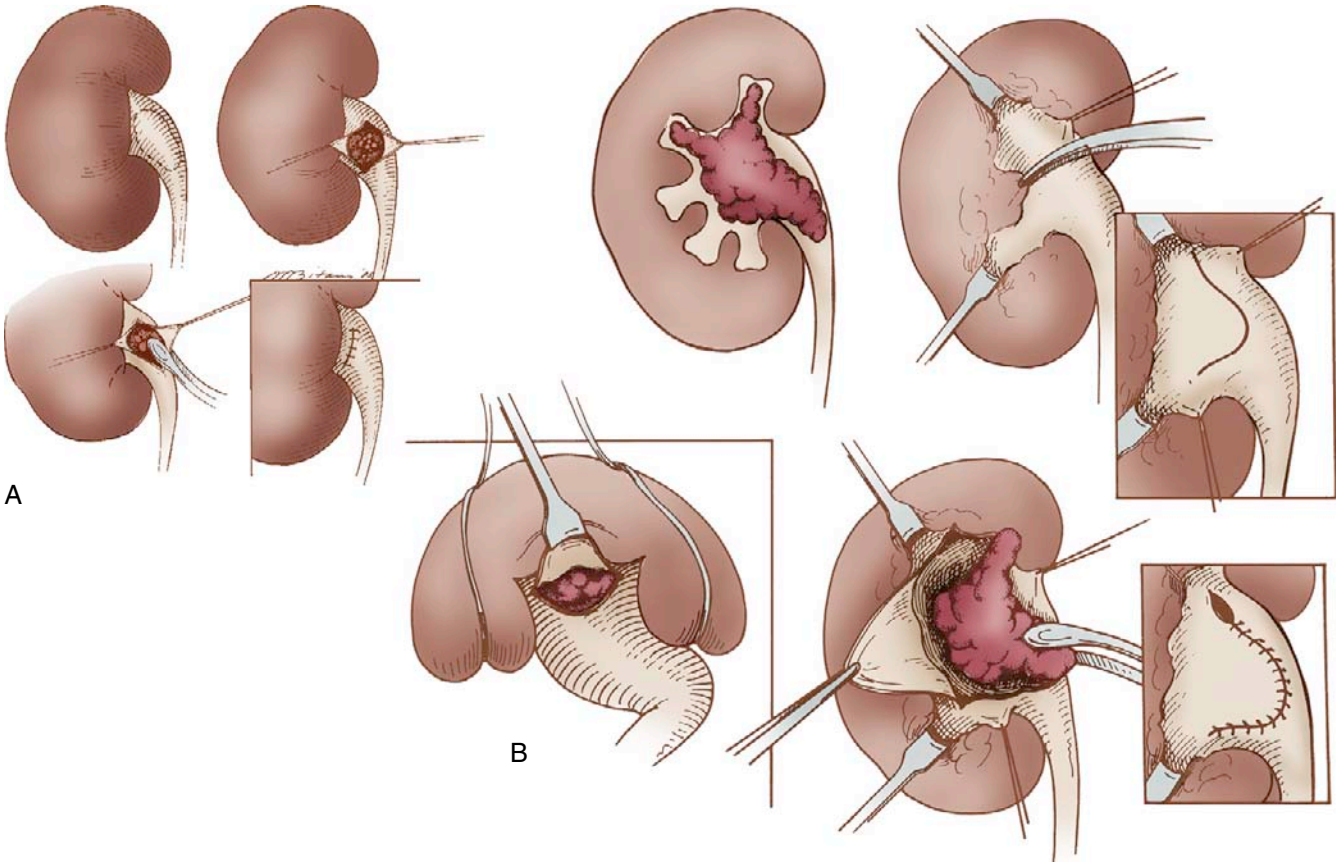


FIGURE 14-76 Pyelolithotomy. **A**, Technique of simple pyelolithotomy. **B**, Technique of extended pyelolithotomy.

NEPHROSTOMY

1. The surgeon passes a curved clamp or stone forceps through a pyelotomy incision into the renal pelvis and then out through the substance of the renal parenchyma through a lower pole minor calyx.
2. The tip of a Malecot, Foley, or Pezzer catheter is drawn into the renal pelvis, and the pyelotomy incision is sutured closed.
3. The distal end of the nephrostomy tube is exteriorized through a separate stab incision in the flank.
4. A drain is placed at the level of the pyelotomy incision, and the wound is closed.

PYELOLITHOTOMY AND NEPHROLITHOTOMY

1. The surgeon opens the renal pelvis (Figure 14-76, *A*), and removes the calculus.
2. The pelvis and collecting systems are thoroughly irrigated with saline using an Asepto syringe to dislodge and remove any small remaining stones from the kidney.
3. Nephrolithotomy or extended pyelolithotomy is employed when stones are locked in the calyceal system and cannot be removed through a pyelotomy incision. In such cases, the renal parenchyma above the stone is incised and the stone removed. In many instances, such a situation is associated with a calyceal diverticulum (Figure 14-76, *B*).
4. After the stone is removed, the collecting system is closed and the renal cortex reapproximated with deep hemostatic 2-0 absorbable sutures.
5. A nephroscope is sometimes used to localize and remove calyceal stones. The nephroscope is also useful with staghorn calculi to remove residual fragments in the pelvic portion of the calculus.
6. An incision in the renal pelvis may be closed with 4-0 absorbable atraumatic sutures.
7. The renal fossa is drained and closed, as described for nephrectomy. Reinforced absorbent dressings are useful because some urinary leakage occurs for 3 to 4 days after surgery.

PERCUTANEOUS NEPHROLITHOTOMY. Percutaneous nephrolithotomy facilitates the removal or disintegration of renal stones using a rigid or flexible nephroscope (Figure 14-77) passed through a percutaneous nephrostomy tract. Accessory instrumentation, such as the ultrasound wand, electrohydraulic lithotripter probe, laser fiber, stone basket, and stone grasper, is passed through the lumen of the nephroscope.

Ideally, the patient is in good health and not obese and the calculus is 1 cm or less in diameter, free-floating, radiopaque, and solitary. However, advances in technology complemented by the experience gained by the uroradiology team have allowed patients with more complex problems to be managed in this manner. Patients who have undergone previous renal surgery, have stone recurrence, or have an established nephrostomy tract may also benefit from this procedure.

Creation of the nephrostomy tract and removal of the stone can be accomplished by three different methods. Proper placement of the nephrostomy wire can decrease the operating time significantly. In the *one-step procedure,* creation of the nephrostomy tract, tract dilation, and stone removal are completed in a

FIGURE 14-77 Kuntz laser working element.

single session. This method is generally preferred unless there are contraindications. In the *immediate two-step procedure,* the radiologist places the nephrostomy tube under radiographic guidance and the urologist removes the stone later the same day or the next morning. The second step is usually done in the OR with the patient administered a general anesthetic. In the *delayed two-step procedure,* the nephrostomy tract is established after the patient has been administered a local anesthetic. The patient is discharged the following day with a 22F or 24F nephrostomy tube connected to drainage. The patient is readmitted to the hospital 5 to 7 days later for the percutaneous removal of the stone after the patient has been administered a general anesthetic.

Of basic concern during the operative phase are the patient's position and body temperature, the potential for sudden and rapid blood loss, the type of anesthesia, medications required during surgery, and catheter management during and after the procedure. The patient's position, which may be prone or up to 30 degrees prone-oblique, and the draping procedure depend on whether the surgery is performed in the radiology department or the OR and the type of x-ray equipment that will be used.

Extracorporeal Shock-Wave Lithotripsy (ESWL). ESWL units use water-filled cushions adjacent to the kidney area. An x-ray image intensifier with two monitors is used to visualize the kidney stone at the focal point of the shock wave. After every 100 shocks, fluoroscopy is used to locate remaining stone particles. Adjustments are made, and the patient is repositioned before further treatments. ESWL is often used with percutaneous nephrolithotomy and transurethral ureteropyeloscopy if the patient does not pass the gravel.

Stones that are treated with ESWL are fragmented by the energy focused on the stone with the lithotripter. The shock waves are administered over a time that can vary from 30 minutes to 2 hours. Shock waves reverberate inside the stone, causing fragmentation with ultimate complete or partial destruction of the calculus. The amount of destruction depends on the number and energy of the shock waves delivered and the hardness of the stone. This technique is effective because shock waves can be transmitted and focused through tissue without loss of energy. A loud, reverberating, popping sound occurs each time a wave pulse is activated. It is advisable that earplugs be worn.

The requirement for anesthesia is determined by the power of the shock wave, the area of shock-wave entry at the skin level, and the size of the shock-wave focal point. The summation of shock waves used during the procedure can cause pain at the skin level. Typically, a general, spinal, or local anesthetic is used with the older lithotripters. Modern versions allow for lithotripsy with only IV sedation, oral sedation, or a transcutaneous electric nerve stimulator (TENS) unit.

The use of a stent before ESWL depends on the patient and the character of the stone or stones. The patient should have a negative urine culture before stent placement. Studies show that complication rates decrease if a stent is used with a stone larger than 1.5 cm. A stent placed before ESWL tends to decrease the need for ancillary interventions, reduces overall complications, and assists in proper positioning for ESWL by delineating the ureteral anatomy and the precise stone location. On the other hand, those patients who tend to readily form stones may demonstrate calcification of the ureteral stent in a relatively short time. Without a stent, the risk of silent renal obstruction resulting in loss of kidney function, obstruction of the ureter, nephritis, and sepsis is increased.

Complications related to ESWL are attributable to the cavitation effects of treatment and are proportional to the number of shocks. The ability of the kidney's tubular cells to survive shock waves is related to the number of shock waves to which the kidney is exposed and not to the energy level. Gross hematuria is seen almost universally, resolves in 12 to 48 hours, and is believed to be attributable to parenchymal edema that spontaneously heals within 1 week. Subcapsular or perirenal hematoma caused by perinephric fluid collections may occur and appears to be higher in the hypertensive patient. Subcapsular hematoma may resolve in 6 weeks or may take up to 6 months, whereas perirenal hematoma will be relieved usually in a matter of days. Impairment of renal function may be seen in patients with solitary kidneys. Iliac artery and vein thromboses have been reported with lithotripsy for ureteral stones. The majority of lithotripsy patients will demonstrate little or no long-term morbidity (Gayer, 2006).

Laser Lithotripsy. Laser lithotripsy has become an exciting alternative to ESWL and electrohydraulic lithotripsy (EHL). The Ho:YAG (holmium:yttrium-aluminum-garnet), tunable pulse-dyed (coumarin), Er:YAG (erbium:yttrium-aluminum-garnet), the tunable Alexandrite (a chromium-doped mineral), or the Q-switched Nd:YAG (neodymium:yttrium-aluminum-garnet) laser systems have the ability to disintegrate stones without damaging soft tissue. The technique may be used during a ureteropyeloscopy or nephroscopy or to manage ureteral stones instead of performing a ureterolithotomy. When the laser probe is discharged in direct contact with the calculus, plasma (ionized gas) coats the stone's surface. This plasma expands with repeated firings, creating a shock wave that fractures the stone. Normal saline is used for continuous irrigation throughout the procedure. It is not necessary to immobilize the calculus. All persons in the room wear laser goggles, and all laser precautions apply (see Chapter 7).

Dismembered Pyeloplasty. *Pyeloplasty* is revision or plastic reconstruction of the renal pelvis. Pyeloplasty is performed to create a better anatomic relationship between the renal pelvis and the proximal ureter and to allow proper urinary drainage from the kidney to the bladder. A temporary nephrostomy is often included to protect the plastic reconstruction of the ureteropelvic junction (UPJ). Tissue healing usually occurs in 10 to 12 days, and the nephrostomy tube is removed once

ureteral patency is demonstrated. *Ureteroplasty* is reconstruction of the ureter distal to the UPJ. A *dismembered pyeloplasty* is the combined correction of the redundant renal pelvis and resection of a stenotic portion of the UPJ.

PROCEDURAL CONSIDERATIONS. The instrument setup is as described for nephrectomy, plus fine plastic and vascular instrumentation and Randall stone forceps. A ureteral stent and red rubber catheters will also be employed. The perioperative nurse assists with positioning the patient in the lateral position.

OPERATIVE PROCEDURE

Open Approach

1. The surgeon exposes the kidney and upper ureter through a supracostal flank incision.
2. Gerota's fascia is entered, and the renal pelvis and ureter are freed while the kidney is rotated medially.
3. The surgeon frees the ureter and stabilizes it with a vessel loop below the level of the UPJ.
4. A 4-0 stay suture is placed in the tip of the ureter, and the ureter is incised, trimmed, and shaped to the desired contour with fine forceps and scissors.
5. Anchoring sutures of 4-0 material are placed for traction during reconstruction of the renal pelvis. A diamond-shaped incision is made into the renal pelvis, and the tissue is removed. The Y-V-plasty technique may be followed. It converts a Y-shaped surgical incision of the renal pelvis into a V by drawing the apex of the arms of the Y to the foot of the Y with absorbable sutures.
6. Sutures are placed at each end of the refashioned renal pelvis, passed to the ureteral stoma, and tagged. The pelvis is irrigated free of clots. The sutures are run in a continuous manner, creating the anastomosis.
7. A Silastic tubing may be used to stent the repaired pelvis until adequate healing has occurred. A nephrostomy tube is also placed within the pelvis to divert urine safely while the edema in the area of the repair resolves.
8. The surgeon closes Gerota's fascia over the repair.
9. A drain is placed where the pelvis was reconstructed, and the surgical incision is closed in layers.

Laparoscopic Approach. UPJ obstruction has recently joined the rank of surgeries that may be treated laparoscopically. Generally, a standard transperitoneal approach is used. The patient may be placed supine with a lateral tilt or in lateral decubitus and the bed rotated to access the ports.

After placement of four trocars as in laparoscopic nephrectomy, the surgeon frees the proximal ureters and renal pelvis. The obstruction at the UPJ is excised, and a spatulated anastomosis is performed using running or interrupted sutures. A ureteral stent is usually left in place.

Decreased postoperative pain and shorter hospitalization make this approach appealing. A higher degree of skill is required for this technique, however, making it an option that has not become standard treatment as yet.

Nephroureterectomy—Open Approach. Nephroureterectomy is removal of a kidney and its entire ureter. This procedure is indicated for hydroureteronephrosis of such a degree that reconstructive repair is impossible. It is also employed for collecting system tumors of the kidney and ureter.

PROCEDURAL CONSIDERATIONS. Open nephroureterectomy requires an extension of the incision anteriorly with the patient positioned semilaterally and fully prepped and draped for the surgeon to access the flank and lower abdomen. Only one instrument set is required, but a second skin-prep setup and set of sterile drapes may be necessary. An alternative to open nephroureterectomy is laparoscopic nephroureterectomy.

OPERATIVE PROCEDURE

1. The surgeon exposes the kidney and upper ureter and performs a nephrectomy as described in the following procedure. The kidney may be placed in a plastic bag to prevent possible spillage of tumor cells.
2. The ureter is mobilized as far distally as possible. The OR bed is adjusted so that surgery on the lower ureter may proceed. The lower ureter and bladder are identified and mobilized.
3. The ureter and a small cuff of the bladder are removed in continuity, and the bladder is repaired with a single layer of 2-0 absorbable interrupted sutures. The ureter and cuff of bladder are pulled superiorly, and the intact kidney and ureter are removed.
4. An 18F or 20F Foley catheter is left in the bladder, and a drain is placed behind the bladder. The incision is closed in layers.

Nephrectomy—Open Approach. Nephrectomy is the surgical removal of a kidney. It is performed as a means of definitive therapy for many renal problems, such as congenital UPJ obstruction with severe hydronephrosis, renal tumor, renal trauma, calculus disease with infection, cortical abscess, pyelonephrosis, and renovascular hypertension.

In routine renal surgery the patient is placed in the lateral position with the dependent iliac crest over the kidney rest. The operative flank is uppermost, with the patient's back brought to the edge of the OR bed. The upper arm is supported on an overhead arm support, and the lower arm is supinated on a padded armboard. It may be flexed slightly at the elbow and angled cephalad to promote better access to the flank. The patient's legs are positioned by placing a pillow between them and flexing the lower leg at the knee. The upper leg remains extended. The kidney rest is then raised, and when the desired bed flexion is achieved, 3-inch adhesive tape is used to stabilize the patient throughout surgery. Routine skin preparation and draping procedures are carried out.

PROCEDURAL CONSIDERATIONS. The nephrectomy setup includes a routine laparotomy setup; kidney instruments (Figure 14-78); a variety of red rubber, Malecot, or Pezzer catheters; a wound drainage system; and vessel loops. In certain nephrectomies the chest or the GI tract may be opened. If the chest is opened, appropriate instruments and postoperative chest drains are needed. Rib resection requires the addition of a Finochietto rib retractor, a large Matson costal periosteotome, an Alexander costal periosteotome, right and left Doyen rib raspatories, a Bethune rib cutter, a double-action duckbill rongeur, a Bailey rib approximator, and a Langenbeck periosteal elevator. When the GI tract is opened, GI technique is used for the anastomosis.

OPERATIVE PROCEDURE

1. The incision is carried through the skin, fat, and fascia. Bleeding vessels are clamped and ligated.
2. The surgeon exposes and incises the external oblique, internal oblique, and transversalis muscles in the direction of the initial skin incision.

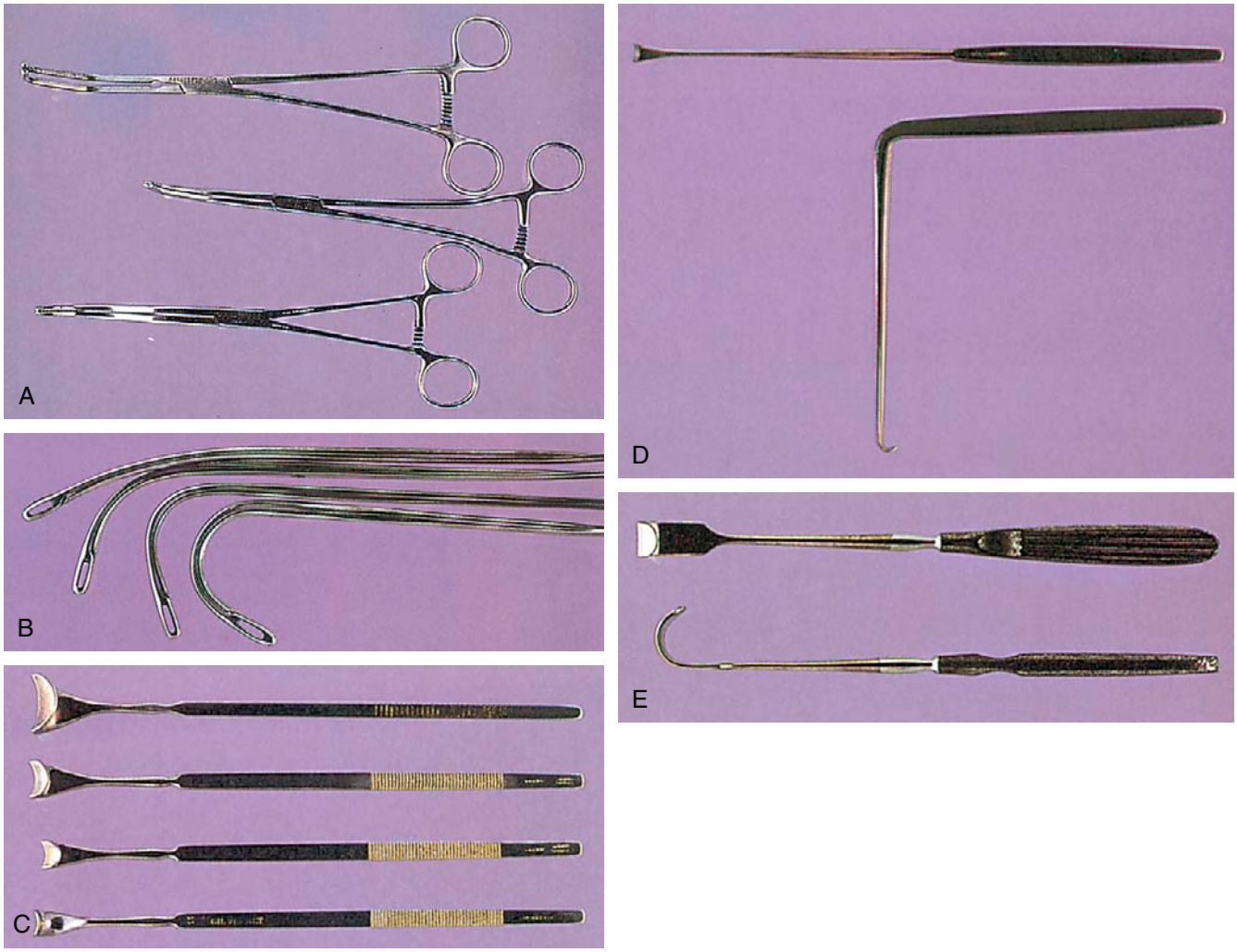


FIGURE 14-78 **A**, Kidney clamps. *Top to bottom,* Satinsky (vena cava) forceps; Herrick kidney forceps; Mayo-Guyon kidney forceps. **B**, Randall stone forcep tips. *Top to bottom,* ¼ curved, ½ curved, ¾ curved, full curved. **C**, Gil-Vernet retractors, front view. **D**, *Top to bottom,* Love nerve retractors: straight, front view; 90-degree angle, side view. **E**, *Top to bottom,* Little retractors, medium: front view, side view.

3. If necessary, a rib or ribs (eleventh and/or twelfth) may be resected to provide better access to the kidney. The surgeon strips the periosteum with an Alexander costal periosteotome and Doyen rib raspatory. A scalpel and heavy scissors are used to cut through the lumbocostal ligaments. The rib is grasped with an Ochsner clamp and cut with rib shears, removing the portion necessary to expose the kidney. Gerota's fascia is identified and incised with Metzenbaum scissors.
4. The surgeon extends the incision and uses blunt and sharp dissection to expose the kidney and perirenal fat. The surgical technologist should save all perirenal fat that is removed during surgery, placing it in a small basin of normal saline for possible use as a bolster to stop bleeding.
5. The ureter is identified, separated from its adjacent structures, doubly clamped, divided, and ligated with absorbable 0 suture.
6. The kidney pedicle containing the major blood vessels is isolated and doubly clamped; each vessel is triply ligated with heavy nonabsorbable ties. Each vessel is then severed, leaving two ligatures on the pedicle, and the kidney is removed (Figure 14-79).
7. The renal fossa is explored for bleeding, and necessary hemostasis is achieved. The fossa is then irrigated with normal saline, and the irrigant is removed by suction.
8. The surgeon closes the fascia and muscle in layers with interrupted absorbable sutures. Retention sutures may be used in obese or chronically ill patients in whom wound healing may be delayed.
9. The skin edges are approximated with sutures or skin staples, and the dressing is applied.

Laparoscopic Nephrectomy. The approach for laparoscopic nephrectomy may be transabdominal (transperitoneal), extraperitoneal (retroperitoneal), or intraperitoneal. Transabdominal is the most common approach. Indications for laparoscopy are generally for benign disease, although more radical surgeries have been accomplished in this manner. A full mechanical antibiotic bowel prep is prescribed. Although surgery time is

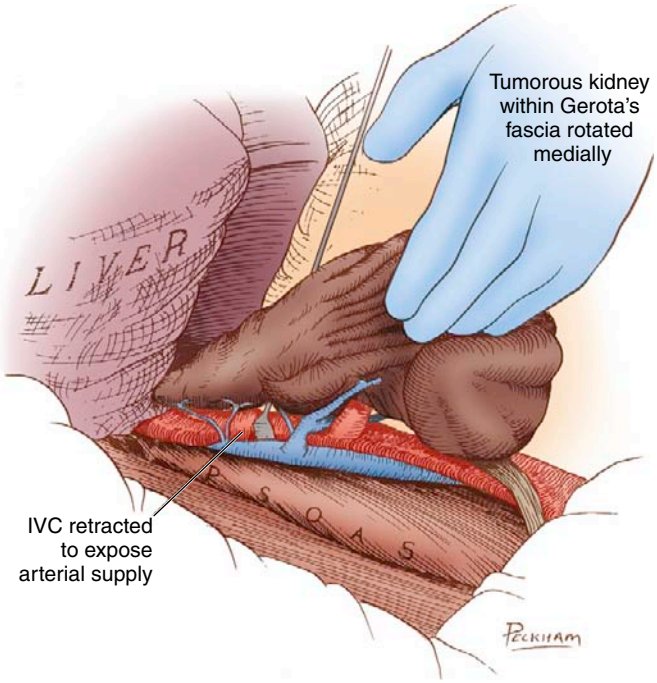


FIGURE 14-79 Nephrectomy. *IVC,* inferior vena cava.

longer (an average of 3½ to 5 hours), postoperative recovery time, analgesia requirements, and total hospital stay are lessened. The procedure always includes cystoscopy with placement of a renal balloon catheter, a ureteral catheter, and a Foley urethral catheter under C-arm fluoroscopy. Indigo carmine may be injected into the skin overlying the renal pelvis.

The patient is initially placed on a beanbag in the supine position. A standard laparoscopy instrument and equipment setup that includes three 5-mm trocars, an insufflation needle, and two 10-mm to 12-mm trocars is used. Cystoscopic and ureteroscopic supplies will be needed, as well as an 0.035-gauge Bentson guidewire, an occlusion balloon catheter, an 0.035-gauge Amplatz stiff guidewire, a 16F Foley catheter and drainage bag, indigo carmine, an irrigator-aspirator, a 1-liter bag of saline, a 1-liter pressure bag (to pressurize the irrigant to 250 mm Hg), a #12 or #11 knife blade, 10-mm clip appliers, the entrapment sack, and tissue morcellator. An open setup should always be available in the event laparoscopy is unsuccessful.

PROCEDURAL CONSIDERATIONS. The patient is prepped and draped as for laparotomy. Use of a draping pack with four large adherent drape sheets, instead of a standard laparotomy sheet, affords better access for the port sites.

The patient may be placed in lateral decubitus position on a deflated beanbag positioner at the outset or turned after endoscopic intervention. Ensuring that the patient is adequately secured to the OR bed is critical. Before prepping the patient, the bed is tilted laterally to afford a central abdominal access. The patient is prepped and draped, and access of the first three ports is achieved. Before the surgeon inserts the remaining trocars, the anesthesia provider returns the bed to its normal configuration so that the patient is again in lateral decubitus position. The kidney rest is then elevated, and the operation continues.

Some surgeons begin the procedure with the patient supine. The contralateral arm is padded with thick foam from the shoulder to the fingertips. The patient is prepped and draped for thoracoabdominal surgery. Extra draping materials are used when the patient is repositioned.

OPERATIVE PROCEDURE

1. The surgeon accesses the peritoneal cavity through a 1-cm transverse, subumbilical, stab-wound incision. After elevation of the anterior abdominal wall with towel clips, the Veress needle is inserted with the stopcock valve control in the closed position.
2. Once the Veress needle is in place, sterile saline is dropped into the lumen of the needle and the valve of the needle is opened. If the saline enters freely (a successful test), the abdominal cavity is inflated with CO_2 until a pressure of 15 to 20 mm Hg is obtained. If saline does not enter freely, it indicates improper placement of the needle.
3. The surgeon nicks the rectus fascia with the knife blade, and replaces the Veress needle with the 10-mm trocar. Towel clips are again used on each side of the incision to stabilize the abdominal wall during insertion.
4. The 10-mm laparoscope is inserted.
5. A second incision is made immediately below the costal margin in the midclavicular line, and a 10-mm to 12-mm trocar is inserted.
6. The surgeon inserts the first of three 5-mm trocars through a small incision 2 cm below the umbilicus in the midclavicular line.
7. The last two 5-mm trocars are placed, one in the anterior axillary line level with the umbilicus and one subcostal in the anterior axillary line. All trocars are then withdrawn until 2 to 3 cm of each sheath protrudes into the abdomen. The surgeon may use polypropylene suture to secure the side arm ports to the patient's skin. Each trocar site is laparoscopically inspected after trocar insertion to identify any bleeding or perforation. On occasion, it may be necessary to extend the incision for trocar insertion.
8. The ascending or descending colon is completely mobilized with electrosurgical scissors and deflected medially. The retroperitoneum is opened.
9. Using gentle motion on the ureteral catheter, the surgeon identifies and dissects the ureter. A Babcock forceps is clamped around the dissected ureter for retraction.
10. The ureter is dissected until the lower pole of the kidney is visualized (Figure 14-80). Any veins encountered are clipped twice proximally and twice distally. The kidney is cleared of surrounding tissue and freed laterally and superiorly. Gerota's fascia is entered to free the adrenal gland and exclude it from the dissection.
11. The renal artery and vein are identified and cleared to create a 360-degree window around each vessel. The clip applier is inserted through the 10-mm to 12-mm port. Two clips are placed on the specimen side, and three clips are placed on the stump side of both the artery and the vein, which are then sharply incised.
12. Two pairs of clips are placed proximally and distally on the ureter, which is sharply incised. The specimen end is grasped, and the kidney is moved into the upper abdominal quadrant.
13. The surgeon introduces the entrapment sac through the 10-mm to 12-mm port. The bottom of the sac is pulled into the abdomen with graspers until the neck of the sac clears the end of the port and is then unfurled.

FIGURE 14-80 Interior view of exposing right kidney laparoscopically.

14. The sac is opened, and the ureteral stump with attached kidney is placed inside. The drawstrings are pulled tight, closing the mouth of the sac.
15. The anesthesia provider returns the patient to the supine position by tilting the OR bed, and the sac strings are extracted through the umbilical port. Under laparoscopic observation, the surgeon removes the port and the neck of the sac is brought to lie on the abdominal surface. The tissue morcellator is inserted into the sac, and the kidney is morcellated under suction in a clockwise fashion.
16. The abdominal cavity is exited with laparoscopic observation of each trocar site, during and after removal, to ensure that hemostasis has been achieved. Fascial layers at the 12-mm trocar sites are closed with 2-0 or 3-0 absorbable suture in a figure-of-eight pattern.
17. Using a 4-0 absorbable suture, the surgeon performs a subcuticular closure of all port sites.

Heminephrectomy. Heminephrectomy is removal of a portion of the kidney. It is usually indicated for conditions involving the lower or upper pole of the kidney, such as calculus disease, or trauma limited to one pole of a kidney. In rare instances in which a patient has only one kidney, such surgery may be used for renal neoplasms to avoid the need for dialysis and subsequent renal transplantation.

PROCEDURAL CONSIDERATIONS. The setup is as described for nephrectomy with the addition of vascular and bulldog clamps.

OPERATIVE PROCEDURE

1. The kidney and its pedicle should be completely mobilized as described for nephrectomy. The main vessels may be temporarily occluded for only 20 to 30 minutes, after which progressive renal damage may occur. Local hypothermia may be indicated to prolong ischemic operating time.
2. The renal capsule is incised and stripped back.
3. A wedge of kidney tissue containing the diseased or damaged cortex is excised. The surgeon clamps the interlobar fat or arcuate and interlobular arteries with Hopkins clamps and suture-ligates them with 4-0 absorbable suture on urologic needles.
4. The surgeon reapproximates the open collecting system with a continuous 4-0 suture.

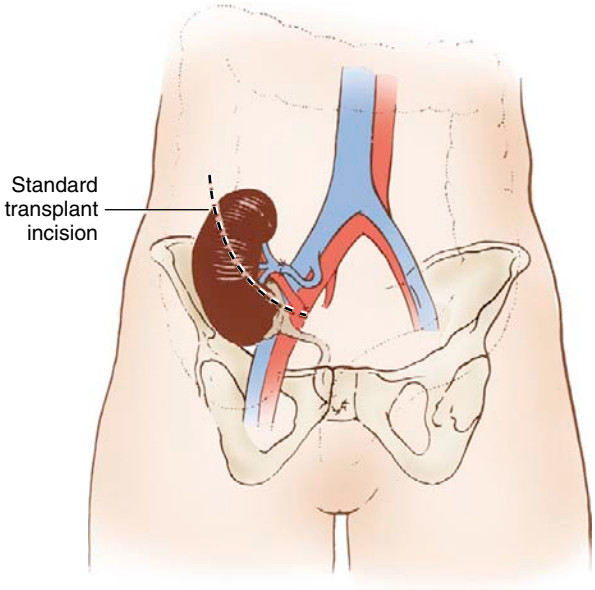


FIGURE 14-81 Transplanted kidney in recipient's iliac fossa.

5. Perirenal fat is placed in the area in which tissue was excised, and the renal parenchyma is reapproximated with horizontal mattress sutures.
6. If possible, the renal capsule is reapproximated with a continuous 2-0 suture.

Radical Nephrectomy. Radical nephrectomy is excision of the kidney, perirenal fat, adrenal gland, Gerota's capsule (fascia), and contiguous periaortic lymph nodes. This procedure is performed for parenchymal renal neoplasms. In the open approach, a lumbar, transthoracic, or transabdominal approach to the kidney is used, depending on the size and location of the lesion. The transthoracic or transabdominal approach is preferred because the blood vessels of the kidney can be more easily reached and ligated before the tumor is mobilized, decreasing the possibility of tumor embolization into the bloodstream. For the laparoscopic approach a retroperitoneal or transperitoneal approach may be employed.

PROCEDURAL CONSIDERATIONS. The setups are as described for open nephrectomy and laparoscopic nephrectomy.

OPERATIVE PROCEDURE. In general, the procedure is as described for nephrectomy with two exceptions: (1) the renal pedicle is ligated before the kidney is mobilized, and (2) Gerota's capsule is not incised but is removed en bloc with the kidney. Involved lymph nodes surrounding the renal pedicle are excised. A chest tube is inserted if the transthoracic approach is used.

Kidney Transplant

Kidney transplant entails transplantation of a living-related or cadaveric donor kidney into the recipient's iliac fossa (Figure 14-81). It is performed in an effort to restore renal function and thus maintain life in a patient who has end-stage renal disease.

Transplant from a Living Donor. The kidney donor must be in good health. ABO (blood typing) and histocompatibility (human leukocyte antigen [HLA] tissue typing) along with a negative white cell (lymphocyte) crossmatch determine

donor-recipient compatibility. It is not necessary to match the Rh factor. Once the donor has been chosen, a complete workup that includes history, physical examination, chest x-ray examination, ECG, CBC, BUN and creatinine values, blood chemistry profiles, coagulation studies, viral titers, and serologic testing is performed. Renal function is assessed by monitoring three creatinine clearances, urinalysis, and blood and urine cultures if hospitalized 72 hours or longer, followed by IVP and excretory urography. A flush aortogram assesses the vascular anatomy, and renal angiography pinpoints the kidney of choice while ruling out the presence of renal lesions. A kidney with a single renal artery is preferred, but kidneys with double and triple arteries may be used if necessary. If there is a family history of diabetes, a 5-hour glucose tolerance test is also performed (UNOS, 2009).

The ideal living donor is an identical twin, although any immediate family member (usually a sibling or parent) may be a donor. The donor is given an IV solution of 1000 ml of 5% dextrose in lactated Ringer's on the evening before nephrectomy. This is followed with 500 ml of 5% dextrose in water over the next 10 to 12 hours. The morning of surgery, about 45 minutes before transport to the OR, 12.5 g of mannitol is administered to ensure diuresis during the induction of anesthesia.

PROCEDURAL CONSIDERATIONS. Two adjacent ORs are prepared for the procedures; surgery on the donor and surgery on the recipient proceed simultaneously.

Usually the right kidney is chosen for removal because of its smaller size, leaving the donor patient with the left and larger kidney. Two IV lines are required. The patient is placed on a beanbag positioning device and moved into the left lateral decubitus position following endotracheal intubation. The lower arm is positioned extended outward on a well-padded armboard at a right angle to the torso; the upper arm is positioned on an elevated lateral armboard. The sternum and anterior superior iliac spine are brought near the edge of the OR bed. A pillow is placed between the patient's legs, and the ankles and feet are appropriately padded. The bed is flexed to 30 degrees, and the upper portion is angled downward to approximately 140 degrees. The skin is prepped from midchest to midthigh and draped to expose the flank area.

Required instruments and equipment are identical to those for a nephrectomy plus an IV pole and supplies for the sterile perfusion table. These include electrolyte solution (placed in an iced basin until needed), two IV extension tubes, a kidney basin with cold (4° C) IV saline solution, a three-way stopcock, an 18-gauge needle catheter, mosquito hemostats, vascular forceps, Metzenbaum scissors, suture scissors, and Kelly hemostats.

An electrolyte solution of Ringer's lactate that contains procaine and heparin may be used to perfuse the harvested kidney. A more common perfusion is CUW (Chelex-treated University of Wisconsin) solution. It contains hydroxyethyl starch, providing a better metabolic substrate for organ metabolism.

Collins or Sachs solution may be used to perfuse cadaveric kidneys after harvest but should never be used to perfuse a kidney from a living donor because of the potential effect of elevated potassium in the recipient from residual perfusate in the kidney.

OPERATIVE PROCEDURE

Open Approach

1. The donor nephrectomy procedure is as described for nephrectomy; however, the ureter and renal vein and artery require meticulous dissection.
2. Maximum length of the ureter is achieved by dividing it at or below the pelvic rim if possible. To preserve adequate ureteral vascularization, the surgeon is cautious not to skeletonize the ureter.
3. Particular care is taken to remove the maximum length of the renal vein and artery. Obtaining the maximum length of the right renal vein sometimes requires partial occlusion of the inferior vena cava with a Satinsky clamp and dissection of a portion of the inferior vena cava. This is done after the ureter has been freed.
4. Repair of the inferior vena cava is made with a continuous 4-0 or 5-0 vascular suture.
5. Five minutes before the surgeon clamps the renal vessels, 5000 units of heparin sodium and 12.5 g of mannitol are systemically administered to the patient to prevent intravascular clotting and maximize diuresis.
6. Immediately after the kidney is removed from the donor, the anesthesia provider administers 50 mg of protamine sulfate intravenously to reverse the heparinization.
7. Furosemide, mannitol, and IV fluids are administered to the donor to maintain adequate urinary output from the donor's remaining kidney.
8. Gentle handling of the kidney is essential. Team members must prevent undue traction on the vascular pedicle, which may induce vasospasm and reduce perfusion of the kidney.
9. To reduce warm ischemia time, the surgeon double-clamps the vein and the artery, excises the kidney, and immediately places it in cold saline solution on a sterile back table, where the kidney is flushed with the designated electrolyte solution. Warm ischemia time (from the clamping of renal vessels to a point at which the kidney is perfused with cold electrolyte solution) should be kept to a minimum to prevent acute tubular necrosis and to maintain maximum renal function after transplantation.
10. Mosquito clamps and fine vascular forceps are used to expose the renal artery to permit insertion of a needle catheter. The cold electrolyte solution passes through the IV tubing and the needle catheter, flushing any remaining donor's blood from the kidney. This also decreases the kidney's metabolic rate by lowering its temperature. Flushing time is usually 2 to 5 minutes.
11. After flushing, the surgeon may trim the vessels of adventitia to facilitate the vascular anastomosis to the recipient's iliac vessels.
12. The kidney, in cold saline solution, is covered with sterile drapes and taken by the surgeon to the room in which the recipient's iliac vessels have been exposed.
13. Wound closure for the donor is as described for nephrectomy.

Laparoscopic Approach. Five trocars are used (four trocars if the left kidney is chosen). Generally the operating trocar is 12 mm, the second and third trocars are 10 mm, and the last two trocars are 5 mm. Instruments required include the following: four 5-mm fenestrated graspers, 5-mm straight and curved dissecting scissors, a coagulating hook, a bipolar grasper, ultrasonic scissors, two 5-mm curved graspers and a 10-mm curved grasper, two needle holders, a clip applier, a vascular stapler, and an atraumatic retrieval bag without a system for opening and closing it and a minimal opening of 15 cm. In addition, the standard open setup needs to be ready with open vascular

instrumentation, a smooth perfusion tip, sterile IV tubing, and sterile ice for ex vivo perfusion.

1. The first 12-mm trocar is introduced through an open technique at a level 2 to 5 cm cephalad to McBurney point to allow access to the superior pole and as far caudad as possible so the renal vein may be divided parallel to the vena cava.
2. The surgeon inserts the second 10-mm trocar in the periumbilical position about 3 cm lateral and cephalad to the umbilicus. This will be used for the laparoscope.
3. The third 10-mm trocar is placed 6 to 8 cm cephalad to the second trocar.
4. A 5-mm trocar is inserted into the flank at the convex border of the kidney.
5. The surgeon places the final 5-mm trocar below the xiphoid process to the left of the round ligament.
6. The OR bed is rotated vertically, and the small intestine and omentum are pushed into the inferior pelvic cavity.
7. Beginning at the foramen of Winslow, the subhepatic parietal peritoneum is incised and followed by division of the triangular ligament of the liver. Grasping forceps are placed posterior to the liver and used to retract the right lobe ventrally.
8. The surgeon incises the pericolic gutter beginning at the cecal base, extending to the hepatic flexure, and ending at the duodenum.
9. The duodenum is then freed of its attachments to the mesenteric root. The entire length of the subhepatic vena cava is exposed to the level of the iliac bifurcation.
10. The renal vein is identified and a vessel loop placed around it. Dissection of the right border of the subhepatic vena cava is carried out along the entire length. The right gonadal vein is clipped and divided at its caval origin.
11. A vessel loop is then passed around the right renal artery.
12. The ureter lies anterior to the iliac vessels. It is located, controlled with a vessel loop, and dissected caudad to cephalad, also removing areolar tissue. Once dissection reaches the inferior pole of the kidney, Gerota's fascia is incised and dissection continues to the renal parenchyma.
13. Pararenal fat is removed and a dissection plane is created against the renal capsule. When the anterior surface of the kidney has been freed the superior pole is separated from the adrenal gland.
14. Dissection is now directed to the inferior renal pole to free the kidney posteriorly from pararenal fat. Once free it is rotated ventrally to expose the vessels already marked with the vessel loops. The vessels are circumferentially dissected, and the kidney is freed.
15. The surgeon clips the distal end of the ureter and divides it at its bifurcation with the iliac vessels. Copious diuresis generally occurs at this point.
16. A 6-cm incision is made just above the pubic symphysis. The aponeurosis is transversely divided, and the rectus abdominis muscles are retracted.
17. The retrieval bag is introduced directly into the peritoneal cavity. It is placed around the kidney and held firmly without obstructing the vessels.
18. The grasper that has been placed in the suprapubic area is used to keep the retrieval bag closed and exert enough traction on the renal vessels to promote maximum length.
19. The renal side of the renal artery is left open while the surgeon applies one or two clips on the aortic side. This is divided in two steps to ensure occlusion.
20. The vein is divided with a vascular stapler, including a small cuff of the vena cava to add extra length.
21. The suprapubic peritoneal opening is widened manually, allowing the kidney to be extracted. It is immediately perfused on ice with 4° C CUW solution. Vessels are individually perfused. The volume corresponds to about 300 ml. This continues until the outflow from the vein becomes completely transparent.
22. The surgeon irrigates the peritoneum and achieves hemostasis. A drain may be inserted into the peritoneal space for a short time postoperatively.
23. The wounds are sutured and dressings applied.

Transplant from a Cadaveric Donor. The ideal cadaveric donor is young, free from infection and cancer, normotensive until a short time before death, and under hospital observation several hours before death. Permission to harvest the donor kidney must be obtained from the family and the medical examiner after brain death has been unequivocally established. Awareness of existing state legislation in this complex area is advisable.

The donor is completely evaluated. The medical history is reviewed for any possible contraindications, such as chronic disease, ongoing systemic infection, IV drug abuse, malignancy, heart or lung disease, trauma to the donor organ, and the presence of human immunodeficiency virus (HIV). Laboratory studies include blood typing, urinalysis, urine and blood cultures, BUN, serum creatinine, CBC, hepatitis B antigen evaluation, Venereal Disease Research Laboratories (VDRL) for the presence of venereal disease, and p24 antigen capture assay for the presence of HIV antigen. Evaluation of arterial blood gases, electrolyte values, and liver enzymes is also necessary. Because of improvements in medical therapy, the only absolute contraindications to organ donation are HIV and metastasis.

Preoperative management of the cadaver donor is vital to the success of the transplant. Organ perfusion, oxygenation, and hydration must be maintained. Arterial blood gas (ABG) evaluation determines ventilatory support, and dopamine may be administered if fluids alone are not able to maintain an adequate systolic blood pressure. Urine output is monitored, and antibiotics may be administered to combat and prevent infection.

PROCEDURAL CONSIDERATIONS. After brain death has been established, the donor is taken to the OR with respiratory and cardiac function maintained mechanically. The donor is placed in the supine position and is prepared for a laparotomy. Anticoagulant and α-adrenergic receptor blocking agents are administered systemically during the procedure. Adequate renal perfusion and function are maintained with IV fluids and diuretics.

Instruments and equipment are the same as those for nephrectomy, with the addition of Metzenbaum scissors, suture scissors, vascular forceps, DeBakey forceps, Dean hemostatic forceps, mosquito hemostats, DeBakey clamps, angled clip appliers with medium and large clips, bulldog clamps, vascular clamps, Deaver retractors, Harrington splanchnic retractors, vascular needle holders, a sternal saw or Lebsche knife and mallet, umbilical tapes, electrolyte solution (lactated Ringer's, Sachs, or Collins), cold packing in an iced basin until needed, an IV pole, IV extension tubes, a kidney basin with cold (4° C) IV saline solution, a three-way stopcock, an 18-gauge needle catheter, a centimeter ruler, the perfusion machine or kidney transplantation equipment, and ice.

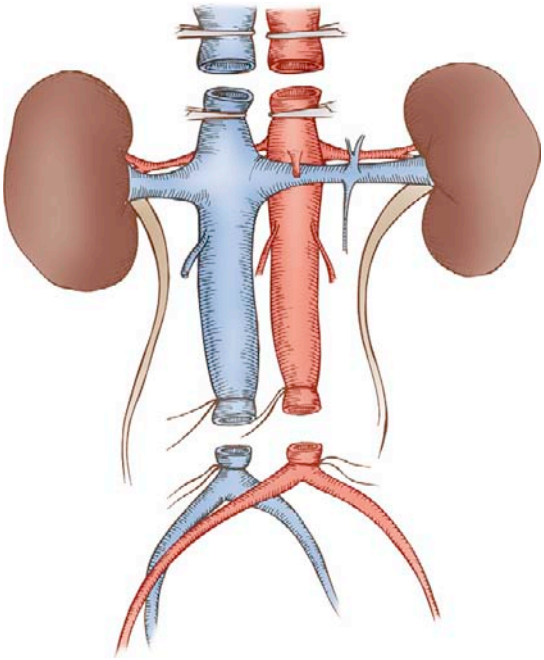


FIGURE 14-82 En bloc resection.

OPERATIVE PROCEDURE

1. The surgeon makes a midline incision from the xiphoid process to the symphysis pubis with bilateral supraumbilical transverse extensions through the skin, subcutaneous layer, fascia, and muscle.
2. Hemostasis is obtained with clamps, ties, suture ligatures, and electrocoagulation.
3. The kidney, renal vessels, and ureter are carefully dissected with Metzenbaum scissors, DeBakey forceps, and Dean hemostatic forceps.
4. The anesthesia provider administers 15,000 units of heparin sodium intravenously 5 to 10 minutes before the renal vessels are clamped.
5. The usual method of resection is en bloc resection (harvesting of donor kidneys) (Figure 14-82), which involves the removal of sections of the inferior vena cava and aorta with both kidneys in continuity.
6. The surgeon makes an incision along the route of the small bowel mesentery up to the esophageal hiatus.
7. The entire GI tract, spleen, and inferior portion of the pancreas are mobilized by dividing the celiac axis and the superior mesenteric artery, exposing the entire retroperitoneal region.
8. Using vascular clamps, the surgeon clamps and divides the inferior vena cava and aorta below the renal vessels.
9. Lumbar tributaries are secured with metal clips and are divided.
10. The kidneys and ureters are freed from their surrounding soft tissues.
11. The ureters are divided distally at the pelvic brim.
12. The surgeon clamps and divides the suprarenal aorta and inferior vena cava at the level of the diaphragm, close to the bifurcation.
13. The vessels and kidney are severed and the aorta and vena cava ligated.
14. After removal of the kidneys, immediate perfusion with cold (4° C) CUW or electrolyte solution is carried out. The kidneys are placed in a container of cold saline solution and surrounded by saline slush in an insulated carrier or placed on a hypothermic pulsatile perfusion machine for transport. While kidney perfusion is begun, the abdominal lymph nodes and spleen are removed for use in tissue typing.
15. The incision is closed with interrupted sutures, and artificial life-support systems are terminated. The perioperative nurse cares for the patient's body, preserving privacy, dignity, and humanity at the patient's death.

Transplant Recipient. Each potential recipient is judged individually in regard to kidney transplantation. Most persons younger than 55 years are acceptable; older patients are less tolerant of postoperative complications. Contraindications for renal transplantation include (1) systemic disease that precludes major surgery, (2) oxalosis (a metabolic disorder), (3) a positive HLA cytotoxic antibody screen, (4) untreatable cardiovascular disease, (5) active cancer, and (6) noncompliance (Ibrahim and Kasiske, 2008). If required, a patient may need to undergo bilateral nephrectomy before renal transplantation for uncontrollable hypertension, for kidney infections, or for reflux when there is a significant history of infections. Occasionally a large polycystic kidney may need to be removed to create a space for the new kidney. Splenectomy may be performed at this time to improve leukopenia and enhance the effects of myelosuppressive and immunosuppressive drugs.

The transplant recipient requires optimal nutritional support and adequate dialysis. All potential sources of infection must be treated. Most commonly these include teeth, bladder, nasal sinuses, and skin. The patient may need a short hemodialysis to control fluid overload or electrolyte imbalances. A repeat cytotoxic crossmatch with fresh serum specimens should follow hemodialysis. Preoperative antibiotics are commonly administered. Other important diagnostic tools for preoperative evaluation are chest x-ray examination, abdominal ultrasonography, voiding cystourethrography, liver function studies, hematologic assays, and serum values for screening hepatitis, HIV, and viral diseases.

PROCEDURAL CONSIDERATIONS. The perioperative nurse positions the patient in the supine position. A Foley catheter with an attached Silastic stenting catheter is inserted into the bladder by sterile technique. From 50 to 75 ml of antibiotic solution is instilled into the bladder through a sterile, catheter-tipped syringe, allowed to remain for 20 minutes, and drained. The patient is prepped from nipples to knees and draped.

OPERATIVE PROCEDURE

1. The surgeon makes a curved right lower quadrant incision through the skin, subcutaneous layer, fascia, and muscle.
2. Bleeding is controlled with clamps, ties, and electrocoagulation.
3. The inferior epigastric vessels are divided between suture ligatures.
4. Retroperitoneal dissection is performed by mobilizing the peritoneum superiorly and medially.
5. A Balfour self-retaining retractor is placed in the wound for exposure, and a wide Deaver retractor used to reflect the peritoneum superiorly and medially.

6. Using Metzenbaum scissors and DeBakey forceps, the surgeon dissects along the entire length of the hypogastric artery and the external and common iliac arteries to the bifurcation of the aorta, continuing down the internal iliac artery.
7. The internal iliac artery is ligated distally and divided, with proximal control maintained by a vascular clamp.
8. The iliac vein may be dissected free by ligating and dividing the internal iliac venous branches with 3-0 nonabsorbable sutures or ligating clips. More commonly, only the hypogastric artery and that portion of iliac vein to be anastomosed are dissected free.
9. The donor kidney is brought into the operative field and placed in cold (4° C) IV saline solution.
10. The surgeon uses mosquito hemostats, 4-inch DeBakey forceps, and curved and straight fine scissors to make the necessary alterations on the donor kidney vessels to facilitate the anastomoses.
11. The donor kidney is returned to the cold IV saline solution until the time of the anastomosis.
12. Two angled DeBakey vascular clamps are placed on the internal iliac vein.
13. A #11 blade is used to make a 1-cm incision in the iliac vein between the clamps.
14. The vessel is rinsed with heparin sodium solution (10 units/ml) in the Asepto syringe.
15. Angled Potts scissors are used to extend the incision to accommodate the donor renal vein.
16. The donor kidney is placed in a 3-inch by 10-inch, cold saline–soaked stockinette, with the renal vessels leaving from a hole in the side. Use of the stockinette prevents direct contact with the kidney and therefore trauma.
17. The surgeon performs the anastomosis of the donor kidney renal vein to the side of the recipient's iliac vein with 5-0 double-armed vascular sutures.
18. In like manner the renal artery is anastomosed end-to-end with the proximal portion of the internal iliac artery using 5-0 vascular sutures.
19. Before placing the final sutures, the vessels are irrigated proximally and distally with heparin sodium solution by using the 10-ml syringe attached to a catheter.
20. The stockinette is removed for adequate visualization of the entire kidney. The angled DeBakey clamps are removed from the venous vessels, and the anastomosis is checked for leakage.
21. The clamps on the internal iliac artery are then released, and the anastomosis is checked.
22. Meticulous inspection is made of the hilum and surface of the kidney for bleeding and infarction.
23. The anesthesia provider administers diuretics intravenously as needed.
24. Attention is then directed to the ureter and bladder.
25. Two long Martius forceps are used to grasp the anterior bladder wall.
26. Using a scalpel with a #10 knife blade, the surgeon makes a 4-cm anterior incision.
27. Two narrow Harrington retractors and one narrow Deaver retractor are inserted into the bladder for exposure.
28. The ureter is passed through the bladder wall and tunneled suburothelially for 2 to 2.5 cm.
29. The surgeon sutures the spatulated end of the ureter into the bladder urothelium with four to six 4-0 or 5-0 atraumatic absorbable sutures, creating a ureteroneocystostomy.
30. A 5F pediatric infant feeding tube is passed through the ureteroneocystostomy, up to the renal pelvis, and out through the urethra with the Foley catheter. This stenting catheter will remain in place for 36 to 48 hours to ensure ureteral patency during a period in which ureteral edema may occur.
31. Retractors are removed, and the bladder is closed in three layers.
32. Continuous 4-0 absorbable suture is used for urothelial closure and interrupted 2-0 absorbable suture for closure of bladder muscles.
33. An overlapping layer of 2-0 nonabsorbable material is used to bury the suture line.
34. The bladder is irrigated with an antibiotic solution to check for leaks.
35. The renal anastomoses are again checked for bleeding.
36. The surgeon places three metal clips on the superior, inferior, and lateral aspects of the kidney to radiographically measure renal size and determine postoperative swelling.
37. Retractors are removed from the incision.
38. Closed-wound suction drains are inserted into the wound, exteriorized through the skin laterally, and secured with 2-0 nonabsorbable suture on a cutting needle.
39. Muscle and fascial layers are closed with a single layer of 0 nonabsorbable sutures on a large atraumatic needle.
40. The subcutaneous layer is closed with 3-0 absorbable sutures on an atraumatic needle.
41. Skin closure is accomplished with skin staples, and dressings are applied.
42. The bladder is irrigated with 50 to 75 ml of antibiotic solution to prevent infection and free any blood clots.

Adrenalectomy

Adrenalectomy is partial or total excision of one or both adrenal glands. It may be performed for several reasons: hypersecretion of adrenal hormones; neoplasms of the adrenal gland; secondary treatment of neoplasms elsewhere in the body that depend on adrenal hormonal secretions, such as carcinoma of the prostate and breast; and pheochromocytoma.

Care of the patient with pheochromocytoma carries with it particular concerns for the perioperative nurse. These patients are subject to extreme elevations in blood pressure, often accompanied by tachycardia, and hypovolemic states that can induce vascular collapse. If an adrenal tumor is being excised, early ligation of the adrenal vein is crucial in avoiding a sudden blood pressure elevation from the manipulation of the gland. After tumor removal there will be a rapid drop in blood pressure that can be minimized by maintenance of blood volume and administration of norepinephrine. With bilateral adrenalectomy, cortisone replacement will be instituted.

Procedural Considerations. Adrenalectomy may be approached as a laparoscopic or an open procedure. The laparoscopic approach is generally associated with less morbidity and shorter hospital stays. For unilateral adrenalectomy, the patient may be placed in the lateral or supine position, depending on the intended approach. If both glands are to be removed the supine or prone position is selected. The prone position is especially useful for a known disorder, such as aldosteronism, localized benign lesions, and solitary adenomas of Cushing's disease, and for debilitated patients with an advanced neoplasm.

The setup for a lateral approach is like that described for nephrectomy, including rib resection instruments, vascular instruments, and vessel clips and appliers. The setup for an abdominal approach is like that described for laparotomy, including vascular instruments, extralong scissors, tissue forceps, Rochester-Péan forceps, Mixter forceps, and needle holders. Penrose tubing is needed for retraction. Vessel clips and appliers also may be needed, as well as various sizes of nonabsorbable braided sutures.

The setup for the posterior approach is like that described for the lateral approach. The patient is placed prone in a 35-degree jackknife position with the kidney rest under the inferior margin of the anterior rib cage. Both arms should be carefully extended cephalad with adequate support under each shoulder.

Operative Procedure

LAPAROSCOPIC APPROACH

1. A 1.5-cm incision is made at the tip of the twelfth rib. The thoracolumbar fascia is entered by blunt dissection, and the 12-mm balloon dissector is placed behind Gerota's fascia and along the anterior axillary line. The balloon is inflated with 800 ml of saline, and the laparoscope is used to confirm balloon placement.
2. The operating balloon trocar is then placed in this position.
3. The surgeon inserts two 10-mm trocars on each side of the initial trocar, along the costal margin, in the anterior and posterior axillary line.
4. The fourth trocar is placed along the posterior costal margin.
5. Dissection begins near the renal hilum, incising into Gerota's fascia.
6. The surgeon identifies, clips, and divides the adrenal arteries.
7. The anterior, lateral aspect of the gland is freed from the upper pole of the kidney.
8. The adrenal vein is clipped and divided.
9. The surgeon mobilizes the posterior, superior, and anterior surfaces of the adrenal gland. A fan retractor is employed to retract the pancreas and spleen, or pancreas and liver, depending on which side the gland is being excised.
10. The adrenal branches of the inferior phrenic vessels and any accessory vessels are clipped and divided. The gland is removed through the original port using a retrieval sac. Hemostasis is achieved. The trocars are then sequentially removed, the incisions closed, and dressings applied.

LATERAL APPROACH—OPEN

1. A flank, thoracolumbar, or transthoracic incision is performed as described for nephrectomy.
2. The rib underlying the chosen approach is resected or deflected for optimum exposure of the upper pole of the kidney.
3. Entry is between the eleventh and twelfth ribs in a flank approach, the tenth and eleventh ribs in a thoracolumbar approach, and the ninth and tenth ribs in a transthoracic approach.
4. An opening is made with scissors through the transverse fascia.
5. The pleura and diaphragm are protected with moist laparotomy packs, and Gerota's fascia is incised to expose the kidney and adrenal gland.
6. The surgeon identifies the gland and dissects it free from the upper pole of the kidney with scissors and Babcock forceps.
7. The blood supply of the gland is identified, clamped or clipped, fescia and divided. Bleeding vessels are ligated.
8. To release the gland, the left adrenal vein, a branch of the left renal vein, is separated by clamping and cutting. The right adrenal vein, a tributary of the vena cava, is also divided. Fine vascular sutures may be required to repair inadvertent injury to the vena cava.
9. When hemostasis has been ensured, the wound is closed sequentially in layers: muscle, fascia, subcutaneous tissue, and skin. Dressings are then applied.

ABDOMINAL APPROACH

1. The abdominal wall is incised with an upper abdominal incision, and the peritoneal cavity is opened and explored.
2. Hemostasis is established.
3. The abdominal wound is retracted, and the surrounding organs are protected with moist laparotomy packs.
4. The surgeon opens the retroperitoneal area near the diaphragm on the left side, exposing the renal fascia.
5. The renal fascia is opened to reveal the left kidney and adrenal gland.
6. Using blunt and sharp dissection, the surgeon frees the adrenal gland from the kidney, clamps all bleeding vessels, and ligates them with 3-0 nonabsorbable sutures.
7. After all bleeding is controlled, the surgeon replaces the kidney in the renal fascia, and closes it with interrupted 0 absorbable sutures.
8. The peritoneum is closed over the left kidney and renal fascia.
9. The abdominal retractors are rearranged to provide access to the peritoneum over the right kidney and adrenal gland. Care must be taken to prevent trauma to the liver.
10. The surgeon repeats the procedure on the right side, taking care to clamp and ligate the short adrenal vein.
11. The abdomen is inspected for bleeding vessels, which are clamped and ligated.
12. The wound is closed and dressings applied.

POSTERIOR APPROACH

1. The surgeon makes an incision over the eleventh or twelfth rib.
2. The periosteum is elevated, avoiding the nerve and vessels on the inferior margin.
3. The diaphragm and pleura are displaced superiorly, and the appropriate rib is resected.
4. Hemostasis is achieved.
5. Gerota's fascia is incised, and through sharp and blunt dissection the surgeon exposes the posterior aspect of the upper pole of the kidney.
6. The upper pole is mobilized, and a padded retractor is placed to deflect the kidney downward for the approach to the adrenal gland.
7. The suprarenal fat is meticulously dissected.
8. Vessel clips are used for control of smaller vessels.
9. Dissection continues superiorly, laterally, and inferiorly while the integrity of the hilum of the adrenal gland is maintained.
10. With right-angled clamps, the adrenal vein and artery are freed, divided, and ligated with 0 or 2-0 braided nonabsorbable ties.
11. Babcock clamps are employed for manipulation and removal of the adrenal gland.
12. Bleeding is controlled, and the wound is inspected for injury to renal structures.
13. The surgeon closes Gerota's fascia with interrupted absorbable sutures.
14. The wound is closed and dressings applied.

REFERENCES

American Cancer Society: *Cancer facts and figures 2008*, Atlanta, 2008, American Cancer Society.

American Medical Systems (AMS): Erectile dysfunction, 2009, available at www.americanmedicalsystems.com/prof_erectile_restoration_product_objectname_prof_male_700_inflatable.html. Accessed May 17, 2009.

Appell RA, Winters JC: Injection therapy for urinary incontinence. In Wein AJ, editors: *Campbell-Walsh urology*, ed 9, Philadelphia, 2007, Saunders.

Association of periOperative Registered Nurses (AORN): Creating a patient safety culture guideline. In *Perioperative standards and recommended practices*, Denver, 2009, The Association.

Denholm B: Tucking patient's arms and general positioning, *AORN J* 89(4):755–757, 2009.

Epstein JL: Pathology of prostatic neoplasia. In Wein AJ et al, editors: *Campbell-Walsh urology*, ed 9, Philadelphia, 2007, Saunders.

Fitzpatrick JM: Minimally invasive and endoscopic management of benign prostatic hyperplasia. In Wein AJ et al, editors: *Campbell-Walsh urology*, ed 9, Philadelphia, 2007, Saunders.

Gayer G: Minimally invasive management of urolithiasis, *Semin Ultrasound CT MRI* 27:139–151, 2006.

Gonzalgo ML: Minimally invasive surgical approaches and management of prostate cancer, *Urol Clin N Am* 35:489–504, 2008.

Han M, Partin AW: Retropubic and suprapubic open prostatectomy. In Wein AJ et al, editors: *Campbell-Walsh urology*, ed 9, Philadelphia, 2007, Saunders.

Ibrahim HN, Kasiske BL: Donor and recipient issues. In Brenner BM, Levine SA, editors: *Brenner & Rector's the kidney*, ed 8, Philadelphia, 2008, Saunders.

Ignatavicius DD: Care of male patients with reproductive problems. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care*, ed 6, St Louis, 2010, Saunders.

Lamm DL et al: Bladder cancer: current optimal intravesical treatment, *Urol Nurs* 25(5):323–332, 2005.

Langenhuijsen JF et al: Cryosurgery for prostate cancer: an update on clinical results of modern cryotechnology, *Eur Urol* 55:76–86, 2009.

Lipshultz LI et al: Surgical management of male infertility. In Wein AJ et al: *Campbell-Walsh urology*, ed 9, Philadelphia, 2007, Saunders.

Novick AC, Fergany A: Renovascular hypertension and ischemic nephropathy. In Wein AJ et al: *Campbell-Walsh urology*, ed 9, Philadelphia, 2007, Saunders.

Rigdon JL: Robotic-assisted laparoscopic radical prostatectomy, *AORN J* 84(5):760–770, 2006.

Scott RD: The direct medical costs of healthcare-associated infections in U.S. hospitals and the benefits of prevention. March 2009, Centers for Disease Control and Prevention, available at www.cdc.gov/ncidod/dhqp/hai.html. Accessed May 17, 2009.

Sherman ND, Amundsen CL: Current and future techniques of neuromodulation for bladder dysfunction, *Curr Urol Rep* 8(6):448–454, 2007.

UNOS: Critical Pathway for the Organ Donor 2009, available at www.unos.org/qa.asp. Accessed May 27, 2009.

Young E et al: Perioperative fluid management, *AORN J* 89:167–178, 2009.

CHAPTER 15

Thyroid and Parathyroid Surgery

JOANNE WENTZELL

The first documented thyroid surgery occurred in the twelfth century (History box). Today surgeons continue to perform surgical procedures on the thyroid gland for various underlying causes. Surgery ranges from lobectomy and isthmectomy for papillary microcarcinomas (lesions smaller than 1 cm) to near-total and total thyroidectomies for symptomatic multinodular goiters. Technologic advances have added new approaches to thyroid and parathyroid surgery, such as minimally invasive surgery (MIS) techniques.

Surgical Anatomy

Thyroid Gland

The thyroid gland (Figure 15-1) is a highly vascular organ that lies in the anterior portion of the neck, deep to the paired strap muscles, resting on the midline of the trachea. It is attached to the cricoid and trachea by the ligament of Berry. The inferior border of the thyroid varies and may be located above or below the sternal notch. It consists of right and left lobes united by a middle portion, the isthmus, and it weighs approximately 20 g (Figure 15-2). The isthmus is situated near the base of the neck, between the second and fourth tracheal rings, and the lobes lie beside the larynx, trachea, and esophagus. The pyramidal lobe, a long, thin projection of thyroid tissue protruding cephalad from the isthmus, is found in about 30% of patients at surgery; it is the vestige of the embryonic thyroglossal duct and migrates from the foramen cecum at the base of the tongue. If the migratory tract fails to degenerate, a fistula or cyst may be present (Loevner and Mukherji, 2008).

Blood supply to the thyroid is from the superior thyroid artery, which originates from the external carotid artery, and from the inferior thyroid artery, which originates from the thyrocervical trunk of the subclavian artery. The points at which these two arteries enter the thyroid gland are referred to as "poles" of the thyroid and are important anatomic landmarks during surgery. The thyroid gland is drained by three pairs of veins (superior, middle, and inferior thyroid veins). Occasionally a single thyroid artery (thyroidea ima) may arise directly from the arch of the aorta or the innominate artery and rise in front of the trachea to enter the midline of the gland inferiorly.

The recurrent laryngeal nerve, a branch of the vagus nerve, innervates the intrinsic muscles of the larynx. The right recurrent laryngeal nerve loops under the subclavian artery and ascends in an oblique direction lateral to the tracheoesophageal groove. The recurrent laryngeal nerve contains both motor and sensory fibers. The motor component innervates the abductor muscles of the true vocal cords. The sensory component supplies sensation to the larynx below the vocal cords. During surgery, care is taken to identify and protect this nerve. Immediate hoarseness occurs if the nerve is divided on one side. If the recurrent nerve is injured bilaterally, acute paralysis of both vocal cords may obstruct the airway and require emergency tracheotomy. Injury to the external branch of the superior laryngeal nerve, which innervates the cricothyroid muscle, results in difficulty shouting or singing high notes.

The thyroid gland produces three hormones: thyroxine (T_4) and triiodothyronine (T_3) (together known as the *thyroid hormones [TH]*) and calcitonin. T_3 and T_4 cannot be synthesized without iodine. Calcitonin increases calcium storage in the bone and decreases blood calcium levels. The primary function of thyroid hormones is to regulate energy metabolism, but they also play an important role in growth and development. Thyroid-stimulating hormone (TSH) is synthesized by the anterior pituitary, and stimulates the production and release of thyroid hormones and the uptake of iodine.

Parathyroid Gland

The parathyroid glands usually consist of four small, mahogany-to-yellow, flat, ovoid masses (Figure 15-3) (Gauger and Doherty, 2004). Normal parathyroid glands are generally small, lobular, and yellow in color, about the size of a lentil bean. It can be challenging to differentiate the gland from a lobule of fat, a thyroid nodule, or lymph node. Thyroid adenomas generally, although not always, tend to be larger, asymmetric, and more of a red-brown hue than normal parathyroids (Figure 15-4). The upper pair of glands lies in proximity to the posterior portion of the superior pole of the thyroid; the lower pair usually (about 60% of the time) lies near the posterior lateral aspect of the lower pole of the thyroid. Ectopic parathyroid glands, more common in the inferior parathyroid glands, may be found in the superior mediastinum, especially within the thymus and as low as the pericardium. Parathyroids may also be buried under the strap muscle, in the carotid sheath, or embedded in the thyroid beneath the capsule (Loevner and Mukherji, 2008). Each parathyroid gland measures approximately 3 mm × 3 mm × 3 mm and generally weighs less than 50 mg; the upper glands are generally smaller than the lower ones. Both the upper and lower parathyroid glands receive their blood supply from the inferior thyroid artery (Figure 15-5). As the blood supply to the superior parathyroid stems from that of the supply to

HISTORY

Formerly Hazardous, Thyroid Surgery Now Minimally Invasive and Focused

Since 2700 BC, long before the thyroid gland was identified, goiters (from Latin *gutter* for "throat") have been described. Europeans living 2000 years ago, especially those living in the Alps, noted a swelling in the neck and called it *bronchocele,* ancient Greek for "tracheal out-pouching." Thousands of years later, Hieronymus Fabricius ab Aquapendente in 1619 recognized that goiters arose from the thyroid gland.

With the Italian Renaissance came an expansion of inquiry into the human body. During this time, the thyroid gland was identified. Around 1500 Leonardo da Vinci depicted the gland and in 1543 Vesalius called the thyroid gland the "laryngeal glands." da Vinci's drawings portrayed the thyroid as two separate glands on either side of the larynx. Thomas Wharton, with his 1656 publication *Adenographia,* is credited for replacing the term "laryngeal gland" with the term "thyroid gland" (Greek *thyreoeides,* for "shield shaped").

In 1170 Roger Frugardi first described thyroid surgery. Thyroid surgery was hazardous, with death rates of more than 40%. High death rates continued until the 1800s when increased knowledge and advances in general anesthesia, antisepsis, and hemostasis became the norm.

In the late 1800s two notable thyroid surgeons—C.A. Theodor Billroth (1829 to 1894) and Emil Theodor Kocher (1841 to 1917)—revolutionized the treatment of thyroid diseases. Despite Billroth's earlier success with thyroidectomies, Kocher is regarded as the father of thyroid surgery. Kocher performed more than 2000 thyroid surgeries in the late 1800s, with only a 4.5% death rate, and he received the Nobel Prize in 1909 for his contributions to this field. In 1914 Kendall isolated the hormone *thyroxine (T_4).* Since 1941 thyroidectomy as treatment of thyroid mass (goiter) has become less frequent because of the use of radioactive iodine (RAI) and antithyroid drugs, which reduce the activity of the thyroid gland.

Over the last 10 years new technology and techniques have been introduced that have greatly improved thyroid and parathyroid surgeries. Minimally invasive and focused approaches have enhanced and refined treatment and surgery for thyroid and parathyroid disease.

Modified from Kaplan EL: Thyroid and parathyroid. In Schwartz SI et al, editors: *Principles of surgery,* ed 6, New York, 1994, McGraw-Hill; Sadler GP et al: Thyroid and parathyroid. In Schwartz SI et al, editors: *Principles of surgery,* ed 7, New York, 1999, McGraw-Hill; Sawin CT: The heritage of the thyroid. In Braverman LE, Utiger RD, editors: *Werner and Ingbar's the thyroid: a fundamental and clinical text,* ed 7, Philadelphia, 1996, Lippincott-Raven; Yousem DM, Scheff AM: Thyroid and parathyroid. In Som PM, Curtin AD, editors: *Head and neck imaging,* ed 3, St Louis, 1996, Mosby.

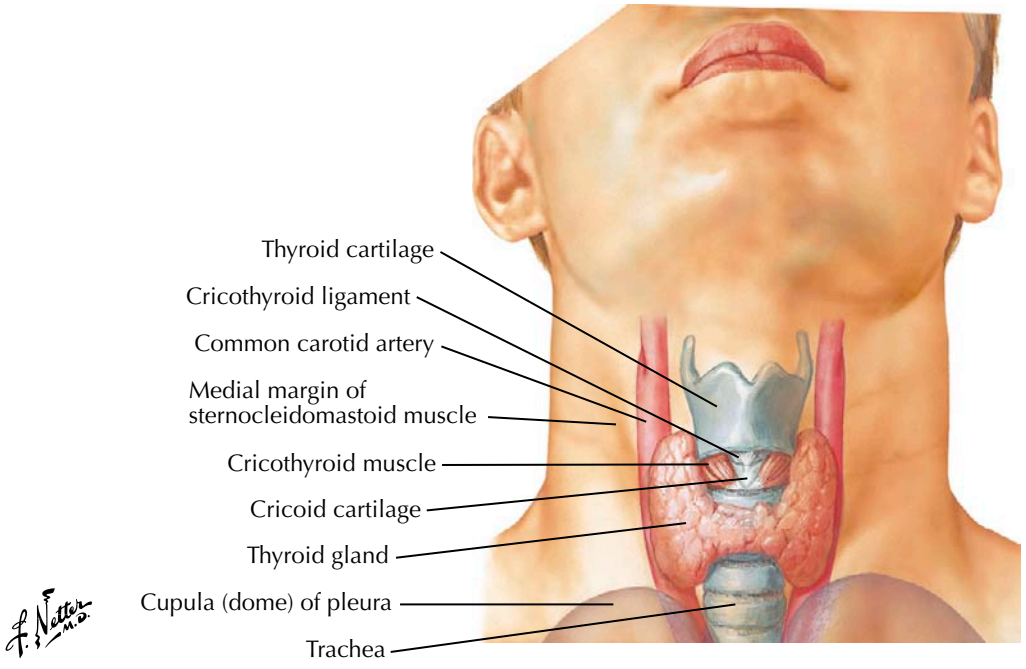


FIGURE 15-1 The thyroid gland.

the inferior parathyroid, disrupting supply to the inferior parathyroid necessarily compromises the supply to the upper parathyroid.

The parathyroid glands secrete parathyroid hormone (PTH), an antagonist to calcitonin. Both PTH and calcitonin work together to maintain calcium homeostasis by increasing calcium removal from storage in bone and increasing absorption of calcium by the intestines.

Perioperative Nursing Considerations

Assessment

Preoperatively, the patient with hyperthyroidism most likely has had appropriate drug therapy that has returned thyroid hormone levels and metabolic state to normal (Elberling et al, 2004).

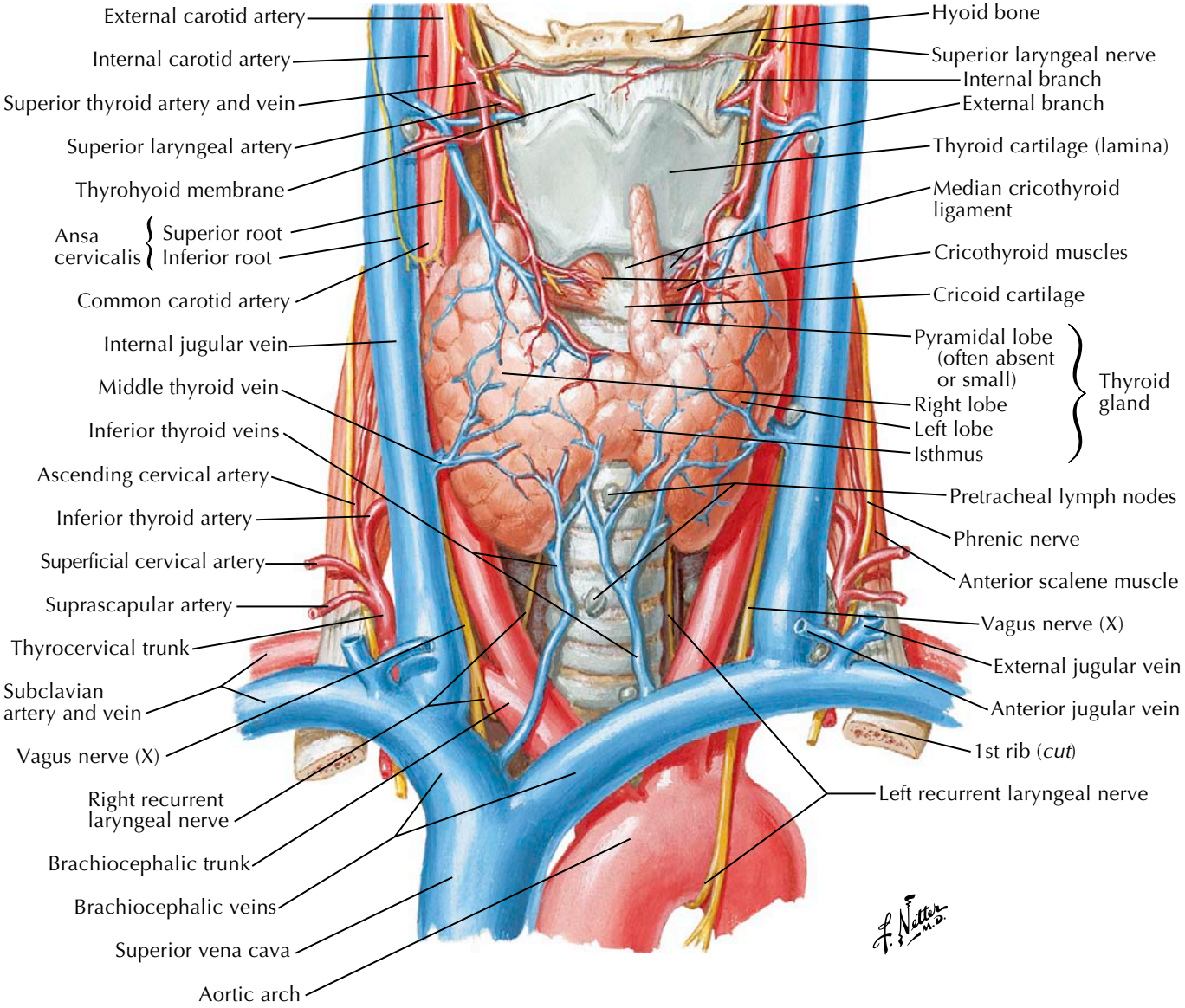


FIGURE 15-2 Thyroid in relation to surrounding structures.

Nonetheless, the perioperative nurse should assess for any symptoms that relate to accelerated metabolism (Box 15-1). The patient's baseline vital signs should be noted for an abnormally elevated resting pulse rate, elevated systolic blood pressure, and cardiac symptoms, such as palpitations or atrial fibrillation. Atrial fibrillation is the most common cardiac complication of hyperthyroidism (Frost et al, 2004). For this reason, the perioperative nurse should confirm whether anticoagulation medication is being taken. The patient's cardiac and respiratory rates, muscle strength, elimination patterns, history of weight loss, heat intolerance, and emotional status should all be noted. The patient, especially a young one, may be anxious about the disease state and the success of surgery, and may express concerns about neck surgery and its cosmetic results. Patients who are concerned about body image should have the opportunity to discuss these issues with the perioperative nurse. Vocalists may be especially concerned about whether surgery will adversely affect their voice. The anesthesia provider may choose to use an endotracheal tube with a smaller diameter than usual in order to minimize any trauma to the vocal cords. Skin integrity should be determined; patients with hyperthyroidism may have finely textured skin and edema in the lower extremities, placing them at higher risk for skin breakdown. The most typical complications specific to thyroid surgery, although infrequent, are hypoparathyroidism and injury to the recurrent laryngeal nerve. Preoperative assessment of the patient's voice tone and quality should therefore be noted.

Large thyroid nodules may cause tracheal shift and present a challenge to the anesthesia provider for intubation and airway management. The size of thyroid enlargement should be noted preoperatively and steps taken to prepare the OR in anticipation of a difficult intubation. The "difficult airway" anesthesia cart should be in the room along with, preferably, two anesthesia providers and the circulating nurse standing by to assist with induction. The anesthesia provider will not extubate a patient who has been difficult to intubate until the anesthesia

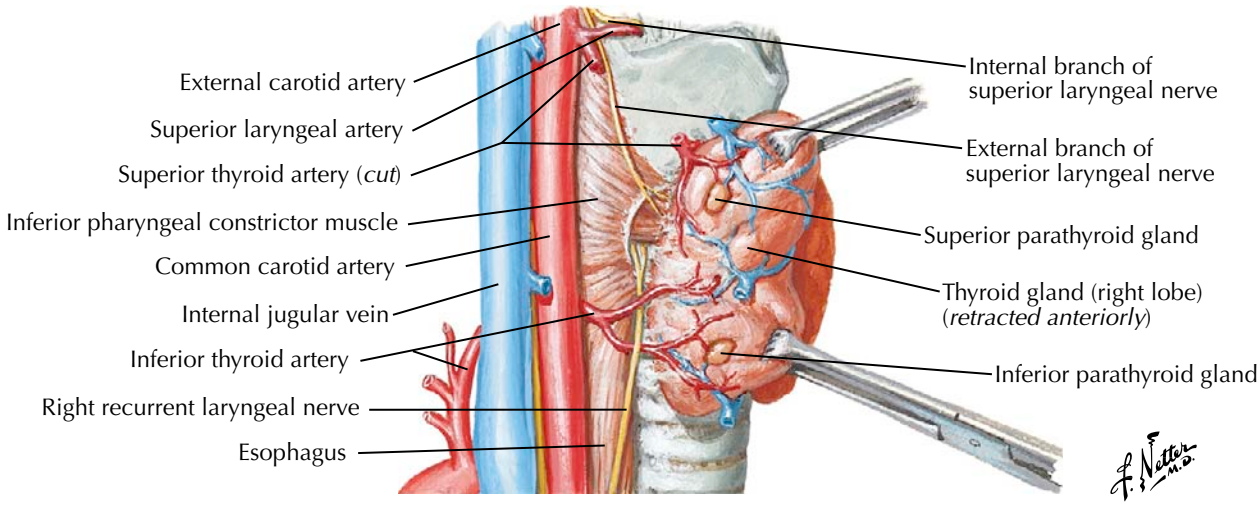


FIGURE 15-3 Right lateral view of thyroid and parathyroids. Note their relation to each other and to the trachea.

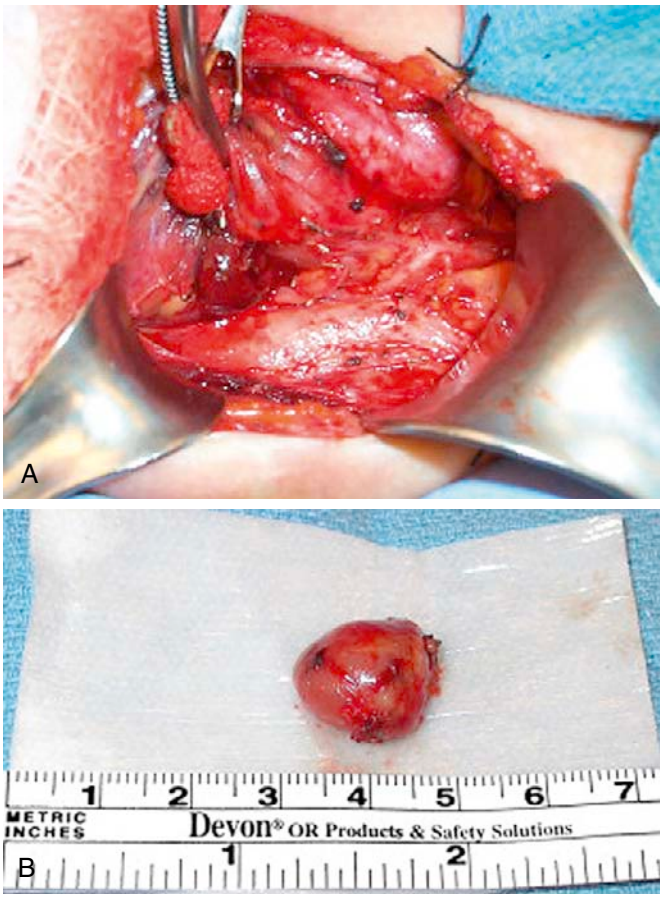


FIGURE 15-4 **A**, A right upper parathyroid adenoma in situ. The thyroid gland is retracted to the midline. The recurrent laryngeal nerve enters the operative field inferiorly and tracks superiorly in the tracheoesophageal groove. The carotid sheath lies lateral to the nerve. The adenoma is the lobular mahogany mass located at the superior pole of the thyroid. **B**, Parathyroid adenoma after removal.

gases have dissipated and the level of consciousness is such that the patient can protect his or her own airway and maintain oxygen saturation with spontaneous breathing. If there is concern about postoperative edema and ensuing airway obstruction from a difficult induction, the anesthesia provider will administer steroids intraoperatively and may chose to leave the tube in postoperatively.

Grossly enlarged thyroids are also more difficult to excise, and intraoperative bleeding is more common and profuse. Finger dissection may be unavoidable and small vessels that retract and contract may rupture during emergence or postoperatively, leading to hemorrhage. Hemorrhage may cause tracheal compression and airway compromise. Patients with thyroidectomies of larger glands generally require a drain and must be closely monitored during emergence from anesthesia and postoperatively. Excessive swelling at the operative site, with or without poor air exchange, must be treated as a potentially life-threatening emergency. The instrument table should be kept sterile until the patient is extubated and out of the room patients who present with large thyroids and/or challenging airway management. A tracheostomy tray with tubes should be readily available should an emergency tracheostomy be necessary.

In addition to clinical signs and symptoms, results of diagnostic tests should be reviewed (Evidence for Practice). Tests performed most commonly before thyroid surgery include measurements of TSH, T_3, and T_4 levels; radioisotope or ultrasonic scans; and a current electrocardiogram (ECG). Adult normal ranges for TSH, T_3, and T_4 levels are as follows (Pagana and Pagana, 2009):

- TSH: 2 to10 microunits/ml
- T_3: 20 to 50 years old, 75 to 205 ng/dl; >50 years old, 40 to 180 ng/dl
- T_4: males, 4 to 12 mcg/dl; females, 5 to 12 mcg/dl; >60 years, 5 to 11 mcg/dl

Thyroid function tests are interpreted in light of the patient's clinical presentation. They complement the findings of the physical examination. The single best test to measure thyroid status in a given person is a TSH assay.

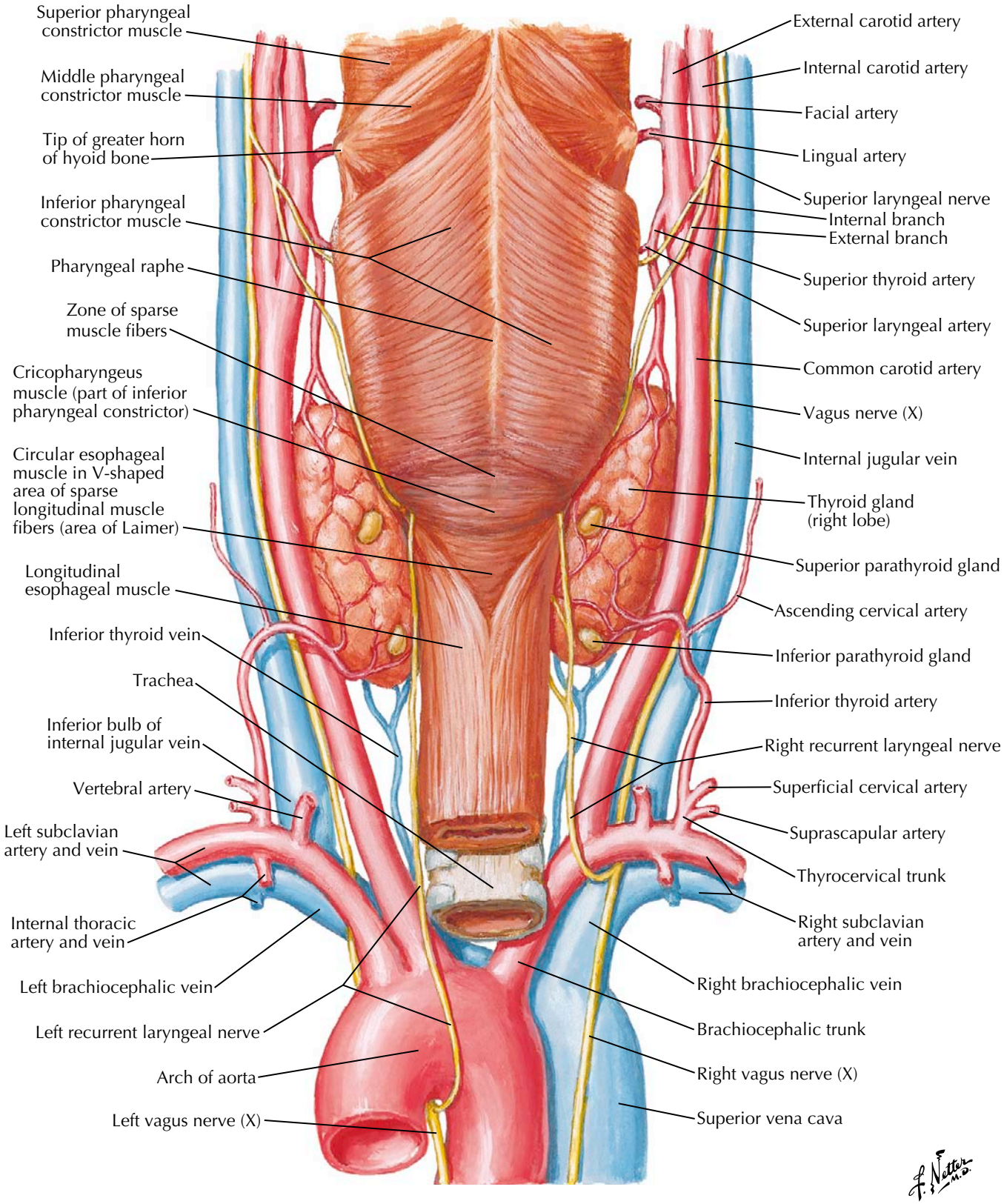


FIGURE 15-5 Posterior view of thyroid and parathyroids. Note relation to carotid sheath and esophagus. Note pathway of recurrent laryngeal nerves.

BOX 15-1

Common Symptoms and Signs of Thyroid Dysfunction

HYPOTHYROIDISM

- Fatigue
- Weight gain
- Cold intolerance
- Hair dryness or loss
- Dry skin
- Depression
- Hoarse voice
- Poor concentration
- Muscle stiffness and pain
- Edema
- Bradycardia
- Constipation
- Menstrual irregularity (especially heavy menses; infertility)

HYPERTHYROIDISM

- Vision changes—myopathy, ophthalmopathy, such as extraocular muscle enlargement, visual loss with prolonged optic nerve compression
- Emotional lability, mood changes
- Irritability
- Exercise intolerance
- Fatigue
- Weight loss
- Heat intolerance and flushing
- Hyperactivity—especially children
- Increased sweating
- Insomnia
- Tremor
- Muscle weakness
- Dyspnea
- Frequent bowel movements
- Menstrual irregularity (oligomenorrhea; infertility)
- More common in elderly—tachycardia and atrial tachydysrhythmias, palpitations, cardiomegaly

Modified from Roberts CG, Ladenson PW: Hypothyroidism, *Lancet* 363(9411):793-803, 2004; Surks MI et al: Subclinical thyroid disease: scientific review and guidelines for diagnosis and management, *JAMA* 291(2):228-238, 2004.

Thyroid Assessment. In addition to palpation of the thyroid gland for size, contour, consistency, lymph nodes, fixation, tenderness, and bruits (Wilson and Giddens, 2009), scans are used to clarify thyroid anatomy. CT and MRI scans are used to assess a thyroid with suspected malignancy for encroachment of the tumor outside the thyroid capsule into the adjacent tissue of the neck. Scans are the most effective means to evaluate local invasion of surrounding tissue.

While palpable thyroid nodules are present in 3% to 5% of healthy adults, ultrasound and autopsy studies show rates of more than 50%. Although most nodules are benign, 7% to 29% will be cancerous. Consequently, the most common endocrine malignancy is thyroid cancer, estimated to be the thirteenth most common cause of any new malignant neoplasm in the United States for 2007, ranking seventh in women (25,480 cases; 3.8%), while causing just over 1% of new cases in men. Prevalence figures are likely to increase further, as the yearly incidence of thyroid cancer has been growing exponentially from 7800 cases in 1974 to 33,550 cases in 2007 (Tuttle, 2007).

EVIDENCE FOR PRACTICE

Screening for Thyroid Dysfunction

A number of symptoms and signs are well-established manifestations of thyroid dysfunction (see Box 15-1). A thorough history and physical is indicated in screening for thyroid cancer. A history of being exposed to neck or whole-body radiation or being raised in iodine-poor areas should be assessed. A rapidly expanding neck mass, new onset of hoarseness, neck or ear pain, or cough are symptoms of concern. Patients with a fixed, immobile mass and/or hoarseness, dysphagia, or respiratory symptoms require CT or MRI imaging as part of evaluation. These symptoms may be indicative of metastasis (Loevner and Mukherji, 2008). Although calcifications were formerly considered a benign finding, some thyroid cancers demonstrate eggshell calcifications.

The American Association of Clinical Endocrinologists (AACE) practice guidelines for the diagnostic evaluation of hyperthyroidism and hypothyroidism recommend TSH assay as the single best screening test. Hyperthyroidism results in a lower-than-normal TSH level (suppressed TSH secretion). To diagnose hyperthyroidism accurately, TSH assay sensitivity, the lowest reliably measured TSH concentration, must be 0.02 milliinternational unit/liter or less.

Serum TSH level is the most sensitive test for detecting mild (subclinical) thyroid hormone excess or deficiency. An elevated serum TSH concentration is present in both overt and mild (subclinical) hypothyroidism. In the latter, the free thyroid hormone (fT_3 and fT_4) levels are, by definition, normal.

Hypothyroidism results from undersecretion of thyroid hormone. In the United States, hypothyroidism affects close to 11 million people each year. The most common cause of primary hypothyroidism is chronic autoimmune thyroiditis (Hashimoto's disease). The most valuable laboratory test is a sensitive measurement of TSH level. Clinical hypothyroidism is treated with levothyroxine replacement therapy. The AACE supports treating subclinical hypothyroidism if TSH levels are greater than 10 microunits/ml or if TSH levels are between 5 and 10 microunits/ml in conjunction with goiter or positive antibodies or both.

Serum TSH measurement is the single most reliable test to diagnose all common forms of hypothyroidism and hyperthyroidism, with high sensitivity (98%) and specificity (92%).

fT_3, Free triiodothyronine; *fT_4,* free thyroxine; *TSH,* thyroid-stimulating hormone.

Modified from American Association of Clinical Endocrinologists: Medical guidelines for clinical practice for the evaluation and treatment of hyperthyroidism and hypothyroidism, *Endocr Pract* 8(6):457-469, 2002; Loevner LA, Mukherji SK: *Thyroid and parathyroid glands: imaging, treatment, and beyond,* Philadelphia, 2008, Saunders; Mauk KL: Rooting out hypothyroidism in the elderly, *Nursing 2005* 35(12):65-66, 2005; Screening for thyroid disease: *Recommendation statement, U.S. Preventive Services Task Force* 140(2):125-127, 2004.

Thus thyroid cancer is poised to become one of the most common cancer diagnoses in living cancer patients (Grebe, 2009).

PREOPERATIVE TESTING

Thyroid Isotope Scan (Thyroid Scintigraphy). A thyroid nodule, the most common endocrine problem in the United States, is any abnormal growth of thyroid cells. Most nodules are discovered during routine physical examination, because they rarely are symptomatic. Imaging of the normal thyroid with radionuclide agents shows normal size, shape, position, and function of the thyroid, with no areas of decreased or increased

uptake. Nodules that are *hot* demonstrate increased uptake of radionuclide agent; this may indicate benign adenoma or localized toxic goiter. *Cold* nodules are hypofunctioning or nonfunctioning and may indicate cyst, nonfunctioning adenoma or goiter, lymphoma, localized area of thyroiditis, or carcinoma. Two commonly used agents in thyroid imaging are radioactive iodine and technetium 99m-pertechnetate ($^{99m}TcO_4^-$).

Ultrasonic Scan. Ultrasonic scans are the treatment of choice to evaluate thyroid nodules and are useful to determine the size and number of nodules within the thyroid as well as to monitor size progression during follow-up. Involvement of the vessels in the neck or mediastinum, although rare, can occur. It is critical that the surgeon and operative team know this before surgery. Radiologic evaluation frequently dictates the extent of the surgery. Several new ultrasonic techniques have been applied to the thyroid. The three-dimensional (3D) ultrasound has proven to be more accurate. Tissue harmonic imaging (THI) uses the first harmonic of the transmitted frequency for image formation and results in images with less "noise." These new techniques improve image clarity but do not improve lesion characterization.

Ultrasonography also helps to facilitate accurate needle placement and sampling of the target nodule during fine needle aspiration (FNA). Ultrasound-guided FNA with cytologic evaluation remains the mainstay for palpable and incidentally found thyroid nodules (Loevner and Mukherji, 2008).

Fine Needle Aspiration. FNA is the most useful diagnostic tool currently available in the management of thyroid nodules. It is the accepted standard of care for all patients who have palpable nodules with normal functioning thyroids, has high accuracy and low risk, and is cost-effective (Lansford and Teknos, 2006). The procedure is usually performed under ultrasound guidance, but may be performed in the surgeon's office. Several samples are usually taken from various parts of the nodule. Pathologic examination of FNA specimens reveals a benign nodule in 70% of biopsies, a nondiagnostic or inadequate biopsy 15% of the time, a suspicious nodule in 10% of cases, and malignancy in 5% of biopsies (*American Thyroid Association,* 2005). A suspicious nodule usually implies a follicular neoplasm, which can be benign or malignant, and requires removal for histologic evaluation.

Patient preparation for FNA should include the following information:

- You will be lying down for the procedure and may expect coldness on your neck from the prepping solution.
- Local anesthesia may or may not be used.
- Once the prick of the needle is felt, no talking, swallowing, or moving is allowed.

FNA may be an emotionally stressful procedure for the patient. Vials of ammonia should be kept in the room in case the patient feels faint. Lowering the head (using Trendelenburg's position or sitting with the head down) is also important to treat vasovagal syncope. Postprocedure education should include (1) the necessity of refraining from using aspirin or aspirin-containing medications or nonsteroidal antiinflammatory drugs (NSAIDs) for the next 24 hours, and (2) the expectation of seeing a half-dollar–size bruise at the FNA site. There are no restrictions on food or activity.

PREOPERATIVE PATIENT EDUCATION. Preoperative patient education for partial or total thyroidectomy includes an explanation of perioperative events, discussion of the incision site and type of dressing to be used, and explanation of any drains, if anticipated. Pain assessment and pain management therapy are reviewed. Patients are advised that there are various ways of protecting their eyesight during surgery, and if ointment is used, they can expect temporary blurred vision when they first open their eyes. If sequential compression devices (SCDs) are to be used for prophylaxis of deep vein thrombosis (DVT), their use and sensation is explained. The patient is encouraged to flex and extend the neck slowly early in the postoperative period. A baseline description of vocal cord function should be noted preoperatively. (For further discussion of patient education, see Patient and Family Education and Discharge Planning section later in this chapter.)

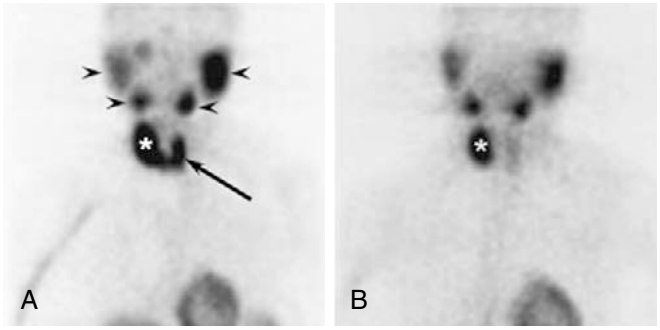


FIGURE 15-6 **A**, Early three-dimensional sestamibi image shows uptake in mass *(asterisk)*, in salivary glands *(arrowheads)*, and in thyroid gland *(arrow)*. **B**, Late three-dimensional sestamibi image shows retention of radiotracer in the adenoma *(asterisk)*, with absence of radiotracer in the thyroid gland. Salivary glands normally retain radiotracer on late images.

Parathyroid Assessment. Elevation of serum PTH level in association with hypercalcemia is diagnostic of hyperparathyroidism in most cases. PTH normal levels are between 10 and 65 pg/ml (values vary with specific laboratory); the concentration of serum ionized calcium (4.5 to 5.6 mg/dl) is usually measured at the same time (Pagana and Pagana, 2009). Causes of primary hyperparathyroidism are single adenoma (80% to 85%), four-gland hyperplasia (10% to 15%), and rarely parathyroid carcinoma (less than 1%). Preoperative localization studies with a parathyroid sestamibi scan (Figure 15-6) or high-resolution ultrasonography can identify parathyroid adenomas with high sensitivity (70% to 80%). Sensitivity decreases significantly for hyperplasia (less than 50%).

Hyperparathyroidism causes an increase in the level of serum calcium and a decrease in the level of serum phosphate. Nursing diagnoses and plans of care are based on these imbalances and the severity of associated symptoms. Some patients are asymptomatic while others have symptoms that manifest themselves as disturbances in the central nervous system or cardiovascular, renal, gastrointestinal, or musculoskeletal system (Box 15-2).

Assessment includes determining whether the patient is apathetic or emotionally irritable; whether there is muscle weakness and atrophy, back or joint pain, nausea, vomiting, constipation, peptic ulcer disease, or cardiac dysrhythmia; and whether there is renal damage, stones, or disease (Canobbio, 2006). If any of these are present, the plan of care is adjusted. Otherwise, perioperative patient education and nursing

BOX 15-2

Parathyroid Dysfunction

HYPERPARATHYROIDISM

Definition

Overactivity of one or more of the parathyroid glands; excessive secretion of parathyroid hormone causes an increase in the level of calcium (hypercalcemia)

Signs and Symptoms

- Polyuria, polydipsia, kidney stones
- Abdominal pain, constipation, nausea, anorexia
- Fractures of ribs, spine
- Joint or back pain
- Depression, paranoia, mood swings
- Muscle weakness and atrophy

Complications

- Cardiac dysrhythmias, cardiac failure
- Gastric ulcer
- Pathologic fractures
- Renal disorders: kidney stones, urinary tract infections, renal failure
- Pancreatitis
- Stupor/coma

HYPOPARATHYROIDISM

Definition

Deficiency of parathyroid hormone, necessary to maintain normal levels of serum calcium; may occur as a result of radiation therapy for head and neck cancer or as a postoperative complication from thyroid or parathyroid surgery; symptoms are related to reduced calcium levels (hypocalcemia)

Signs and Symptoms

- Personality disturbances: anxiety, depression, irritability
- Tetany: muscle cramps, spasms (hands, face, feet); paresthesias: numbness and tingling (around mouth, lips, and tongue)
- Dry, scaly skin; brittle nails; thin, patchy hair
- Weak tooth enamel/dental caries
- Cataracts

Complications

- Cardiac dysrhythmias
- Seizures
- Psychoses
- Cardiac arrest

Modified from Canobbio MM: *Mosby's handbook of patient teaching,* ed 3, St Louis, 2006, Mosby; Workman LM: Care of patients with problems of the thyroid and parathyroid glands. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, Philadelphia, 2010, Saunders.

management of the patient undergoing parathyroidectomy are essentially the same as those for thyroidectomy. In the early postoperative period for both thyroidectomy and parathyroidectomy, the patient is closely observed for any signs of hypocalcemia. The serum calcium level reaches its lowest level in 48 to 72 hours after surgery and returns to normal within the following 2 to 3 days. Symptoms include numbness and tingling of extremities and around the lips. Hyperactive tendon reflexes and a positive Chvostek's sign (tapping on the facial nerve elicits contraction of facial muscles) can be demonstrated on physical examination. Tetany may develop and is exhibited by carpopedal spasms, tonic-clonic convulsions, and laryngeal stridor, which can be fatal.

Nursing Diagnosis

Nursing diagnoses related to the care of patients undergoing thyroid and parathyroid surgery might include the following:

- Impaired Swallowing related to mechanical obstruction (enlarged thyroid preoperatively; edema or hematoma postoperatively)
- Risk for Imbalanced Body Temperature related to altered metabolic rate and surgical environment
- Disturbed Body Image related to surgical scar in prominent location
- Ineffective Airway Clearance related to obstruction (enlarged thyroid preoperatively; edema or hematoma postoperatively) or bilateral recurrent laryngeal nerve injury
- Impaired Gas Exchange related to postoperative bleeding or swelling or inability to move secretions

Outcome Identification

Outcomes identified for the selected nursing diagnoses may be stated as follows:

- The patient will maintain normal swallowing.
- The patient will maintain normal body temperature.
- The patient will verbalize decreased disturbance in feelings related to body image.
- The patient will maintain a patent airway.
- The patient will maintain effective gas exchange.

Planning

The entire surgical team has mutual accountability for patient safety (Banschbach, 2008). The perioperative nurse and surgical technologist should know the OR team members who will participate in the procedure as well as the roles each team member will assume (Haynes et al, 2009). Careful planning, assessment, and tailoring the plan of care to the surgery and specific patient needs reduce inherent risks (Risk Reduction Strategies). The perioperative nurse should consider a patient who is not at optimal weight at high risk for pressure ulcer development and plan on padding pressure areas to prevent skin and tissue damage. Intraoperatively, warm saline should be provided for irrigation and a forced-air warming device used. Patients with hypothyroidism are at increased risk of becoming hypothermic (Hegarty et al, 2009).

A rapidly progressive and potentially fatal complication for patients with hyperthyroidism is thyroid storm (thyrotoxic crisis) (Kuwajerwala et al, 2007). The perioperative staff must recognize and differentiate between uncomplicated thyrotoxicosis and thyroid storm (Box 15-3) and be prepared to act quickly. The use of a rapid response team (RRT) for patients in crisis impacts treatment and patient outcomes (Rapid Response Team box) (Steel and Reynolds, 2008). Thyroid storm can occur in patients who have been partially controlled or whose hyperthyroidism is untreated. Thyrotoxic crisis can be precipitated by a stressful event, such as surgery. By planning a quiet, calm atmosphere and helping the patient relax, the perioperative nurse can reduce the risk of thyroid storm. Collaborating with the surgical and anesthesia team, the perioperative nurse can plan for appropriate interventions to assist in reducing body temperature and heart rate, provide oxygen and intravenous solutions, and administer medications

RISK REDUCTION STRATEGIES

Perioperative Care of Thyroid and Parathyroid Surgery Patients

Risk reduction springs from the adage that "an ounce of prevention is better than a pound of cure." It is much better to prevent a problem than to treat one. A strong base of knowledge coupled with skills, experience, clinical judgment, and caring helps ensure the best possible patient outcomes (Benner et al, 2009).

Risk reduction strategies for patients undergoing thyroid and/or parathyroid surgery include the following:

PREOPERATIVELY

- The appropriate scans and preadmission testing are done.
- Patients are thoroughly screened for inpatient versus ambulatory status (Patient Screening and Assessment in Ambulatory Surgical Facilities, 2009).
- A detailed history and physical is completed.

INTRAOPERATIVELY

- Appropriate body alignment and padding are used to prevent nerve injury and postoperative discomfort.
- The OR team recognizes and is prepared for patients who are at risk for difficult intubation.
- Attention to sterile technique is a core team value.
- Gentle tissue handling reduces the risk of damage to nerves, parathyroid glands, and surrounding structures.
- Achieving and maintaining hemostasis promotes visibility and reduces postoperative bleeding.
- Hypertension is treated and controlled.
- The scrub person keeps instruments sterile for those patients who are at risk for postoperative bleeding. This would include patients with large thyroids that necessitated finger dissection and those who were difficult to intubate.

POSTOPERATIVELY

- The patient is monitored closely for airway difficulty.
- Hypertension is treated and controlled.
- The incision site is observed for swelling and/or bleeding. Ice packs may be applied to reduce swelling.
- Coughing should be minimized and neck support during coughing demonstrated.
- Complications of hemorrhage, compromised airway, thyroid storm, and hypocalcemia are recognized and treated immediately.
- The patient's condition is carefully assessed to determine that criteria are met for discharge to home on the day of surgery.
- Discharge instructions are clear, concise, and thorough; reviewed verbally; and provided in written format. Patients "teach-back" the instructions in their own words (TJC, 2007). Questions are encouraged and time allotted for answering them.

BOX 15-3

Thyroid Storm

MORTALITY/MORBIDITY

Thyroid storm is a fulminating state that is fatal if untreated, with death rates of 20% to 30%.

PHYSICAL SYMPTOMS

- Thyroid storm may be difficult to differentiate from signs of uncomplicated thyrotoxicosis. It is an accentuation of the same signs. Onset is heralded by high-grade fever, mental obtundation, and decompensation of one or more organ systems as a result of severe hypermetabolism.
- Only guidelines are presented in the following table that compares symptoms of uncomplicated thyrotoxicosis and thyroid storm.

Uncomplicated Thyrotoxicosis	Thyroid Storm
Heat intolerance, diaphoresis	Hyperpyrexia, temperature in excess of 106° C, dehydration
Sinus tachycardia, heart rate 100-140 beats/min	Heart rate faster than 140 beats/min, hypotension, atrial dysrhythmias, congestive heart failure
Diarrhea, increased appetite with weight loss	Nausea, vomiting, severe diarrhea, abdominal pain, hepatocellular dysfunction with jaundice
Anxiety, restlessness	Confusion, agitation, delirium, frank psychosis, seizures, stupor, or coma

CAUSES

Causes of rapid rise in thyroid hormone levels:

- Thyroid or parathyroid surgery
- Radioiodine therapy
- Withdrawal of antithyroid drug therapy
- Vigorous thyroid palpation
- Iodinated contrast dye
- Thyroid hormone medication

Other common precipitating factors:

- Infection
- Emotional stress
- Tooth extraction
- Diabetic ketoacidosis
- Hypoglycemia
- Trauma
- Bowel infarction
- Parturition
- Pregnancy toxemia
- Pulmonary embolism
- Cerebrovascular accident
- Gestational trophoblastic disease

Modified from Kuwajerwala NK et al: *Thyroid, thyrotoxic storm following thyroidectomy,* available at emedcine.medscape.com/article850924. Accessed January 24, 2009.

as prescribed in the event thyrotoxic crisis occurs (Surgical Pharmacology).

A Sample Plan of Care for a patient undergoing thyroid and parathyroid surgery is on p. 576.

Implementation

Positioning. Proper patient positioning on the OR bed is crucial for optimal exposure of the thyroid gland. The patient is positioned supine. Some surgeons prefer a beach chair position or a wedge under the back. Hyperextension of the neck is required for maximal exposure. A headrest provides proper support, keeps the head straight, and prevents aggravation of prior neck problems. Alternatively, a shoulder roll may be used. The arms are tucked at the side, the elbows are padded to protect the ulnar nerve, the palms face inward, and the wrist is maintained in a neutral position (Denholm, 2009). A drape secures the arms. It should be tucked snuggly, but not

RAPID RESPONSE TEAM

Rapid response teams (RRTs) handle many critical situations, all of which require skill, knowledge, quick thinking, and immediate action. RRTs are called to treat patients who show signs of developing rapidly deteriorating conditions. Early response and treatment by a specialized, proficient, and experienced team can prevent further deterioration and greatly enhance outcomes for many patients.

The team's assessment and diagnostic skills must complement their abilities to respond to and treat the particular crisis appropriately. The team members should have advanced certification in critical care, PALS and ACLS. They are called a team because they must be able to work together efficiently and smoothly.

Staff nurses and other caregivers, and in some institutions members of the patient's family, should be encouraged to initiate the RRT early when there is a concern about a patient's condition or they believe that "something's not right." The earlier the treatment, the less likelihood there is of a problem escalating out of control.

There must be a rapid response cart with all the medications and equipment needed to deal with a crisis. Supplies should also include airway equipment, a defibrillator, IV supplies, and monitoring equipment.

In the instances of potential patient complications described in this chapter, the RRT would treat hypocalcemia, hemorrhage, or thyroid storm appropriately.

SURGICAL PHARMACOLOGY

Thyroid Storm

PREOPERATIVE PROPHYLACTIC CARE FOR THYROID STORM

Potassium iodide (KI) is used preoperatively in thyrotoxicosis to decrease thyroid blood flow.

EMERGENCY CARE DURING THYROID STORM

- Maintain a patent airway and adequate ventilation.
- Give antithyroid drugs as prescribed: propylthiouracil (PTU, Propyl-Thyracil), 300-900 mg/day; methimazole (MMI) (Tapazole), up to 60 mg/day.
- Administer sodium iodide solution, 2 g/day IV as prescribed.
- Give propranolol (Inderal, Detensol), 1-3 mg IV as prescribed. Administer slowly, over 3 minutes. The patient should be connected to a cardiac monitor and a central venous pressure line should be in place.
- Esmolol (Brevibloc), 500 mcg/kg IV followed by 50-200 mcg/kg, minimum maintenance dose, is useful in patients at risk for complications from beta-blockade.
- Guanethidine or reserpine is substituted for propranolol in patients with congestive cardiac failure, bronchospasm, or history of asthma, although they cannot be used for patients who are in cardiovascular shock or collapse.
- One hour after administration of PTU or MMI, hormone release can be inhibited by large doses of iodine, which reduce thyroidal iodine uptake. Lugol's solution, 30 gtt/day PO in 4 divided doses, or a saturated solution of potassium iodide, 5 gtt orally or via an NG tube q6hr, can be used.
- Ipodate sodium, 0.5-3 g/day PO, can be administered instead of iodine.
- Patients unable to take PTU or MMI also can be treated with lithium 300 mg PO q6hr in conjunction with iodine. The lithium dose is adjusted as necessary to maintain levels at about 1 mEq/L.
- Plasmapheresis, plasma exchange, peritoneal dialysis exchange transfusion, and charcoal plasma perfusion are other techniques used to remove excess circulating hormone for patients who do not respond to the initial line of management.
- Monitor continuously for cardiac dysrhythmias.
- Monitor vital signs every 30 minutes.
- Provide comfort measures, including a cooling blanket.
- Give nonsalicylate antipyretics such as acetaminophen (FeverAll, Panadol) as prescribed (normally 650 mg PO q4hr).
- Aggressive fluid and electrolyte therapy, 3-5 L/day, is needed for dehydration and hypotension. Therefore invasive monitoring is advisable in elderly patients and in those with congestive cardiac failure. Fluid therapy should include glucose.
- Multivitamins, especially vitamin B_1, are added to prevent Wernicke's encephalopathy.
- Glucocorticoids reduce iodine uptake and antibody titers of thyroid-stimulating antibodies with stabilization of the vascular bed. They must be used with caution, however, as they have significant adverse effects. Dexamethasone (Decadron, Dexone), 2 mg IV q6hr, or hydrocortisone (Cortef, Solu-Cortef), 100 mg IV q8hr, may be given.
- Hypertension must be controlled with agents such as guanethidine (Ismelin), 1-2 mg/kg/day PO, or reserpine, 2.5-5 mg IM q4-6hr.
- Treat heart failure if present.

IM, Intramuscularly; *IV,* intravenously.

Modified from Kuwajerwala NK et al: *Thyroid, thyrotoxic storm following thyroidectomy,* available at emedcine.medscape.com/article850924. Accessed January 24, 2009; Workman LM: Care of patients with problems of the thyroid and parathyroid glands. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, Philadelphia, 2010, Saunders.

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Impaired Swallowing related to mechanical obstruction (enlarged thyroid preoperatively; edema postoperatively)

OUTCOME
Patient will maintain normal swallowing.

INTERVENTIONS
- Keep suction line and suction catheter connected and ready until patient is discharged from OR.
- Monitor for and report difficulty swallowing during emergence from anesthesia or transport to PACU.
- Gently suction oropharyngeal secretions as required.
- Keep vein open postoperatively until patient can swallow without difficulty.

NURSING DIAGNOSIS
Risk for Imbalanced Body Temperature related to altered metabolic rate

OUTCOME
Patient's body temperature will be maintained within normal range.

INTERVENTIONS
- Monitor patient's temperature; report abnormalities.
- Provide light covers if temperature is elevated or patient states that he or she is too warm.
- Use forced-air warming device intraoperatively as needed to maintain temperature.
- Use fluid warmer for intravenous fluids as needed to maintain body temperature.
- Change linens preoperatively and postoperatively if wet from perspiration.
- Avoid using plasticized drapes.

NURSING DIAGNOSIS
Disturbed Body Image related to surgical scar

OUTCOME
Patient will verbalize decreased disturbance in feelings related to body image.

INTERVENTIONS
- Explain that incision is made in natural fold of skin.
- Explain that techniques used for surgical closure minimize scarring.
- Instruct patient in postoperative turning measures that decrease strain on suture line.
- Suggest that jewelry, scarves, and certain necklines can be used to cover scar until normal fading occurs.
- Advise patient to refrain from prolonged exposure to direct sunlight or tanning salons while incision is healing.

NURSING DIAGNOSIS
Ineffective Airway Clearance related to obstruction secondary to enlarged thyroid (preoperatively), edema (postoperatively), or laryngeal nerve injury

OUTCOME
Patient's airway will remain patent.

INTERVENTIONS
- Position patient so that enlarged gland does not obstruct airway. Head of transport vehicle may need to be elevated preoperatively.
- Assist anesthesia provider during induction and extubation. Have oxygen and suction available.
- Monitor respiratory rate and signs of respiratory distress (stridor, wheezing, dyspnea, labored respirations).
- If distress occurs because of recurrent laryngeal nerve injury, a tracheotomy may be required. Have oxygen, suctioning equipment, and a tracheotomy tray available.
- Observe neck dressing and back of neck for signs of edema or bleeding (postoperatively). Hemorrhage at the incision site or respiratory distress from tracheal compression may require urgent reintubation for airway protection and a return to the OR for wound re-exploration.

NURSING DIAGNOSIS
Impaired Gas Exchange related to postoperative bleeding or swelling, bilateral recurrent laryngeal nerve surgical injury, or inability to move secretions

OUTCOME
Patient's gas exchange will remain effective.

INTERVENTIONS
- Monitor respiratory status and results of pulse oximetry.
- If patient is extubated in OR, be prepared to assist anesthesia provider; closely observe for respiratory stridor or respiratory obstruction (recurrent laryngeal nerve malfunction). Tracheotomy may be required; oxygen, suctioning equipment, and a tracheotomy tray should be available.
- Assess color of nailbeds.
- Monitor surgical site for swelling and bleeding.
- Suction patient's secretions as needed.
- Monitor patency of surgical drain and amount/nature of drainage in collection device, as applicable.
- Instruction in coughing and deep breathing should include supporting the neck; placing both hands behind the neck when coughing reduces strain on the suture line.

OR, Operating room; *PACU,* postanesthesia care unit.

tightly, under the patient, not under the mattress. This prevents the arm from shifting downward intraoperatively and resting against the OR bed rail. All pressure points should be padded, especially for patients not at optimal weight. Should the patient be too large to tuck the arms safely at the sides, arm sleds or side extensions for the OR bed may be used to accommodate the arms. Reduction of venous congestion can be accomplished by a 30-degree reverse-Trendelenburg's tilt of the OR bed (see Chapter 5 for a full discussion of surgical positioning).

Skin Preparation. The operative area (chin and anterior neck region, lateral surfaces of the neck from the earlobes down to the outer aspects of the shoulder, and upper anterior chest region to the nipples) is prepped with an antimicrobial solution. Appropriate precautions must be taken to prevent pooling of solution under the neck or in the axillary area. Alcohol-based prep solutions around the head and neck area present a risk for surgical fire. They must be used with caution, allowing time for the prep to dry and the fumes to dissipate. Bed sheets that become soaked with a flammable prep solution should be

removed from the OR. After the skin prep, the patient is draped with sterile towels and a fenestrated sheet. A sterile towel, lap sponge, or self-adherent tape strips may be placed on each side of the neck to prevent pooling of blood under the neck during surgery. Self-adherent tape strips or drapes also promote maintenance of the integrity of the sterile field and reduce the risk of intraoperative fire hazard by sealing off the operative site from anesthetic vapors that may have leaked and become trapped under the drapes. If lap sponges are used, they should be noted on the count sheet to avoid confusion in accounting for all counted items. After draping is complete, the time-out is taken. The following must be verified: correct patient, correct site, and correct procedure to be performed; and supplies may also be included (Perioperative Grand Rounds, 2009). The time-out is documented. The surgeon then marks the incision site with a marking pen or the pressure of a full-length fine silk tie to help ensure a wound line that blends with the patient's neck creases and skin lines.

Evaluation

Evaluation of intraoperative interventions determines the effectiveness of the plan of care. The hand-off report to postanesthesia care unit (PACU) or ambulatory recovery personnel includes the surgical procedure, type of anesthesia used, local anesthetics administered, location of drain (if any), dressing used, condition of skin postoperatively, and any other information specific to the patient's postoperative care. Documentation, using hospital protocol, reflects achievement of patient outcomes related to planned interventions; these should also be included in the hand-off nursing report to PACU personnel. Outcomes identified for the selected nursing diagnoses may be stated as follows:

- The patient maintained normal swallowing.
- The patient maintained normal body temperature.
- The patient verbalized decreased disturbance in feelings related to body image.
- The patient maintained a patent airway; there was no edema or hematoma at the surgical site or signs of respiratory distress.
- The patient maintained adequate gas exchange; O_2 saturation remained normal. The patient was extubated without incident.

Patient and Family Education and Discharge Planning

Patient education and discharge planning include any family members, significant others, or even friends who will help the patient at home (Patient and Family Education). Written discharge instructions are provided and orally reviewed, with clarification of information and correction of misperceptions. The name and telephone number of the physician or nurse to call with questions is provided, as is information regarding a follow-up office appointment, if that is available. General information, such as the name of the thyroid or parathyroid procedure and any changes that will occur as a result of the surgery, is explained. Signs and symptoms to report include those of hypocalcemia. If hypocalcemia occurs, it usually manifests itself within 2 days after surgery (Burman, 2005). The patient should report any numbness or tingling around the lips or extremities, twitching, or spasms. Time is also spent to discover the patient's concerns, anxieties, thoughts, and feelings. Patient education begins with the perioperative nursing assessment and continues through discharge and perhaps even home care. The advent of thyroidectomies and parathyroidectomies performed in ambulatory surgery centers has introduced a new set of needs and challenges for the patient, family, and perioperative staff (Mirnezami et al, 2007) (Ambulatory Surgery Considerations).

Surgical Interventions

UNILATERAL THYROID LOBECTOMY, SUBTOTAL LOBECTOMY, BILATERAL SUBTOTAL LOBECTOMY, NEAR-TOTAL THYROIDECTOMY, AND TOTAL THYROIDECTOMY

Unilateral thyroid lobectomy or hemithyroidectomy is the removal of one thyroid lobe with excision of the isthmus. The isthmus is completely removed to prevent postoperative hypertrophy in response to the lobectomy with subsequent airway impingement. *Subtotal lobectomy* is a lobectomy that spares the posterior capsule and a portion of adjacent thyroid tissue. *Bilateral subtotal thyroidectomy* is removal of both lobes of the thyroid in the fashion stated for subtotal thyroidectomy. *Near-total thyroidectomy* is a total lobectomy with contralateral subtotal thyroidectomy. *Total thyroidectomy* is the removal of both lobes of the thyroid and all thyroid tissue present. For patients with cancer of the thyroid, total thyroidectomy is the desired surgical treatment (Sarkar, 2004; Tuttle, 2007), followed by iodine-131 remnant ablation. Preventing thyroid cancer recurrence does not depend on surgical approach, but on complete surgical excision of the tumor (Loevner and Mukherji, 2008). Following surgery, the thyroid cancer patient is prescribed thyroid hormone suppression therapy and monitored by physical examination, laboratory studies (serum thyroid function and thyroglobulin levels), and scans.

The purpose of the surgical intervention relates to the patient's medical diagnosis. *Goiter* refers to any enlargement of the thyroid gland and includes both benign and malignant nodules; the enlargement is visible over the anterior neck (Wilson and Giddens, 2009). *Benign adenomas* are encased in a fibrous capsule, distinct from surrounding thyroid tissue. *Malignancies* occur most commonly in patients under 20 or over 60 years of age. Excising the lymph nodes with suspected or known cancer of the thyroid remains a standard therapy. Radiologic studies aid in the understanding of nodal metastasis and determining which levels of the neck to dissect. Contralateral metastasis is generally associated with large tumors. Young patients tend to respond favorably to treatment and have a better prognosis than older patients (Loevner and Mukherji, 2008).

Graves' disease, the most common cause of hyperthyroidism, is associated with diffuse, bilateral enlargement of the thyroid gland. Surgery is not the first response for Graves' disease, but is reserved for those patients who fail medical therapy (antithyroid drugs and radioactive iodine) or have a contraindication to medical therapy. *Hashimoto's thyroiditis* is believed to be an autoimmune disease in which nontender enlargement of the gland occurs. Surgery is performed to relieve tracheal obstruction. *Nontoxic nodular goiter* involves production of insufficient hormones and is noninflammatory in character; in

PATIENT AND FAMILY EDUCATION

Home Care After a Thyroidectomy

- Give both patient and caregiver *verbal* and *written* instructions. Provide them with the name and telephone number of a physician or nurse to call if questions or problems arise. Have patient and/or caregiver teach back instructions in own words. Allow time for questions.
- Make sure the patient knows to sit up slowly and allow his/her legs to dangle for 1-2 minutes before getting up. The caregiver should accompany the patient on the first walk at home.
- Explain and discuss with patient the surgical procedure performed. The patient should be able to state the name of the surgical procedure performed.
- Wound/incision care
  - Teach patient to keep the surgical site clean and dry.
  - Teach methods to conceal surgical site without affecting healing. Suggest loosely buttoned collars, high-neck blouses, jewelry, or scarves.
  - Explain that paper strip over wound will peal off in 7 to 10 days; when ends curl, it may be removed.
  - Inform patient that lotion may soften healing scar and improve its appearance (if approved by physician).
- Warning signs: review signs and symptoms that should be reported to physician or nurse.
  - General: respiratory distress, bleeding
  - Wound infection: redness, warmth, swelling, persistent drainage from site, unrelieved tenderness
  - Total thyroidectomy: signs and symptoms of hypothyroidism: intolerance to cold; decreased body temperature; dry, rough, or scaly skin; puffy face, hands, and feet; periorbital edema; decreased blood pressure; bradycardia; nonspecific fatigue, weakness; decreased exercise tolerance; weight gain; constipation; anorexia; delayed deep tendon reflexes; muscle aches and joint stiffness; speech changes (slowed, slurred, monotonous); somnolence, lethargy; impaired memory, inattentiveness, slow cognition; loss of initiative; paranoia, depression, agitation; decreased libido; female: decreased or missed menstrual cycles; abdominal distention
  - Parathyroid damage: signs of hypocalcemia: numbness, tingling, twitching, spasm, tetany
- Medication management
  - Explain purpose, dosage, schedule, and route of administration of any prescribed drugs, as well as side effects to report to physician or nurse.
  - Provide list of all medications patient is to take (including those that are not newly prescribed; this is part of discharge medication reconciliation and safety) (Risk Reduction Strategies)
  - Discuss importance of not taking over-the-counter medications without first checking with physician or nurse.
  - If patient had total thyroidectomy, explain importance of taking thyroid replacement medication regularly.
  - If patient has parathyroid damage, explain need for calcium supplements.
- Activity
  - Encourage patient to discuss allowances and limitations with respect to occupation, recreation, and activities.
  - Teach prescribed head and neck exercises: flexion, lateral movement, hyperextension.
  - Teach importance of balance between activity and rest.
- Diet
  - Discuss need to maintain well-balanced diet.

FOLLOW-UP CARE

- Stress importance of regular follow-up visits to monitor thyroid levels: thyroid-stimulating hormone (TSH), thyroxine (T_4). Make sure patient has necessary names and telephone numbers.

Modified from Canobbio MM: *Mosby's handbook of patient teaching,* ed 3, St Louis, 2006, Mosby; Workman LM: Care of patients with problems of the thyroid and parathyroid glands. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, Philadelphia, 2010, Saunders.

such cases thyroid tissue proliferates in an apparent attempt to produce the minimal hormonal requirement. Surgery may be indicated to relieve tracheal or esophageal obstruction or to rule out a malignant nodule of the thyroid. *Total thyroidectomy* may be done for malignant tumors (Box 15-4). An intraoperative frozen section may be indicated to confirm the diagnosis. If the diagnosis is not definitive on frozen section, a hemithyroidectomy may be the treatment of choice. If the permanent histologic report is benign, the patient has the unaffected thyroid lobe preserved and intact. If the pathology, however, proves to be carcinoma, a complete thyroidectomy is then performed as soon as possible.

Minimally invasive approaches to thyroid surgery arose in the late 1990s and early twenty-first century for treatment of small thyroid nodules. These include minimally invasive open thyroidectomy (MIT) and minimally invasive video-assisted thyroidectomy (MIVAT). Minimally invasive thyroid surgery is performed for both partial and total thyroidectomies (Dhingra, 2008). Researchers are conducting studies on natural orifice transendoscopic surgery (NOTES); in the future, skin incisions may become obsolete for some surgeries (Research Highlight, p. 580, top).

Minimally invasive thyroidectomies reduce postoperative pain, decrease hospital length of stays, and improve cosmetic results (Research Highlight, p. 580, bottom) and may be done using a local anesthetic. Minimizing dissection and resultant dead space eliminates the need for external drains in most cases. Smaller incisions, minimal use of surgical drains, and prophylactic calcium supplementation have enabled thyroid surgery to be performed safely on an ambulatory basis (Dinghra, 2008).

AMBULATORY SURGERY CONSIDERATIONS

Patient Teaching, Preparation, and Screening

If the patient will be discharged home on the same day as surgery, thorough patient teaching and preparation with written instructions is critical. It is paramount that nursing staff have strong critical thinking and assessment skills to screen patients for problems that may preclude same-day discharge. Safe and successful ambulatory surgery depends, in part, on recognizing which patients can be sent home and which patients should be admitted.

The nursing staff must verify that the patient has arranged for someone to drive him/her home and for a caregiver (family/friend) to assist during the first 24 hours at home. Surgery cannot be done on an ambulatory basis if these arrangements have not been made.

Patients must be thoroughly and carefully screened as to eligibility for ambulatory thyroidectomy or parathyroidectomy (Patient Screening and Assessment, 2009). Ambulatory surgery is contraindicated in patients with grossly enlarged thyroids or comorbid medical conditions, such as cardiac disease, uncontrolled hypertension, brittle diabetes, and sleep apnea. Intraoperatively, patients who had a difficult intubation or who bled excessively should be excluded from discharge on the same day as surgery.

The nursing staff should ascertain the patient's ability to understand and cooperate with discharge instructions.

The patient is sent home with prescriptions for pain management, calcium supplements, thyroid hormone (if indicated), and other medications specific to preexisting conditions. All medications should be reviewed (discharge reconciliation) and a list provided.

The patient must meet discharge criteria: the patient must be fully awake, alert, and oriented and be able to void, swallow, and drink fluids without nausea or vomiting.

The need for deep breathing, mobility, and hydration must be emphasized.

The patient should be cautioned not to drive or drink alcohol for at least 24 hours.

Patients and families are under physical and emotional stress and often will find the environment and information received overwhelming. Standardized printed discharge instructions from the surgeon, specific to the surgery performed, with space available to customize information for the patient, provide a valuable tool and reference resource for the patient and family/caregiver to use at home.

Perioperative staff must ascertain that the patient and caregiver understand the symptoms indicating a significant problem that needs immediate attention, as well as actions to take and persons to contact in case of an emergency. These include signs and symptoms of dyspnea, hemorrhage, thyroid storm, and hypocalcemia.

The patient should be instructed to call the physician's office for a follow-up visit if this has not been arranged.

RISK REDUCTION STRATEGIES

Discharge Medication Reconciliation

Medication reconciliation is an ongoing National Patient Safety Goal (NPSG). Up to 75% of potential adverse drug events occur during discharge (Pippins et al, 2008) as patients and their caregivers review, as part of discharge preparation, new medications and must understand which medications to stop or change. Their ability to concentrate or ask questions may be compromised by other needs such as making follow-up appointments and planning for multiple, and sometimes complex, changes in routine activities. In one study, only 27.9% of discharged patients were able to identify their medications, 37.2% knew the purpose of all their medications, 14.0% were able to state the common side effect(s) of all their medications, and 41.9% were able to state their diagnosis or diagnoses (Makaryus and Friedman, 2005).

Discharge reconciliation has several specific aspects. Drug formulary and related changes that occurred at admission must be addressed. If, for example, the patient's home medication was one drug but the patient was switched to another in the drug formulary, this change must be reconciled. A resolution must be made and clearly communicated to prevent the patient from taking both, or neither, of these medications. Prescriptions must be provided. The full medication list must be communicated clearly to both the patient and the caregiver. A simple printed discharge summary that includes details of the medications, including dose, indication, and directions, can reduce postdischarge medication errors. This same form can be sent to the next provider of care (i.e., primary care provider or specialist).

Adapted from Makaryus AN, Friedman EA: Patients' understanding of their treatment plans and diagnosis at discharge, *Mayo Clin Proc* 80:991-994; 2005; Meisel S: *Falling through the cracks: medication reconciliation at admission and discharge,* Medscape CME, March 2009, available at cme.medscape.com/viewprogram/19223?src=cmemp. Accessed April 6, 2009; Pippins JR et al: Classifying and predicting errors of inpatient medication reconciliation, *J Gen Intern Med* 23:1414-1422, 2008; The Joint Commission, Accreditation Program for Hospitals: *National Patient Safety Goals,* Oakridge, Ill, 2009, Author.

MIVAT is generally reserved for thyroid nodules within specific size limits as well as for low-stage papillary thyroid carcinomas. As MIVAT has evolved and surgeons have become more proficient with the technique, the only absolute contraindications for its use are thyroid malignancies beyond low-stage papillary carcinoma and preoperative evidence of lymph node metastasis. Relative contraindications include prior conventional thyroidectomy, nodules larger than 35 mm and 30 ml, and a history of thyroiditis (Dinghra, 2008). Studies indicate that it is safe to perform MIVAT thyroidectomies as ambulatory procedures under certain conditions (Terris, 2006).

Procedural Considerations

The patient is positioned supine. A drape pack with fenestrated sheet is required along with a basic instrument set and the addition of thyroid instruments. An electrosurgical unit (ESU), an exhaust system for surgical smoke (AORN, 2008), gauze dissectors, and a small drain (optional) are commonly used. A headlight for the surgeon and assistant may be required. A nerve monitor may be used during surgery to protect the laryngeal nerve. The patient is prepped from the chin to the upper chest, using fire safety precautions (see Chapter 2 for a discussion of fire prevention strategies in surgical settings).

RESEARCH HIGHLIGHT

Transoral Access for Endoscopic Thyroid Resection

Advances in thyroid surgery have been facilitated by intraoperative neuromonitoring to prevent laryngeal nerve paralysis, early measurement of intraoperative parathyroid hormone (IoPTH) levels to avert symptomatic hypocalcemia, and improved devices for hemostasis and dissection to better control bleeding. The authors of this study suggest the sublingual transoral approach as a promising minimally invasive endoscopic access to the thyroid gland from outside the neck region.

Sublingual transoral access was first evaluated in two fresh human cadavers. An experimental investigation then was performed using a porcine model. A total of 10 endoscopic transoral thyroidectomies were performed using a modified axilloscope with an obturator, ultrasonic scissors, and a neuromonitoring system to identify the recurrent laryngeal nerve.

Complete transoral thyroid resection was achieved with both human cadavers and live pigs. Despite the complexity of the anatomic region, the transoral procedure was successfully and smoothly performed. The neuromonitoring system ensured normal function of the recurrent laryngeal nerves on both sides after removal of the thyroid gland. No complications occurred during the procedures or afterward.

Endoscopic transoral thyroid resection is possible. A follow-up study undertook preclinical investigation in human cadavers, again demonstrating adequacy of access and feasibility of the procedure. The next step will be its broad application in living pigs before it may be applied in humans. Finally, large prospective, randomized trials comparing the outcomes of different endoscopic procedures are needed to establish levels of evidence and grades of recommendation for transoral access.

Modified from Benhidjeb T et al: *Natural orifice surgery on thyroid gland: totally transoral video-assisted thyroidectomy (TOVAT): report of first experimental results of a new surgical method,* 2009, available at www.ncbi.nlm.nih.gov/pubmed/. Accessed April 4, 2009; Witzel K et al: Transoral access for endoscopic thyroid resection, *Surg Endosc* 22(8):1871-1875, 2007.

BOX 15-4

Malignant Thyroid Nodules

PAPILLARY CARCINOMA
- Most common form (>70%)
- Poorly encapsulated
- Calcifications present—uncommon in other carcinomas

FOLLICULAR CARCINOMA
- Second most common form (15%)
- Well-differentiated
- Associated with iodine deficiency

HÜRTHLE CELL TUMOR
- Derived from follicular epithelium
- Associated with regional nodal metastasis

MEDULLARY CARCINOMA
- Undifferentiated tumor
- Higher death rate than differentiated

ANAPLASTIC CARCINOMA
- More common in females and elderly
- Highly aggressive
- Rapidly fatal; death usually occurs within 1 year of diagnosis

UNCOMMON CARCINOMAS
- Primary lymphoma
- Primary squamous cell
- Metastatic thyroid tumors

Modified from Deitch M: Thyroid Cancer, *Adv Nurses* 10(14):24, 2008.

RESEARCH HIGHLIGHT

Cosmetic Surgery Techniques Can Enhance Thyroid Surgery Results

As noted in the plan of care for patients undergoing thyroid and parathyroid surgery, concern about appearance after surgery is not unusual. This prospective analysis included 248 patients (198 women and 50 men) who underwent varying approaches to thyroid surgery—from a standard (i.e., several inches long) neck incision for large thyroids, to minimally invasive techniques that cut the incision size in half, to endoscopic approaches that further reduced incision size. The following techniques were reported to improve aesthetic results:

- Having the patient sit or stand while incision sites were marked to ensure that they blend with the natural lines of the body
- Minimizing incision size
- Trimming skin edges at the incision sites. In minimal access techniques, skin edges sometimes become frayed as large nodules are removed from relatively small incisions. Rather than make a bigger incision, skin edges are excised to improve reapproximation.
- Using surgical glue instead of sutures. Surgical glue allows accurate skin edge apposition without the risk of "railroad-tracking" from skin sutures. It is also convenient for patients. Instead of returning for suture removal, they can peel the glue off.
- Minimizing trauma to surrounding skin. Instead of creating extensive flaps, as described in conventional approaches, a modified approach involves minimal flap creation, sparing extensive tissue dissection.
- Avoiding use of drains
- Using other techniques, such as the ultrasonic harmonic scalpel, to reduce overall surgical trauma

In this analysis, only 1 of the 248 patients required additional treatment for the surgical scar; that female patient required steroid injections for hypertrophic scarring. The application of well-known cosmetic surgery principles improved optimal outcomes relating to the appearance of postoperative incision sites.

Modified from Terris D: *Cosmetic surgery techniques can enhance thyroid surgery results,* Medical College of Georgia, available at https://my.mcg.edu/portal/page/portal/News/archive/2007. Accessed January 24, 2009.

Surgeons may use the harmonic scalpel or LigaSure Precise. The heated blade of the harmonic scalpel retains its heat longer than an electrosurgical unit blade. Appropriate precautions must therefore be used to avoid inadvertent burning of adjacent tissue. Thyroidectomies are done through a small incision and visualization is critical for successful extraction. Bleeding can obscure the view and hinder the progress of the surgery. Therefore, surgeons may use hemostatic agents intraoperatively to maintain hemostasis (Research Highlight).

RESEARCH HIGHLIGHT

Dissection and Hemostasis with Hydroxylated Polyvinyl Acetal Tampons in Open Thyroid Surgery

The objectives for thyroidectomy are avoidance of injury to the recurrent laryngeal nerves, conservation of the parathyroid glands, accurate hemostasis, and excellent cosmesis. To achieve these objectives major improvements and new technologies have been proposed and applied in thyroid surgery; among these are performing mini-invasive thyroidectomies, using a regional anesthetic, conducting intraoperative neuromonitoring, and implementing new devices for dissection and hemostasis. Minor bleeding from small vessels, however, can still present major complications in thyroid surgery. Bleeding obscures visualization and is the major cause of converting minimally invasive to open thyroidectomies.

Hydroxylated polyvinyl acetal (HPA) tampons are made with a synthetic, open cell foam structure able to absorb fluids up to 25 times their initial weight. Their surface is smooth and they do not stick to tissues. They have an initial, mildly hard, firmness that allows their use as blunt dissection devices. They are designed in different shapes, forms, and sizes. Specific tests demonstrated that HPA tampons are fully biocompatible and able to reduce bacterial growth.

Studies were performed to test the efficacy of HPA tampons for tissue dissection and minor bleeding control during several thyroid procedures. They were found to be exceptionally useful for absorbing blood from minor and diffuse loss, helping to control bleeding by a combined action of fluid absorption and local compression. The tampon's porous design allowed use of a suction device through the tampon itself. The initial mildly hard consistency of the HPA tampons allowed their use in blunt tissue dissection.

The authors concluded that the use of HPA tampons was efficient for controlling minor bleeding, removing fluids, and performing blunt tissue dissection during thyroid surgery.

Modified from Dionigi G et al: Dissection and hemostasis with hydroxylated polyvinyl acetyl tampons in open thyroid surgery, *Ann Surg Innov Res* 1:3, 2007, available at www.aornjournal.org/article/S0001-2092(07)00583-2/fulltext#further-reading. Accessed April 6, 2009.

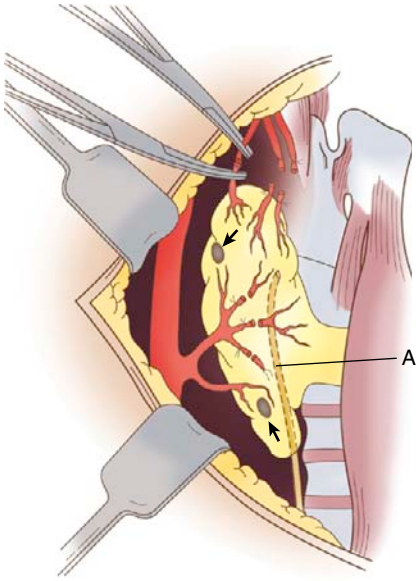


FIGURE 15-7 Safe thyroid principles emphasize the following: division of all branch vessels on the capsule of the thyroid with fine mosquito hemostats to prevent injury to the superior laryngeal nerve while detaching the superior thyroid artery and to prevent injury to the parathyroid glands while detaching the inferior thyroid artery; mobilization of parathyroid glands *(arrows)* by medial-to-lateral dissection to preserve their vascular pedicle; constant awareness of the location of the recurrent laryngeal nerve *(A)*, especially near its penetration into the larynx.

Open Thyroidectomy Operative Procedure

Figure 15-7 provides an overview of safe thyroidectomy principles.

1. A transverse incision (slightly curved and symmetric) is made parallel to the normal skin line crease of the neck, through the skin and first layers of the cervical fascia and platysma muscle, about 2 cm above the sternoclavicular junction.
2. An upper skin flap is undermined to the level of the thyroid notch of the thyroid cartilage; double skin hooks or Allis clamps are placed on the dermis and retracted anteriorly and superiorly to facilitate dissection. A lower flap is then undermined to the sternoclavicular joint. A knife, fine curved scissors, tissue forceps, and gauze sponges are used to undermine the flaps. Bleeding vessels are clamped with hemostats and ligated with fine nonabsorbable sutures. Lateral retraction with a vein retractor or Army-Navy retractor helps identify the plane for dissection.
3. Flaps are held away from the wound with stay sutures inserted through the cervical fascia and platysma muscle or by a self-retaining retractor.
4. The fascia in the midline is incised between the strap (sternohyoid and sternothyroid) muscles with a knife. Care must be taken to preserve the anterior jugular veins. The fascia may be lifted on either side with forceps during the dissection to help define the plane of dissection and protect the jugular vessels. The sternocleidomastoid muscle may be retracted with a loop retractor. Ordinarily, it is not necessary to divide the strap muscles. However, if additional exposure is required, such as with a very large gland, they may be divided between clamps using Mastin muscle clamps, Kocher clamps, or hemostats and a knife. The divided muscles are retracted from the operative site to expose the target lobe.
5. The inferior and middle thyroid veins are ligated with fine nonabsorbable sutures or hemoclips, and divided with Metzenbaum scissors.
6. The lobe is first rotated medially, and loose areolar tissue is then divided posteriorly and medially toward the tracheoesophageal sulcus with hemostats and Metzenbaum scissors. Small sponges are used for blunt dissection. Bleeding is controlled with hemostats, hemoclips, and ligatures,

as well as with the ESU; a bipolar ESU may be used. The recurrent laryngeal nerve, which enters the cricothyroid muscle at the level of the cricoid cartilage, is identified and carefully preserved. Electrocoagulation should not be used in the vicinity of the recurrent or superior laryngeal nerve because the spread of current could damage the nerve. Nerve integrity monitoring systems (NIMSs) are helpful in identifying the branches of the laryngeal nerve. NIMSs should supplement, not replace, good surgical technique and anatomic awareness (Loevner and Mukherji, 2008). Vigorous suction and dissection may cause injury to the nerve and parathyroid glands. The scrub person should prepare a radiopaque 4 × 8 inch sponge on the end of a forceps for the surgeon or assistant to use in gently blotting the area.

7. The thyroid lobe is pulled downward, a Lahey goiter or polar retractor inserted as necessary, and the avascular tissue between the trachea and upper pole of the thyroid dissected by means of Metzenbaum scissors.
8. The superior thyroid artery is defined by blunt dissection with a peanut sponge on a clamp; it is then isolated with a right-angle clamp. The artery is ligated with nonabsorbable suture or clamped with hemoclips, and divided. Care is taken here to avoid injury to the superior laryngeal nerve. The upper parathyroid gland is often identified at this time.
9. The inferior thyroid artery is identified and preserved. The inferior parathyroid is likewise identified. Only branches of the inferior thyroid artery that do not supply the parathyroid glands are ligated, using fine forceps, sutures, and scissors. The thyroid lobe is then dissected away from the recurrent laryngeal nerve with Metzenbaum scissors and hemostats. Bleeding vessels are clamped with hemostats or hemoclips, and ligated with fine nonabsorbable sutures.
10. The lobe is elevated with Babcock clamps and freed from the trachea with fine scissors, forceps, knife, and hemostats, or with cautious electrodissection. The fibrous bands attached to the trachea and cricoid cartilage are divided.
11. The isthmus of the gland is elevated with fine forceps and divided between hemostats with scissors, removing the lobe and isthmus. The cut edge of the remaining thyroid may be oversewn to maintain hemostasis. If a pyramidal lobe is present, it is removed, along with the lobe to which it is attached, to its termination in the neck, which may reach the hyoid bone. If it is necessary to transect the hyoid bone, a small bone cutter is used.
12. The cut surface of the opposite lobe requires careful hemostasis. Interrupted sutures may be used for this purpose as well as for reapproximation to the pretracheal fascia.
13. The excised thyroid is examined for inadvertent parathyroid inclusion. If a parathyroid is present, it is removed and reimplanted.
14. The strap muscles, if severed, are reapproximated with fine interrupted absorbable or nonabsorbable sutures. If necessary, a drain is inserted into the thyroid bed and exteriorized through the midline. Some surgeons prefer to drain the wound laterally through the sternocleidomastoid muscle and the lateral extremity of the incision, believing that this produces better healing and cosmetic results. A hemostatic agent may be placed in the lateral gutter to facilitate hemostasis.
15. The edges of the platysma muscle are reapproximated. The skin edges are then reapproximated with subcuticular fine absorbable sutures.
16. Wound closure tapes (e.g., Steri-Strips) are applied to the wound edges and gauze dressings, if required, are placed on the wound with minimal tape.

SUBSTERNAL OR INTRATHORACIC THYROIDECTOMY

Extensions of goiters enlarging into the substernal and intrathoracic regions may occur. If they cause tracheal and esophageal obstruction, they are usually excised surgically. Longer instruments are sometimes required. Splitting the sternum is rarely necessary because access to the substernal part of the gland is usually satisfactory through the standard thyroid incision.

MINIMALLY INVASIVE THYROIDECTOMY

Minimally Invasive Open Thyroidectomy

The length of the incision is the major difference between minimally invasive and traditional thyroidectomy. An incision of less than 6 cm is considered minimally invasive. Because of its smaller size, the site of the incision is critical for optimum access and visualization. After the incision is made, the remaining procedure is the same as that for conventional thyroidectomy (Dinghra, 2008).

Minimally Invasive Video-Assisted Thyroidectomy (MIVAT)

Procedural Considerations. The possibility of conversion to open thyroidectomy should be included on the operative consent form. Instruments and supplies for a possible open procedure are readied. Surgical skin preparation is done as in an open procedure in the event conversion is necessary. A set of long Miccoli instruments is added to the standard thyroid or neck dissection setup (Figure 15-8, *A*). A 30-degree endoscope and harmonic scalpel with scissors are used to ligate and divide vessels (Figure 15-8, *B*). Fire safety precautions are implemented for illuminated light cords, endoscopes, light sources, and cable connections.

Intraoperative Procedure

1. The patient is positioned and draped as for thyroidectomy. A horizontal incision of 3 cm or less is marked and then carefully made between the sternal notch and cricoid cartilage, usually less than 2 cm inferior to the cricoid (Figure 15-9).
2. Subcutaneous tissue is electrodissected and the raphe of strap muscle is then separated superiorly and inferiorly for about 3 cm. The anterior jugular veins are preserved.
3. Blunt dissection is used to separate the strap muscle from the thyroid.
4. The middle thyroid vein is clipped and divided.
5. Miccoli retractors are used to retract the strap muscles and soft tissue, exposing the superior lobe and vascular bundle.
6. The endoscope is introduced to visualize the upper pole. Three persons are needed: the surgeon, an assistant for retraction, and an endoscopist.

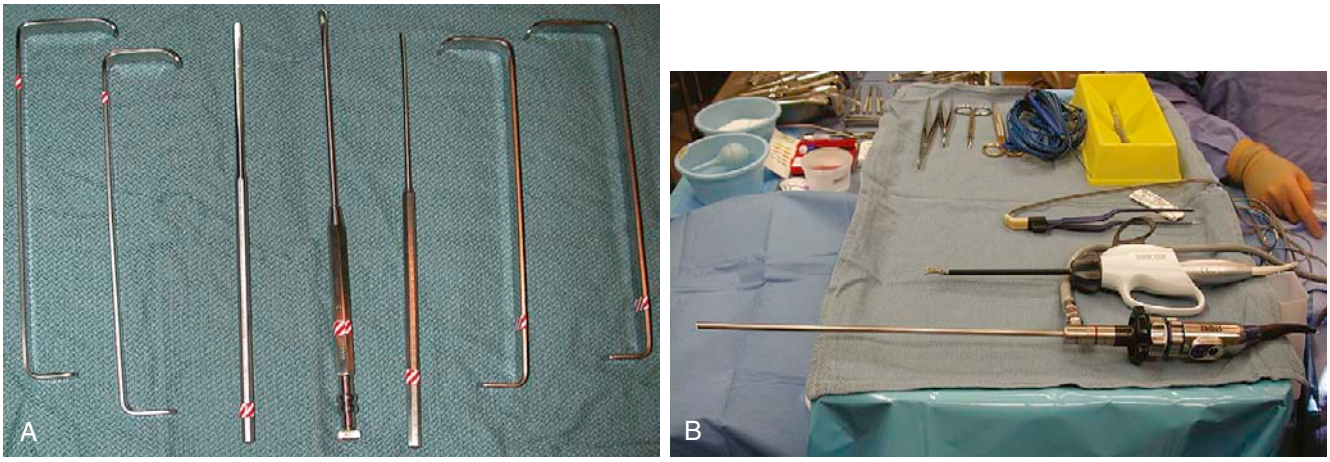


FIGURE 15-8 **A**, Miccoli instrument set designed for MIVAT. **B**, Endoscope and harmonic scalpel.

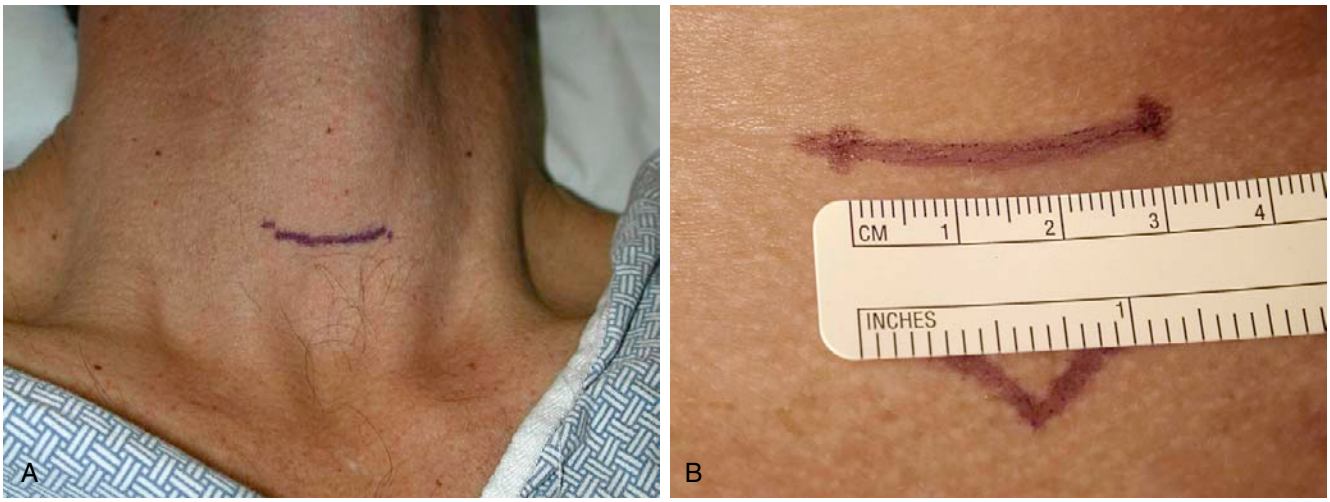


FIGURE 15-9 **A**, MIVAT incision location. **B**, MIVAT incision length.

7. Miccoli spatula-shaped and aspirator dissectors are used to dissect the superior pole and vascular bundle (Figure 15-10). Care is taken to identify and preserve the external branch of the superior laryngeal nerve.
8. The thyroid lobe is then retracted medially and its lateral and posterior attachments are dissected. The recurrent laryngeal nerve and parathyroids are protected and preserved (Figure 15-11).
9. After sufficient mobilization of the lobe, the remainder of the procedure is accomplished under direct visualization. The isthmus is transected to complete the lobectomy.
10. The same procedure is repeated on the other side for complete thyroidectomy.
11. Hemostasis is achieved, the wound is irrigated, strap muscles are reapproximated, and the skin is closed (Figure 15-12).

Postoperatively, analgesics, antiemetics, and prophylactic antibiotics are administered in PACU. Preoperative thyroid hormone supplementation is continued. For inpatients, ionized calcium and albumin levels are checked in PACU and then every 6 to 8 hours. Hypocalcemia is a serum calcium level below 8.0 mg/dl. If patients are discharged the same day as surgery, prophylactic calcium supplements will be prescribed for several weeks. Ambulatory patients are provided with contact information and told to notify their surgeon immediately if they experience signs of hypocalcemia. Early signs include perioral numbness or paresthesia and a positive Chvostek's sign.

THYROGLOSSAL DUCT CYSTECTOMY

Thyroglossal duct cyst is the most common congenital cyst found in the neck. Although this cyst may be found in patients of any age, 50% usually are seen before 20 years of age and about 70% by 30 years of age. The thyroglossal duct is an embryonic structure arising from the descent of the thyroid gland into the anterior portion of the neck. When present in an adult, it exists as a pretracheal cystic pouch attached to the hyoid bone, with or without a sinus tract to the base of the tongue at the foramen cecum (Figure 15-13). Thyroglossal duct cystectomy requires complete excision of the cyst in continuity with its tract, the central portion of the hyoid bone, and the tissue above the hyoid bone extending to the base of the tongue to avoid recurrent cystic formation and to prevent infection (Warner, 2004).

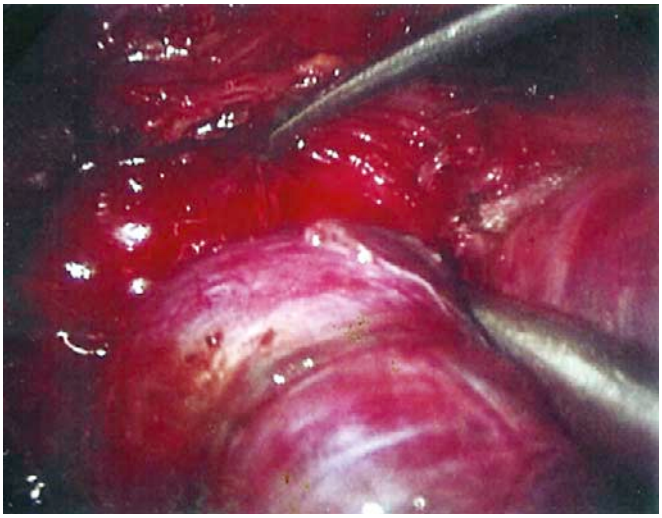


FIGURE 15-10 Video-assisted dissection of the right superior pole.

FIGURE 15-11 Identification of the recurrent laryngeal nerve during video-assisted right thyroid lobectomy. A parathyroid gland is also identified.

Procedural Considerations

The perioperative nursing assessment should be appropriate to the patient's age because the patient is frequently a child or teenager (see Chapter 25 for a detailed discussion of the needs of younger patients). Reassurance and age-appropriate information about the procedure are given. The patient is positioned supine, with the neck supported in extension. Bone instruments are needed in addition to the basic instrument set.

Operative Procedure

1. After the head is extended and the chin elevated, a transverse incision is made between the hyoid bone and thyroid cartilage through the subcutaneous tissue.
2. The platysma muscle is incised and flaps raised as described for thyroidectomy.
3. The strap (sternohyoid and sternothyroid) muscles are separated in the midline.
4. Sharp and blunt dissection is used to mobilize the cyst and duct, up to the attachment to the hyoid bone. The hyoid bone is transected twice, removing the center section with bone-cutting forceps. The segment of bone and the cyst are freed from adjacent structures.
5. The duct is traced superiorly through or near the hyoid up to the musculature of the tongue and removed completely. Methylene blue dye injection is used occasionally to visualize the whole tract.
6. The cyst is removed and the strap muscles closed with interrupted fine nonabsorbable sutures. A drain may be placed. The skin is then closed with subcuticular fine absorbable sutures and dressings are applied.

NECK DISSECTION

Neck dissection for metastatic node disease remains controversial as there is a high correlation of recurrence of cancer with little impact on long-term survival despite neck dissection. Lateral neck dissection is reserved for patients who have clinically proven lateral neck disease or gross metastasis along

FIGURE 15-12 **A**, Surgical scar at 2 weeks. **B**, Surgical scar at 6 weeks.

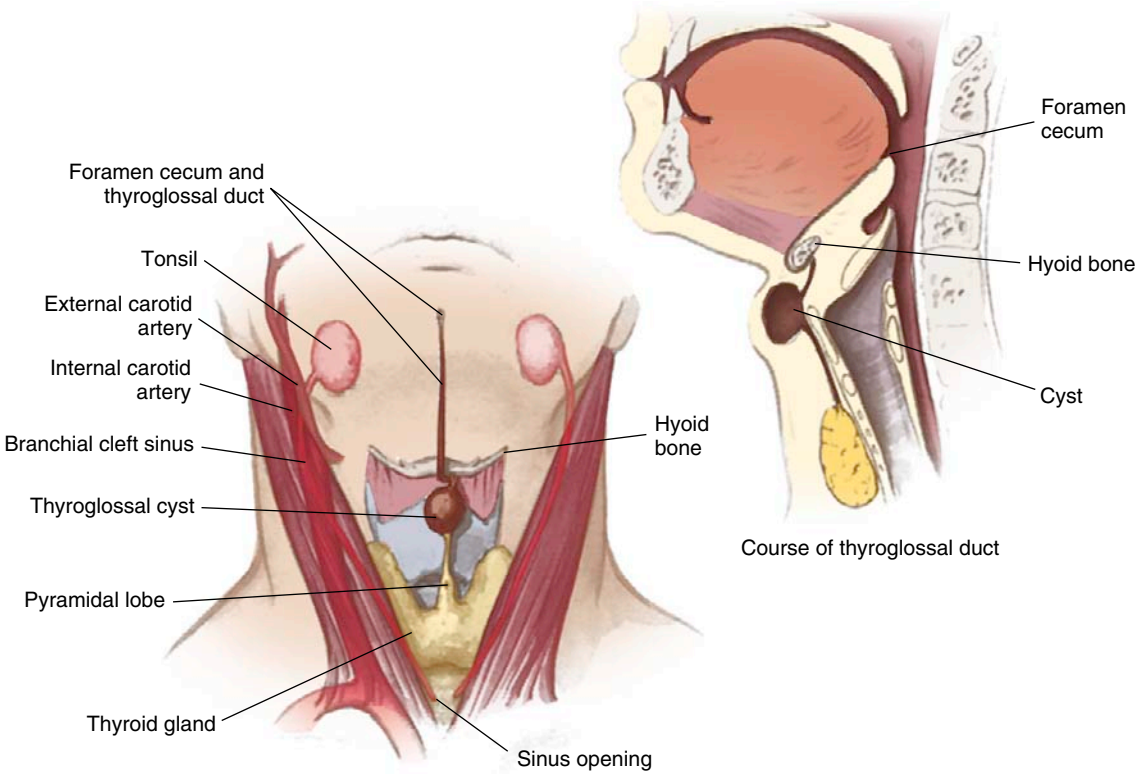


FIGURE 15-13 Thyroglossal cyst showing both anterior and lateral views.

the jugular vein. Central compartment dissection is reserved for those who have clinically apparent or suspicious nodes first noted during the primary surgery.

Patients are closely monitored postoperatively with ultrasound and thyroglobulin to screen for recurrence. Adjuvant radioactive iodine ablation is used for high-risk thyroid cancer patients, including those with residual disease in the thyroid bed, large tumors, multifocal disease, nodal metastasis, vascular and extrathyroidal invasion, and cancer with an aggressive history well as younger patients with distant metastasis (Loevner and Mukherji, 2008). Surgery is the treatment of choice for resectable recurrent thyroid carcinoma. The overall 10-year survival rate is 90%.

PARATHYROIDECTOMY

Parathyroidectomy is excision of one or more parathyroid glands. Normal or atrophic glands are generally not removed. The presence of adenomas (hypersecreting neoplasms), hyperplasia, or carcinoma requires surgical excision. For carcinomas, resection of the ipsilateral thyroid lobe and lymph nodes is essential, although metastasis may still occur by way of the bloodstream. Any residual parathyroid cancer may secrete parathormone, causing hypercalcemia and its attendant problems.

Previously, the gold standard for parathyroidectomy was bilateral neck exploration with biopsy of all four glands to confirm the presence of adenoma or hyperplasia. New technologies, however, have offered less invasive surgical options that pinpoint the affected gland and obviate the need to biopsy, and potentially damage, healthy parathyroid glands. The four-gland exploration for single-gland involvement is being replaced by radio-guided, minimally invasive ambulatory procedures utilizing intraoperative PTH levels and/or the gamma probe. Patients with a negative sestamibi scan are excluded from minimally invasive parathyroidectomy protocols although intraoperative PTH levels are still helpful in identifying multiple adenomas (Loevner and Mukherji, 2008). Often, the diagnosis of an adenoma can be made by gross inspection of the glands by the surgeon, but such diagnoses must be confirmed histologically by the pathologist.

Minimally invasive techniques cannot be used for hyperplasia. Hyperplasia requires removal of three and one-half glands through a bilateral neck exploration. A portion of a gland must remain to prevent hypocalcemia and its complications.

Procedural Considerations

During bilateral neck exploration multiple biopsies may be performed to determine the presence or absence of parathyroid tissue. Numerous specimen containers should be available (Patient Safety). Some surgeons perform parathyroidectomy using a minimally invasive approach with intraoperative parathyroid hormone assays to determine if the gland removed was the cause of hypersecretion. The perioperative nurse should ascertain that a pathologist is alerted and ready to analyze blood samples and tissue specimens. Preoperative localization studies, if done, should be conducted in the OR. If the surgeon is performing a focused parathyroidectomy (as described under Minimally Invasive, Focused Parathyroid Surgery), several blood tubes will be required to measure parathyroid levels intraoperatively. The circulating nurse will note excision

PATIENT SAFETY

Handling Multiple Specimens

The perioperative nurse is accountable for specimen collection, identification, and handling. During parathyroidectomy, multiple specimens may be collected. To accurately identify and safely manage these specimens, the perioperative nurse should do the following:

- Verify specimen collection and handling needs with the surgeon. This should occur before the procedure starts and may be part of the time-out or preoperative briefing (Paige et al, 2008).
- Have available an adequate number of specimen containers, labels, laboratory forms, and appropriate preservative.
- Take an additional time-out when the specimen is collected, in which the surgeon, scrub person, and nurse agree on the name of the specimen, its type, and source location.
- Label the specimen with a patient label naming the contents of the container. When multiple specimens are collected, they may be labeled A, B, C, etc. to indicate the order of harvesting.
- Communicate to the pathology department the nature of the procedure and anticipated specimens. Plan for direct communication about specimens between the surgeon and pathologist or perform a read-back or repeat-back of pathology findings.
- Use Standard Transmission–Based Precautions.
- Log (chain of custody) specimens according to institutional protocol.
- Arrange for timely transport of specimens to the pathology department.
- Document specimen collection in the intraoperative nursing record according to institutional protocol.

Modified from AORN recommended practices for the care and handling of specimens in the perioperative environment. In *Perioperative standards and recommended practices,* Denver, 2009, The Association.

time and collaborate with the anesthesia provider to anticipate and handle postexcision blood samples. Mediastinotomy instruments should be available (see Chapter 22). The patient is positioned, prepped, and draped as described for thyroidectomy. Hemoclips should be available.

Operative Procedure (Open Approach)

Although it is quickly being replaced with the focused approach to parathyroidectomy, in the classic open approach, with the thyroid gland visible, bilateral neck exploration of the "normal" locations of the four parathyroid glands is conducted. Meticulous hemostasis by means of mosquito hemostats and fine ligatures is a prerequisite to location and identification of these small glands.

The thyroid gland is gently rotated anteriorly to provide access to the posterior thyroid sulcus, where the parathyroid glands are almost always found. Identification of the parathyroid vascular pedicle, as it leaves either the superior thyroid artery or the inferior thyroid artery, is a means of locating both the inferior and superior glands. Metzenbaum scissors, mosquito hemostats, hemoclips, and gauze dissector (Kittner or peanut) sponges are used during dissection.

Attention then turns to the posterior lateral surface of the thyroid lobe or just beneath the lower thyroid pole, where the lower parathyroid glands are frequently found. Finding the vascular pedicle from the inferior thyroid artery may aid in identification (see Figure 15-5). Occasionally, the lower pair is found in the thymic capsule or tissue, in which case a portion of the thymus is resected. A mediastinotomy is indicated for a small percentage of patients. Thoracoscopy (see Chapter 22) is also a successful, minimally invasive technique that may be used to remove parathyroid tumors that are deep in the mediastinum.

If one of the parathyroid glands shows evidence of disease, an effort is made to find other glands on the same side to ensure that they are disease-free. When found, biopsy is performed, using a marker such as a hemoclip. The surgeon resects the diseased gland by clamping the vascular pedicle with mosquito hemostats, dividing with small scissors or a knife, and ligating with a fine nonabsorbable suture or hemoclip. The amount of parathyroid tissue that should be removed remains controversial and relates to whether single or multiple glands are involved. As previously noted, a portion of a gland must remain to prevent hypocalcemia and its complications.

A current alternative for multiple gland involvement is to excise all four glands and to transplant a portion of one in an accessible site, such as the neck or forearm, for later removal if hypercalcemia recurs. The amount of remaining parathyroid tissue can then be adjusted to regulate PTH to the desired level. This eliminates reexploration and potential injury to the recurrent laryngeal nerve. The parathyroid is morselized and divided into several segments. An incision is made in the forearm or neck and four separate grooves with purse-string sutures are made in the muscle. Some parathyroid tissue is placed and secured in each groove. The sites are then marked with one, two, three, and four hemoclips, respectively. If PTH levels remain high, the sites can be easily identified by the clips and more parathyroid tissue excised.

The neck region is then explored for aberrant parathyroid tissue, which is also resected. The remainder of the procedure is as described for the thyroid gland.

Minimally Invasive, Focused Parathyroid Surgery

A variety of minimally invasive techniques have evolved over the last decade. The most widely used is the focused minimally invasive open approach (focused parathyroidectomy, [FP]) where imaging has identified a single parathyroid lesion (Simpson et al, 2007). A localization study with sestamibi scan or ultrasound is used to identify the offending adenoma and to determine an optimum incision site. FP can be performed using a local anesthetic. Ambulatory surgery patients are provided specific education about postoperative oral calcium supplementation. In their study, Norman and Politz (2007) concluded that use of a specific calcium dosing protocol prevented postoperative development of symptomatic hypocalcemia in 93% of patients, identified patients at high risk of hypocalcemia, and allowed most patients who developed symptoms of hypocalcemia to self-medicate in a simple and predictable fashion.

PTH-Guided Parathyroidectomy. One relatively new approach is the intraoperative intact, rapid assessment PTH approach. Given that blood samples must be drawn before, during, and after the procedure to measure PTH levels, an arterial line is inserted and a baseline PTH measurement is taken preoperatively.

A small 2-cm incision is made in the neck based on the localization studies. Once the suspect parathyroid gland is exposed, a pre-excision blood sample is taken. As a result of manipulation, the pre-excision blood level may test higher than the baseline level. The pre-excision level becomes the marker for measuring the post-excision drop in PTH level.

The excised gland is placed in sterile saline and kept on the instrument table until the pathologist confirms a sufficient drop in PTH blood levels. A drop of 50% or more is considered verification that the parathyroid adenoma was excised. Blood levels are also drawn at 5, 10, and 20 minutes post-excision. When the adenoma is excised a dramatic drop in PTH level is frequently achieved by the 10-minute post-excision PTH sample. If the 10-minute drop is significant, the surgeon may opt not to have the pathologist run a 20-minute post-excision blood sample. If the hormone level fails to drop sufficiently, the ipsilateral parathyroid is explored as the next most likely adenoma. False positives have been reported in patients who have slow metabolic rates, are renal insufficient, or have large adenomas, 3 g or greater (Loevner and Mukherji, 2008).

Any normal parathyroid that was excised and placed in saline is then morselized with a #15 blade to increase surface area and then reimplanted. After the fascia is reapproximated, a clamp or scissors is used to create a groove in the strap muscle. A purse-string stitch of fine nonabsorbable suture is placed around the groove. The morselized parathyroid tissue is placed inside the groove and the purse-string tightened and tied. Parathyroids respond well to reimplantation.

Sestamibi-Guided Parathyroidectomy. Another minimally invasive technique is the sestamibi-guided, or radio-guided, parathyroidectomy. Sestamibi is given preoperatively and a gamma probe used intraoperatively to pinpoint the adenoma. When this technique is used postoperative normocalcemia has been reported in 97% of patients (Loevner and Mukherji, 2008).

REFERENCES

Association of PeriOperative Registered Nurses: AORN Position Statement on Surgical Smoke and Bio-Aerosols, 2008, available at www.aorn.org/PracticeResources/AORNPositionStatements/SurgicalSmokeAndBioAerosols. Accessed April 4, 2009.

Banschbach SK: Mutual accountability for the common goal of patient safety, *AORN J* 88(1):11–13, 2008.

Benner P et al: *Expertise in nursing practice: caring, clinical judgment, and ethics*, ed 2, New York, 2009, Springer.

Burman KD: Advances in thyroid cancer treatment, *Medscape Diabetes & Endocrinology* 7(1), 2005, available at www.medscape.com/viewarticle/496261. Accessed April 12, 2009.

Canobbio MM: *Mosby's handbook of patient teaching*, ed 3, St Louis, 2006, Mosby.

Denholm B: Tucking patient's arms and general positioning, *AORN J* 89(4):755–757, 2009.

Dhingra JK: Minimally invasive surgery of the thyroid. Emedicine from WebMD, 2008, available at www.WebMD.com. Accessed November 19, 2008.

Elberling TV et al: Impaired health-related quality of life in Graves' disease: a prospective study, *Eur J Endocrinol* 151:549–555, 2004.

Frost L et al: Hyperthyroidism and risk of atrial fibrillation or flutter: a population-based study, *Arch Int Med* 164:1675–1678, 2004.

Gauger PG, Doherty GM: Parathyroid gland. In Townsend CM et al, editors: *Sabiston textbook of surgery*, ed 17, Philadelphia, 2004, Saunders.

Grebe SKG: Diagnosis and management of thyroid carcinoma: a focus on serum thyroglobulin, *Expert Rev Endocrinol Metab* 4(1):25–43, 2009.

Haynes AB et al: A surgical safety checklist to reduce morbidity and mortality in a global population, *N Engl J Med* 360(5):491–499, 2009.

Hegarty J et al: Nurses' knowledge of inadvertent hypothermia, *AORN J* 89(4):710–713, 2009.

Kuwajerwala NK et al: Thyroid, thyrotoxic storm following thyroidectomy, 2007, available at emedcine.medscape.com/article850924. Accessed January 24, 2009.

Lansford CD, Teknos TN: Evaluation of the thyroid nodule, *Cancer Control* 13(2):89–98, 2006.

Loevner LA, Mukherji SK: *Thyroid and parathyroid glands: imaging, treatment, and beyond*, Philadelphia, 2008, Saunders.

Mirnezami R et al: Day-case and short-stay surgery: the future for thyroidectomy? *Int J Clin Pract* 61(7):1216–1222, 2007.

Norman JG, Politz DE: Safety of immediate discharge after parathyroidectomy: a prospective study of 3,000 consecutive patients, *Endocrinol Pract* 13(3):105–113, 2007.

Pagana KD, Pagana TJ: *Mosby's diagnostic and laboratory test reference*, ed 9, St Louis, 2009, Mosby.

Paige JT et al: Implementation of a preoperative briefing protocol improves accuracy of teamwork assessment in the operating room, *Am Surg* 74(9):817–823, 2008.

Patient Screening and Assessment in Ambulatory Surgical Facilities, *Pennsylvania Patient Safety Advisory* March 6(1):3–9, 2009, available at www.patientsafetyauthority.org. Accessed April 2, 2009.

Perioperative Grand Rounds: The inside of a time out, *AORN J* 89(4): 808, 656, 2009.

Sarkar SD, Savitch I: Management of thyroid cancer, *Appl Radiol* 33(11): 34–45, 2004.

Simpson H et al: Long term follow up following focused parathyroidectomy for primary hyperparathyroidism. Presented at Society for Endocrinology BES 2007, Birmingham, UK. Endocrine Abstracts 13 P85, 2007.

Steel AC, Reynolds SF: The growth of rapid response systems, *Jt Comm J Qual Patient Saf* 34(8):489–495, 2008.

Terris D: *Outpatient thyroid surgery safe for most patients, study shows*, Medical College of Georgia: 2006, available at https://my.mcg.edu. Accessed January 24, 2009.

The Joint Commission Public Policy Initiative: *"What Did the Doctor Say?" Improving Health Literacy to Protect Patient Safety*, TJC, Oak Bridge Terrace, IL, 2007.

Thyroid nodules, 2005, American Thyroid Association, available at www.thyroid.org. Accessed April 12, 2009.

Tuttle RM: NCCN Thyroid Carcinoma Guidelines Update, 2007. cme.medscape.com/viewarticle/555684. Accessed April 12, 2009.

Warner BW: Pediatric surgery. In Townsend CM et al, editors: *Sabiston textbook of surgery*, ed 17, Philadelphia, 2004, Saunders.

Wilson SF, Giddens JF: *Health assessment for nursing practice*, ed 4, St Louis, 2009, Elsevier.

CHAPTER 16

Breast Surgery

ELIZABETH B. PEARSALL

Most surgical procedures on the breast are performed to establish a definitive diagnosis or to treat breast cancer. Changing hormone levels from puberty throughout the remainder of life affect breast tissue in its physical and microscopic characteristics. In association with these changes, numerous aberrations and tumors can occur.

The occurrence of breast changes, benign or malignant, are some of the most emotionally upsetting health problems confronting women. Breast cancer is the most common cancer in women (Weaver, 2009); it accounts for nearly one of every three cancers diagnosed. The probability of developing breast cancer increases with age. Estimates are that one in eight women in the United States will develop breast cancer during her life. If the cancer is detected early, there is a 97% 5-year survival rate. Breast cancer risk increases if a woman's mother, sister, or daughter had breast cancer, especially if the cancer developed before menopause. Early menarche (before 12 years of age) and a late natural menopause (after 50 years of age) are associated with a slightly increased risk for developing breast cancer. Further, a woman who has cancer in one breast is at increased risk for cancer in the other breast (American Cancer Society, 2009). Heightened public awareness, an increased number of women practicing self-examination, and early detection of breast masses by mammography have started to slow the annual increase in breast cancer mortality.

Surgical Anatomy

The breasts are bilateral mammary glands that lie on the pectoralis major fascia of the anterior chest wall. They are surrounded by a layer of fat and are encased in an envelope of skin. The breasts extend from the second to the sixth rib and horizontally from the lateral edge of the sternum to the anterior axillary line. The largest part of the mammary gland rests on the connective tissue of the pectoralis major muscle and laterally on the serratus anterior (upper outer quadrant of the breast), with a normal globular contour occurring as a result of fascial support (Cooper's ligaments). An elongation of mammary tissue normally extends laterally on the pectoralis major toward the axilla and is known as the *tail of Spence* (Figure 16-1).

Each breast is made up of 12 to 20 glandular lobes separated by connective tissue. Each lobe drains by a single lactiferous duct that opens on the nipple. The nipple, located at about the fourth intercostal space, forms a conical projection into which the ducts open independently of each other on the surface. A pigmented circular area called the *areola* surrounds the nipple. Smooth muscle fibers of the areola contract to allow for nipple projection.

Three major arterial systems (Figure 16-2) supply the mammary glands with blood. The two main sources are branches of the internal mammary and lateral branches of the anterior aortic intercostal arteries, all of which form an extensive network of anastomoses over the breast. The third source is the pectoral branch, deriving from a branch of the axillary artery. The veins that mainly drain the breasts follow the course of the arteries. Superficial veins frequently dilate during pregnancy.

Lymph drainage generally follows the course of the vessels. Lymphatics drain into two main areas represented by the axillary nodes and the internal thoracic chain of nodes (Figure 16-3). The internal thoracic nodes are few, but are responsible for most lymph drainage from the inner half of the breast. Thus the lymph system can also be a channel for the spread of malignant disease from the breast to associated areas of the chest wall or to the axilla.

The breast's sensory nerve supply is primarily threefold: the anterior cutaneous branches of the upper intercostal nerves, the third and fourth branches of the cervical plexus, and the lateral cutaneous branches of the intercostal nerves.

The mammary glands are affected by three types of physiologic changes: (1) those related to growth and development, (2) those related to the menstrual cycle, and (3) those related to pregnancy and lactation. The mammary glands are present at birth in both males and females. Hormonal stimulation, however, produces the development and function of these glands in females. Estrogen promotes growth of the ductal structures, whereas progesterone promotes lobular development. Occasionally, developmental errors of the breast occur. Additional nipples or extramammary tissue in the axilla or over the upper abdomen may be present. Absence of one or both nipples may also occur and may be associated with absence of the underlying pectoral muscle and chest wall.

BENIGN LESIONS OF THE BREAST

Fibrocystic change in the breast is an all-encompassing term used to describe many different breast changes. Examples of benign lesions that are generally considered when fibrocystic changes are discussed are multiple lesions of fibrous disease, intraductal papillomas, cysts, and solid masses, such as fibroadenomas (Table 16-1). These changes affect almost all women at some time in their lives. Frequently pain is present, which calls attention to the problem. Pain, fluctuations in size, and multiple lesions are common features that help differentiate these generally benign lesions from cancer.

Nipple discharge is more commonly associated with benign lesions than with cancer. A postmenopausal woman who has

some duct ectasia or who has borne children can manually produce nipple discharge. Discharge is usually significant only if it is spontaneous and persistent. Chronic unilateral nipple discharge, especially if bloody, should prompt an investigation for occult carcinoma.

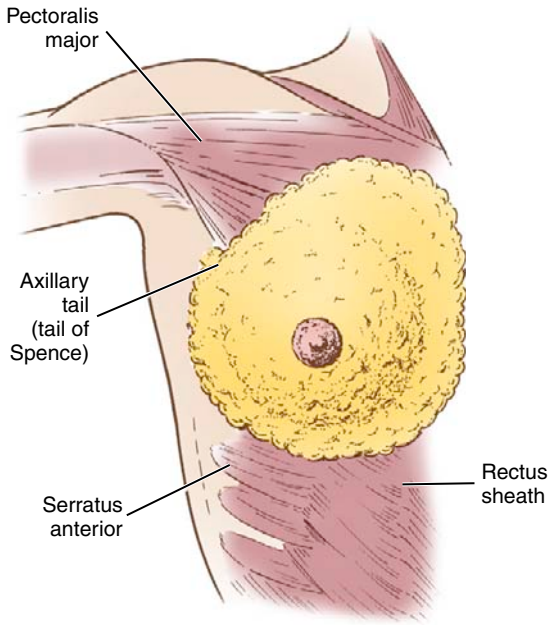


FIGURE 16-1 Normal distribution of mammary tissue of adult female breast.

BREAST CANCER

Breast cancer affects primarily women, although it can occur in the mammary gland of men. Until it can be prevented, early detection is the best hope for cure. All women should practice monthly self-examination to detect palpable lesions, and they should immediately report any changes or masses to a physician. External physical changes, such as dimpling of the skin, can also indicate the presence of a benign or malignant pathologic process. The older the patient, the more likely it is that a mass is malignant. The most common form of breast cancer is infiltrating ductal carcinoma (Table 16-2).

The cause of breast cancer remains unknown. Many factors, including environmental, dietary (National Cancer Institute, 2007), and familial influences, have been suggested as contributors to its development (Table 16-3). The belief that breast cancer spreads by direct extension from its initial site in the breast to adjacent lymph nodes may not always be correct. Breast cancer may be a systemic condition at the time of diagnosis (History box). Distant metastases may have already occurred without adjacent lymph node involvement at the time of its palpable detection. This could explain why radical breast surgery of the past, which involved removal of the affected breast and all axillary and thoracic lymph nodes, did not greatly lower mortality. Survival from breast cancer is best when detected early, reducing axillary lymph node involvement and improving long-term survival. Tumor size can usually be correlated with involvement of lymph nodes. The larger a tumor is, the more likely it is that lymph nodes are involved.

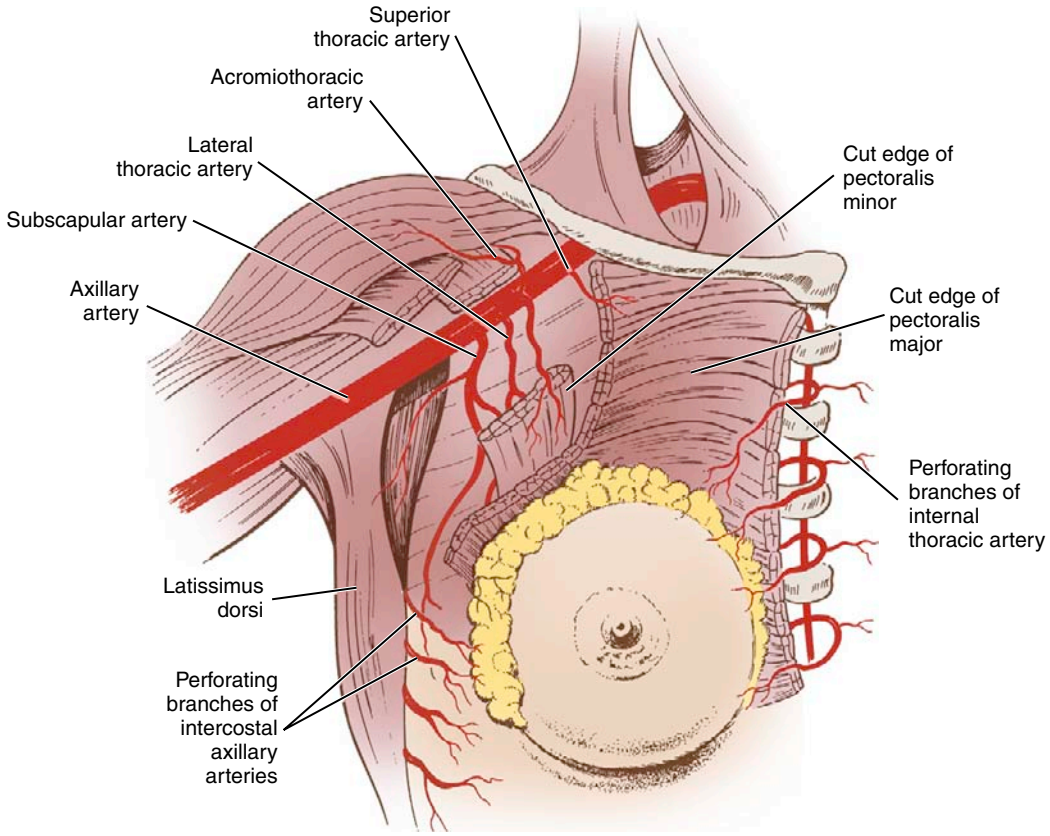


FIGURE 16-2 Normal arterial blood supply of the breast.

Less radical surgery is the treatment of choice today. Surgical excision of the tumor, the use of radiation therapy alone, or a combination of surgery, chemotherapy, and radiation therapy are current treatment recommendations. The use of adjuvant chemotherapy is particularly recommended for premenopausal women with axillary-node metastasis. Studies show that similar therapy can benefit node-negative breast cancer patients. New studies and new therapeutic options are continually being developed and tested. Clinical use of accelerated partial breast irradiation (APBI) is the subject of ongoing clinical trials.

HISTORY

Breast Surgery through the Ages

Over 3500 years ago, ancient Egyptians first noted breast cancer, describing it as "bulging tumors" with no cure. In 460 BC, Hippocrates described breast cancer as a "humoral" disease caused by an excess of black bile. Hippocrates believed the body consisted of four "humors" (blood, phlegm, yellow bile, and black bile) and any imbalance of the humors caused sickness or death. He claimed surgery was dangerous because he had noted that women who had the tumor excised died quickly and those who did not have surgery lived longer. Galen, in 200 AD, believed that some tumors were worse than others and surgery was not an option.

By the eighteenth century, the humoral theory of the origin of breast cancer was losing credibility. Some theories of the cause of breast cancer were that it was derived from curdled milk or a sedentary lifestyle, or that it occurred more frequently in childless women. People also thought the disease was localized. Dr. LeDran, a French physician, and Dr. LeCat were both of the opinion that surgery was the only way to cure the cancer.

By the mid-nineteenth century, most doctors agreed that surgery was the answer. Dr. William Halstead of New York dominated breast cancer surgery with radical mastectomy for most of the next century. He theorized that the cancer was a cellular disease. He urged women to have radical mastectomies before the tumor spread to the lymph nodes. Scottish physician Bealson discovered that a bilateral oophorectomy shrank his patients' breast tumors. Surgeons then began to perform radical mastectomy and bilateral oophorectomy, but the surgery was debilitating to the patient. Other radical surgeries to halt estrogen supply to the breast tumor were removal of the pituitary gland and adrenalectomy.

In 1955 Dr. George Crile argued cancer was not localized, but it spread throughout the body. Dr. Bernard Fisher theorized that cancer cells spread systemically by the circulatory and lymph system and that surgery could not cure cancer. Crile and Fisher both advocated a more systemic approach to breast cancer.

In the 1990s, after an initial increase in breast cancer rates, the number of breast cancer deaths reached a plateau in 1995 and then started to decline. By 1995 less than 10% of women inflicted with breast cancer had a mastectomy. Improvements in chemotherapy, radiation, hormone treatment, mammography, and surgery helped reposition breast cancer from an urgent disease to a chronic condition. Breast cancer theory has come full circle, from Hippocrates' theory of systems of imbalanced humors to the present view of breast cancer as a systemic condition.

Modified from *A history of breast cancer,* 2008, available at www.randomhistory.com/1-50/029cancer.html. Accessed April 6, 2009.

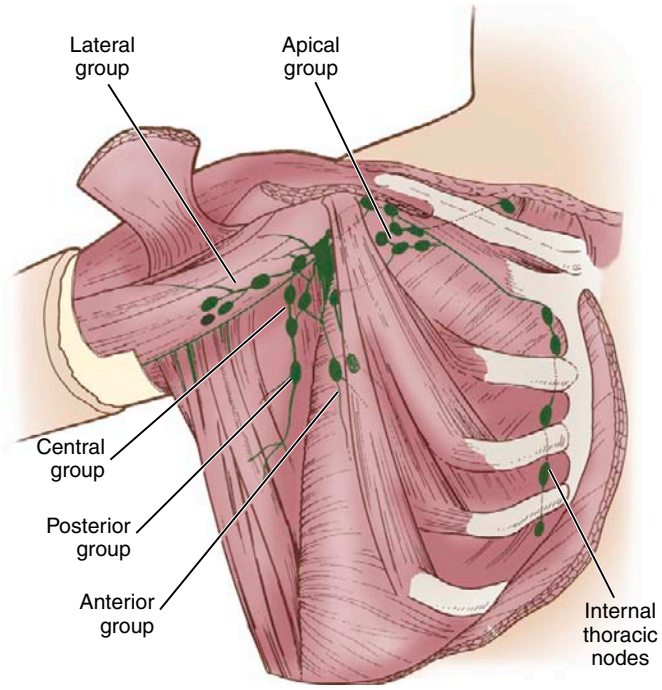


FIGURE 16-3 Distribution of axillary and thoracic lymph nodes.

TABLE 16-1

Typical Presentation of Benign Breast Disorders

Breast Disorder	Description	Incidence
Fibroadenoma	Most common benign lesion; solid mass of connective tissue that is unattached to surrounding tissue	Teenage years into 30s
Fibrocystic breast disease (FBD)	*First stage:* characterized by premenstrual bilateral fullness and tenderness *Second stage:* presence of bilateral, multicentric nodules *Third stage:* presence of microscopic and macroscopic cysts	Late teens and 20s
Ductal ectasia	Hard, irregular mass or masses with nipple discharge, enlarged axillary nodes, redness, and edema; difficult to distinguish from cancer	Women approaching menopause
Intraductal ectasia	Mass in duct that results in nipple discharge; mass is usually not palpable	Women 40-55 yr of age

Data from American Cancer Society: *Noncancerous breast conditions, 2009,* Atlanta, Author; Ignatavicius DD, Workman ML: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, St Louis, 2010, Saunders.

TABLE 16-2

Types of Invasive Breast Cancer

Breast Cancer Type	Percent of Breast Cancers	Specific Features
Ductal carcinoma	≈80	Can appear as microcalcifications, can vary widely in appearance, can have features of other histologic subtypes of breast cancer
Lobular carcinoma	10-15	Begins in milk (lobules) glands of breast, high rate of bilaterality, grows as single file of malignant cells around ducts and lobules, poorly defined mass
Medullary carcinoma	1-5	Forms distinct boundary between tumor tissue and normal tissue, well circumscribed, frequent phenotype of *BRCA1* hereditary breast cancer
Tubular	2	Infrequently metastasizes to lymph nodes, slow growing, long-term survival approaches 100%
Inflammatory carcinoma	≈1	Rapidly growing, often with metastasis present at diagnosis, first manifestations are breast skin edema and redness and warmth with dimples or ridges

Data from Imaginis: *What is breast cancer? 2008,* available at www.imaginis.com/breasthealth/breast_cancer2.asp. Accessed June 1, 2009; Mulholland M et al: *Greenfield's surgery: scientific principles & practice,* ed 4, Philadelphia, 2006, Lippincott Williams & Wilkins; Brunicardi FC et al: *Schwartz's principles of surgery,* ed 8, New York, 2005, McGraw-Hill.

TABLE 16-3

Risk Factors for Breast Cancer

Factors	Comments
HIGH INCREASED RISK (RELATIVE RISK >4.0)	
Female gender	99% of all breast cancers occur in women.
Age >65 yr	Incidence increases with age and peaks in sixth decade.
Genetic factors	Inherited mutations of *BRCA1* and/or *BRCA2* increase risk.
Family history	Two or more first-degree relatives with breast cancer at an early age increases risk.
History of previous breast cancer	Risk for developing cancer in opposite breast is 5 times greater than average population at risk.
Breast density	Dense breasts contain more glandular and connective tissue.
MODERATE INCREASED RISK (RELATIVE RISK 2.1-4.0)	
Family history	One first-degree relative with breast cancer moderately increases risk.
Biopsy-confirmed atypical hyperplasia	Overactive growth of cells increases risk.
Ionizing radiation	Women who received frequent low-level radiation exposure to thorax have increased risk, especially if exposure occurred during periods of rapid breast formation.
High postmenopausal bone density	High estrogen levels over time both strengthen bone and increase breast cancer risk.
LOW INCREASED RISK (RELATIVE RISK 1.1-2.0)	
Reproductive history	Childless women have an increased risk, as do women who bear their first child near or at age 30.
Menstrual history	Risk for breast cancer rises as interval between menarche and menopause increases. Women who undergo bilateral oophorectomy before age 35 have only 40% of risk for breast cancer compared to women who undergo natural menopause.
Oral contraceptives	There is a slight increase in breast cancer risk in women taking oral contraceptives.
Hormone replacement therapy (HRT)	Recent and long-term use of hormone replacement therapy slightly increases risk.
Obesity	Postmenopausal obesity (especially increased abdominal fat), increased body mass, insulin resistance, and hyperglycemia have been reported to be associated with increased risk for breast cancer.
OTHER RISK FACTORS	
Alcohol	The equivalent of two drinks per day may increase risk by 21%.
High socioeconomic status	Breast cancer incidence is greater in women of higher education and socioeconomic background. This relationship is possibly related to lifestyle differences, such as age at first birth.
Jewish heritage	Women of Jewish Ashkenazic heritage have higher incidences of *BRCA1* and *BRCA2* genetic mutations.

Modified from American Cancer Society: *Breast cancer facts and figures 2007-2008,* Atlanta, 2009, Author; Ignatavicius DD, Workman ML: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, St Louis, 2010, Saunders.

In APBI the radiation is focused on the area of greatest risk for tumor recurrence, the lumpectomy site, instead of whole breast irradiation (WBI). Such focused radiation treatment therapies reduce the traditional 6-week radiation treatment plan to 1 week (Fearmonti et al, 2007).

Minimally invasive cryoablation technology to freeze and destroy core biopsy–proven fibroadenomas has been approved by the U.S. Food and Drug Administration (FDA) and is now performed safely in an office setting (Bland et al, 2009). Another breast surgery alternative is focused ultrasound (FUS) with magnetic resonance guidance (MRgFUS), which allows for imaging and tissue temperature monitoring while controlling the FUS beam direction during ablation of breast lesions (Bland et al, 2009).

SCREENING TECHNOLOGIES

Imaging methodologies, such as mammography and ultrasonography, have helped to detect breast masses too small for clinical detection (Hulvat et al, 2009). The American Cancer Society recommends clinical breast exams by a physician every 3 years for women ages 20 to 39 years and annual clinical breast exams and mammograms for women 40 and older (Table 16-4). The American College of Physicians recommends that women who are not at high risk for breast cancer should have regular mammograms starting at age 50. High-risk women, such as those who have a family history of breast cancer or who have detected a lump in the breast, should start annual mammograms at age 40 (Zuckerman, 2007).

The most common screening mechanism for asymptomatic women is x-ray (film-screen) mammography (Figure 16-4). In mammography, the entire breast is visualized as x-ray beams are directed in several planes through it. Mammograms detect abnormal-appearing densities, irregular or spiculated margins, microcalcifications, and clusters of calcium deposits that are clinically nonpalpable. These masses may be as small as 1 cm in diameter (Mulholland et al, 2006). Often, previous mammograms are used for comparison. Screening mammography has led to identification of more nonpalpable breast masses. The accuracy of mammography depends on careful x-ray technique and breast size, structure, and density. Radiation dosage varies with individuals and techniques. As a result of improved radiologic techniques, radiation exposure in a mammogram is very low. The benefits of this screening mechanism far outweigh the minute risks of radiation exposure. Advances in computer-assisted detection allow the computer to analyze the mammogram, placing asterisks and triangles on small potential problem areas, which a radiologist then reviews. If screening mammography reveals a suspicious area, the patient is asked to return for diagnostic mammography (explained in the following paragraphs).

Digital mammography takes an electronic image of the breast and stores it directly in a computer. Digital mammography uses less radiation than film mammography and improves image storage and transmission, as images are stored and sent electronically. Radiologists also can use software to interpret digital mammograms. One obstacle to greater use of digital mammography is its cost, currently about 1.5 to 4 times more than film systems. Digital screening mammograms are more accurate than film screening mammograms, with a 70% detection rate compared with 55% for film screens. Women most likely to benefit from digital screening are those younger than 50 with dense breast tissue and who are premenopausal or perimenopausal (Hulvat et al, 2009).

When there is a palpable mass or other abnormality identified on screening mammography, a diagnostic imaging evaluation is done (Mikula, 2008). Additional diagnostic mammographic views are obtained, and the radiologist assigns a BI-RADS (Breast Imaging Reporting and Data System) score (Box 16-1). An ultrasound may then be ordered.

Ultrasonography differentiates between solid and cystic lesions. As a screening methodology, its sensitivity and specificity are less definitive than mammography. Ultrasonography can be useful with dense or dysplastic breasts and in pregnant or lactating women.

Magnetic resonance imaging (MRI) is another technique used as an adjunct to mammography in the detection of breast lesions. Breast MRI can image dense breast tissue,

TABLE 16-4

American Cancer Society Breast Cancer Screening Guidelines for Asymptomatic Women*

Age	Screening Activity
20-39 yr	Breast self-examination (BSE) monthly
	Clinical breast examination (CBE) every 3 yr
40 yr and older	BSE monthly
	CBE annually
	Screening mammography (two views of each breast) annually

*Asymptomatic women who are identified to be at higher risk need to have an individualized screening plan that may differ from these guidelines. From American Cancer Society: *Breast cancer facts and figures 2007-2008,* Atlanta, 2009, Author.

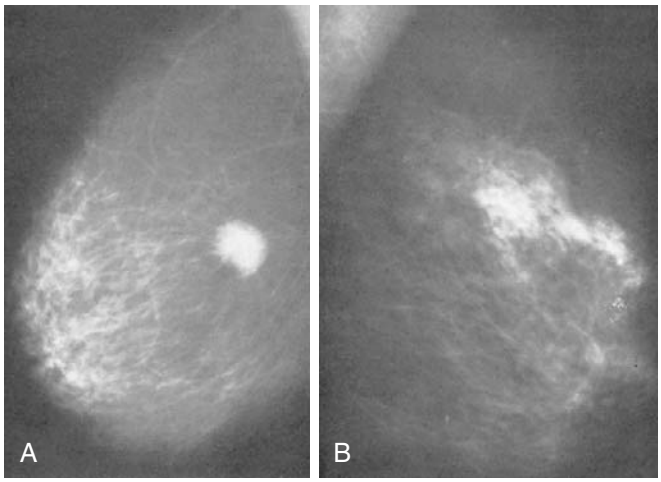


FIGURE 16-4 Mammographic features of malignancy. **A**, A stellate mass. The combination of a density, surrounding spicules, and distortion of the breast architecture strongly suggests a malignancy in this mammogram. **B**, Clustered microcalcifications. Fine, irregular, and branching forms suggest malignancy in this mammogram. Fine calcifications, less than 0.5 mm in size, are more often associated with cancer than are larger, coarse calcifications.

which shows poorly with conventional mammography. There is interest in the use of MRI to improve selection for breast-conserving therapy (BCT). In 2007 the American Cancer Society recommended that MRI be used for women at high risk. Such women include those who have known breast cancer–associated *BRCA1* or *BRCA2* gene mutations, have a first-degree relative with a *BRCA1* or *BRCA2* gene mutation, have a lifetime risk of breast cancer of 20% to 25% or greater according to risk assessment tools, had radiation therapy to the chest between 10 and 30 years of age, or have certain rare syndromes. The 2008 study by Martinez-Cecilia found that preoperative MRI improved tumor staging and changed the surgical approach for 13% of study patients; MRI discovered an additional malignant lesion in 8% of patients, and showed a tumor larger than originally believed in 16 patients, altering the planned surgery.

Molecular breast imaging (MBI) involves injection of a short-lived radiotracer, which is absorbed by breast tissue and preferentially so by breast tumors. MBI is especially useful in detecting breast cancer in women with dense breasts and who are at higher risk of developing the disease. This new technique has shown good promise as a helpful adjunct to screening mammography (U.S. Department of Health and Human Services, 2008).

Positron emission tomography (PET) scans with the glucose analog 2 are also being used for breast cancer detection. This scan is about 88% accurate for large breast tumors. For lesions less than 1 cm, the sensitivity of PET is 57% (Hulvat et al, 2009).

DNA-based genetic testing for *BRCA1* and *BRCA2* is not recommended for women without family histories that suggest risk for these gene mutations. A recent meta-analysis estimated that the lifetime risk for breast cancer was 47% to 66% in carriers of *BRCA1* and 40% to 57% in carriers of *BRCA2*. Other studies have shown even higher estimates. Managing breast cancer risk for women with these mutations includes frequent screening and prophylactic surgeries (Nelson, 2009).

In some instances, such as when a lesion previously detected by mammogram is too small to palpate, mammograms are repeated immediately before surgery. The lesion is localized by the insertion of a needle or a wire within a needle (the procedure is often referred to as "needle" or "wire" localization). The wire is placed within the suspect area, and the distal end is left on the outside of the skin. The needle may be left in place or removed after insertion of the wire (Figure 16-5). The needle or wire is then taped in place, and the patient sent to the OR for surgical biopsy. Wire localization and surgical biopsy occur on the same day. After biopsy, the specimen is sent to the radiology department for mammographic validation of correct surgical excision of the questionable breast tissue. The tissue is then sent for pathologic examination.

BOX 16-1

BI-RADS Assessment Scores

Category 0: The screening mammogram indicates additional screening is necessary. Prior mammograms, if available, are used for comparison. Additional imaging may include spot compression, magnification, special mammographic views, or ultrasound.
Category 1: The results are negative.
Category 2: The findings are benign.
Category 3: The findings are probably benign. Short-term follow-up is advised.
Category 4: The findings are suspicious. Biopsy is considered.
Category 5: The findings are highly suggestive of malignancy. Preliminary biopsy is needed; surgical treatment likely required.
Category 6: Known biopsy-proven malignancy. This category may be used for a second opinion before excisional biopsy, radiation therapy, chemotherapy, or mastectomy or for following tumor response during chemotherapy.

Modified from Mikula C: Mammography and biopsy, *Adv Nurs* 10(9):21-23, 2008.

DIAGNOSTIC TECHNIQUES

Once a mass is identified, the physician has multiple techniques to establish a diagnosis. During a fine needle aspiration biopsy (FNAB), the physician anesthetizes a small area of the breast with lidocaine. A 22- or 25-gauge needle attached to a 20-ml syringe is inserted into the mass, and a small amount of the contents is aspirated. Cytologic examination of the aspirate can assist in microscopic evaluation of the mass. FNAB yields greater diagnostic accuracy if the physician has been thoroughly trained in the technique. In a review of 31,340 procedures, FNAB sensitivity ranged from 65% to 98%. False-positive rates were less than 1%. As diagnosis of malignancy by FNAB is extremely reliable, treatment options can then be discussed with the patient and definitive surgery performed without the need for a surgical biopsy (Mulholland et al, 2006).

Advances in instrumentation now allow for simultaneous biopsy and removal of mammographic densities that are up to 20 mm in size using digital stereotactic imaging and minimally invasive instruments to locate and remove tissue for diagnosis. The patient is assessed preoperatively for neck or back problems. In addition, the patient should not be receiving anticoagulant therapy. Masses located near the patient's areola, high in the axilla, or near the chest wall are not appropriate for this technique. The patient is placed on a specially designed table (Figure 16-6) in the prone position with the affected breast through the table's 10-inch aperture to the work area below. The patient's head is turned away from the physician. Padding is placed under bony prominences to improve comfort. When the suspicious area in the breast is located through stereotactic imaging, its coordinates are transferred to the table's automated instrument. After preparing the skin with an antiseptic

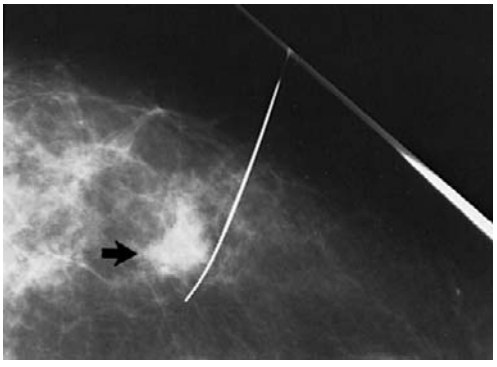


FIGURE 16-5 Mammogram section. Craniocaudal view of breast. Arrow indicates breast lesion localized by wire before surgical excision.

solution while the patient is administered a local anesthetic, the physician makes a small incision in the breast. The physician positions the disposable device to remove the identified tissue. Additional biopsies can be made if indicated, and coagulation can be used if necessary. A titanium vessel clip can be placed at the base of the biopsy specimen as a point of reference for future evaluations. A postoperative dressing is then applied to the area. The benefits to the patient include small incisions for cosmetic results, decreased disfigurement, shortened time between detection and diagnosis, and elimination of the need for more involved surgical intervention (Stephan, 2009).

SURGICAL TREATMENT OPTIONS

Surgical treatment ranges from minimally invasive breast biopsy, lumpectomy, and wide excision of the tumor mass; to modified radical mastectomy involving the breast and axillary lymph nodes; to salpingo-oophorectomy (Research Highlight). The goal of surgery is removal of the cancerous mass with a margin of normal tissue and a good cosmetic result. When a specimen of breast tissue is sent to the laboratory, it is inked to mark the relationship between the tumor and the surgical margins of the excision. The pathologist evaluates these margins on all sides of the tumor for malignant cells. If a margin is positive, it indicates that malignant cells may remain in the breast. Additional surgery is usually required until the margins contain only normal tissue (Re-excision for Close Margins, 2008).

The choice of procedure depends on the size and site of the mass, the characteristics of the cells, the stage of the disease, and the patient's choice. A breast cancer diagnosis is usually staged to measure the extent of the disease and to classify patients for possible treatment modalities (Figure 16-7). The TNM (T = tumor; N = node; M = metastasis) classification has been adopted as a mechanism to clinically stage this disease. Staging results are used in designing a specific treatment plan. Radiation therapy, chemotherapy, or hormonal therapy may be used with surgery or as alternative treatment methods. An intravenous (IV) access port may be surgically placed for later infusion of chemotherapeutic drugs, fluids, or nutrition as well as to withdraw blood and laboratory specimens (Ambulatory Surgery Considerations).

Excised tumors or core needle biopsies are evaluated for their estrogen-binding and progesterone-binding abilities. Techniques have been developed to assess the ability of breast cancer to bind with estrogen and progesterone.

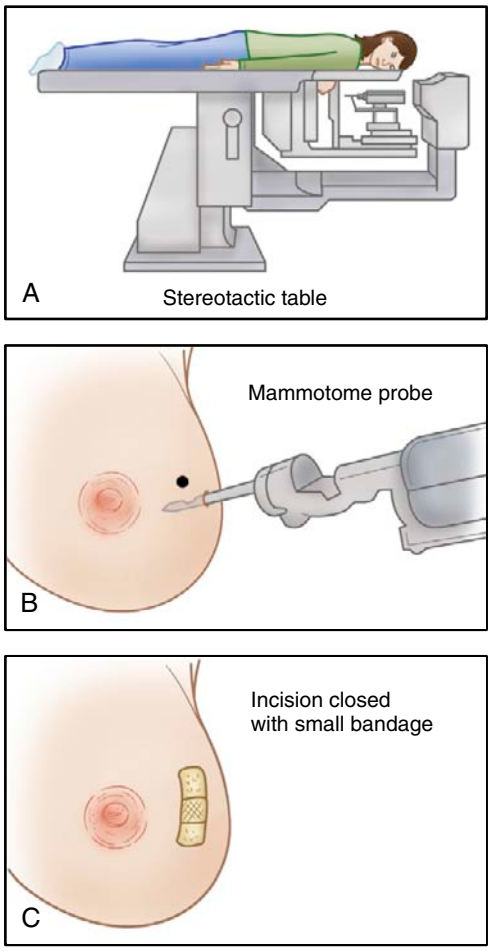


FIGURE 16-6 A, In stereotactic procedures, patients lie facedown on a special table. The woman's breast protrudes through a hole in the table's surface, where it is lightly compressed and immobilized while a computer produces detailed images of the abnormality. B, Once the biopsy area has been located and mapped, the Mammotome probe is inserted through a small ¼-inch incision in the breast, where it gently vacuums, cuts, and removes breast tissue samples. C, The incision is then closed with a small adhesive bandage.

RESEARCH HIGHLIGHT

Salpingo-Oophorectomy to Reduce Cancer Risk in Women with *BRCA* Mutations

According to a meta-analysis undertaken by Rebbeck and colleagues, prophylactic salpingo-oophorectomy reduces the risk for breast cancer by 50% and the risk for ovarian and fallopian tube cancer by 80% in women who carry mutations in the *BRCA1* or *BRCA2* gene. Their study quantified cancer risk reduction and is currently the most authoritative review. Salpingo-oophorectomy surgery reduces risk but is not 100% risk-eliminating. These new risk estimates should help women decide whether to undergo this surgery. Researchers and clinicians need to find ways to improve the efficacy of this surgical intervention by using optimal timing and type of surgery. Breast cancer reduction with prophylactic salpingo-oophorectomy was greater in *BRCA1/2* mutation carriers younger than 50 years than in women ages 50 and older. However, removal of both ovaries before age 45 increases risk for cardiovascular death 20 to 30 years later. Women with inherited mutations in *BRCA1* or *BRCA2* genes have a substantially elevated risk for breast and ovarian cancer, with a lifetime risk for breast cancer of 56% to 84%. This meta-analysis provides strong data about risk reduction estimates, which provide surgeons and patients with better information about risk-reducing salpingo-oophorectomy (RRSO). Discovering that RRSO is associated with a large reduction in *BRCA* mutation–related breast cancer risk, especially among women who are premenopausal at RRSO, makes this surgery much more acceptable to high-risk women.

Adapted from Greene MH, Mai PL: What have we learned from risk-reducing salpingo-oophorectomy? *J Natl Cancer Inst* 101(2):70-71, 2009; Rebbeck TR et al: Meta-analysis of risk reduction estimates associated with risk reducing salpingo-oophorectomy in *BRCA1* or *BRCA2* mutation carriers, *J Natl Cancer Inst* 101(2):80-87, 2008.

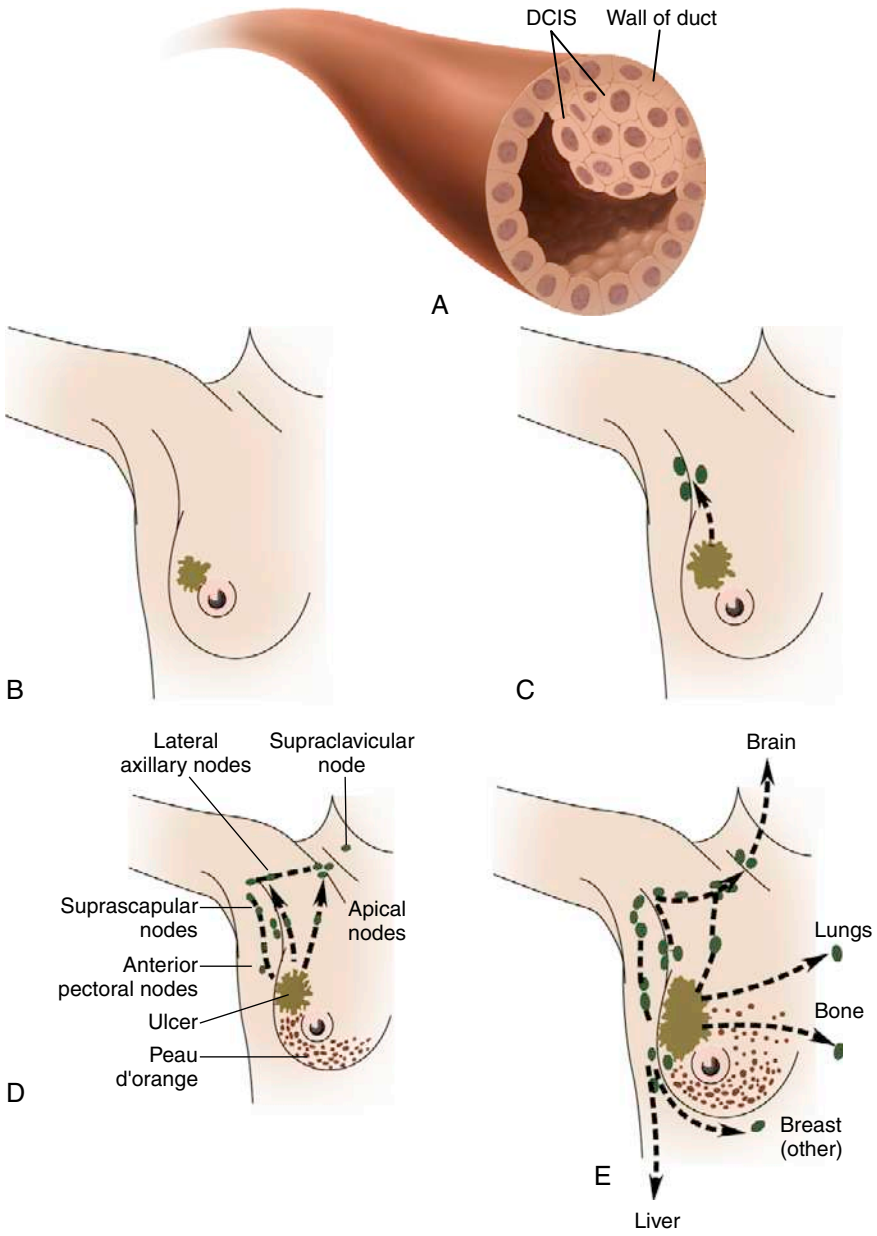


FIGURE 16-7 Staging of breast cancer. **A,** *Stage 0* is carcinoma in situ. Lobular carcinoma in situ (LCIS) is defined as abnormal cells that are in the lining of a lobule. LCIS seldom becomes invasive cancer. However, having LCIS in one breast increases the risk of cancer for both breasts. Ductal carcinoma in situ (DCIS) is defined as abnormal cells that are in the lining of a duct. DCIS is also called intraductal carcinoma. The abnormal cells have not spread outside the duct. They have not invaded the nearby breast tissue. DCIS sometimes becomes invasive cancer if not treated. **B,** *Stage I:* tumor <2 cm with no axillary lymph node involvement. **C,** *Stage IIa:* cancer cells found in axillary lymph nodes, or tumor ≤2 cm with metastasis to axillary lymph nodes, or tumor >2 cm but not >5 cm with no metastasis to axillary lymph nodes. *Stage IIb:* tumor >2 cm but not >5 cm with positive axillary lymph node involvement, or tumor >5 cm with negative axillary lymph node involvement. **D,** *Stage IIIa:* tumor ≤5 cm with metastasis to axillary lymph nodes that are attached to each other or to other structures, or has spread to lymph nodes behind breast bone; or tumor >5 cm and has spread to axillary lymph nodes that are alone or attached to each other or to other structures, or has spread to lymph nodes behind the breast bone. *Stage IIIb:* tumor of any size that has grown into the chest wall or skin of the breast, causing swelling of the breast or nodules in breast skin; may have spread to axillary lymph nodes that are attached to each other and to other structures and may have spread to lymph nodes behind the breast bone. Inflammatory breast cancer: breast is red, swollen (at least stage IIIb). *Stage IIIc:* tumor of any size that has spread either to the lymph nodes behind the breastbone and axillary lymph nodes or to the lymph nodes above or below the collarbone. **E,** *Stage lV:* distant metastatic cancer.

AMBULATORY SURGERY CONSIDERATIONS

Port Insertion

A breast cancer patient who needs further medical treatment may opt to have an implanted venous access port placed under the skin in either the chest, abdomen, or upper arm. This access port is used for repeated infusions of chemotherapeutic agents, solutions, other drugs, pain management medication, or blood products as well as for procurement of blood samples. Consequently, the patient's veins do not need to be repeatedly accessed. Port insertion is commonly done in an ambulatory surgery setting by a surgeon or in an interventional radiology department by a radiologist. The port has a soft, pliable plastic catheter that is threaded into the subclavian vein or right atrium by way of the subclavian or internal jugular vein under x-ray guidance. The catheter is then attached to a metal base with a rubber dome, which is placed under the skin by the interventionist. Preoperatively, the patient is instructed to refrain from consuming solid foods or full liquids for at least 6 hours before the procedure. Clear liquids may be ingested 2 hours before the procedure. Regular medications may be taken the morning of the insertion unless instructed otherwise. No aspirin, aspirin products, or antiinflammatory medications may be taken for 1 week before port insertion. Drug allergies are noted. The Universal Protocol is observed. After the procedure, the patient will be observed for approximately 1 hour before discharge. Discharge instructions are as follows:

- Give both the patient and the caregiver verbal and written instructions and the telephone numbers of the physician and nurse so that questions or concerns can be addressed.
- Review the purpose of the port insertion and discuss how long it will stay in place.
- Discuss protecting the skin over the port and keeping the incision clean and dry.
- If fever, chills, swelling, redness, bleeding, discharge, shortness of breath, or chest pain develops, seek prompt medical attention.
- No blood pressure measurement or blood draws are to be done from the arm containing an arm port.
- The port needs to be flushed monthly to keep it patent. Demonstrate this technique and have the patient repeat critical steps for port flushing.
- Explain that removal of the port will be an outpatient procedure when it is no longer needed medically.

Adapted from Canobbio MM: *Mosby's handbook of patient teaching,* ed 3, St Louis, 2009, Mosby; Department of Radiology, Abington Memorial Hospital Interventional Radiology: *Patient information—implanted venous access device,* available at www.abingtonir.com/images/uploaded/Abington/venousaccess_Info.pdf. Accessed May 12, 2009.

This positive binding capability identifies the patient with a hormone-dependent tumor (Figure 16-8). It is estimated that about two thirds of all breast cancers are positive for estrogen binding, and a majority of these tumors are also positive for progesterone binding. The presence of these receptor sites is conducive to hormone manipulation, with the goal of preventing breast cancer cells from receiving stimulation from estrogen. The use of anti-estrogen tamoxifen, in addition to surgery and chemotherapy, increases disease-free survival in premenopausal women with positive binding for estrogen.

Another therapy can be offered by aromatase inhibitors (AIs). These may be nonsteroidal, such as anastrozole and letrozole. Aromatase inhibitors are only effective in postmenopausal women. They appear to work better than tamoxifen on certain breast cancers, with fewer side effects. A large study found that anastrozole may prevent 70% to 80% of the most common breast cancer tumors that occur in postmenopausal women; this was compared with 50% for tamoxifen (Hulvat et al, 2009). A new class of parenteral hormone therapy, estrogen receptor (ER) down-regulators (e.g., fulvestrant [Faslodex]), is available for the treatment of metastatic breast cancer (Hormonal Therapy Changes, 2007).

Some of the most promising data reported in recent years for advanced breast cancer have involved HER-2 (human epidermal growth factor receptor 2), a cellular proto-oncogene coding for a transmembrane receptor. Agents such as trastuzumab (Herceptin) to target HER-2 were first approved for treatment of metastatic HER-2–positive breast cancer in 1998 (Surgical Pharmacology). Research and understanding of the immune system, the development of methods to evaluate aspects of the immune response, and ongoing development of monoclonal antibodies are transforming the field of immunotherapy and breast cancer treatment.

A new drug class in experimental targeted therapy medicine called poly (ADP-ribose) polymerase enzyme (PARP) inhibitors

SURGICAL PHARMACOLOGY

Herceptin

Trastuzumab (Herceptin) is a recombinant humanized immunoglobulin B (IgB) monoclonal antibody that targets the extracellular domain of HER-2. Trastuzumab interferes with the many steps in the tumor cell cycle and sensitizes HER-2–positive cancers to other cytotoxic therapies. HER-2–positive patients usually have more aggressive disease. Data from trials sponsored by the National Cancer Institute, which were terminated prematurely because of the superiority in the groups treated with trastuzumab, reported a 52% reduction in the risk of recurrence and a 33% reduction in the risk of death in the trastuzumab group compared with patients who received standard regimens. A major limitation to the use of trastuzumab in all studies is cardiotoxicity, especially when given concurrently with Adriamycin. Cardiotoxicity lowers considerably when given after Adriamycin therapy. Resistance to trastuzumab eventually occurs in most metastatic breast cancer patients who initially respond to the treatment. Additional research is being conducted on other members of the epidermal growth factor family. One agent is lapatinib, which targets epidermal growth factor and HER-2. Lapatinib in combination with trastuzumab in vitro shows a synergistic effect. Lapatinib also inhibits growth of HER-2–overexpressing breast cancer cells when long-term trastuzumab therapy becomes resistant. Observed side effects are tachycardia, congestive heart failure, nausea, vomiting, diarrhea, anemia, leukopenia, edema, arthralgia, bone pain, rash, acne, herpes simplex virus, anaphylaxis, and flulike symptoms of fever, headache, and chills. It is contraindicated in patients hypersensitive to Chinese hamster ovary cell protein. Teach patients to take acetaminophen for fever, avoid hazardous tasks, report signs of infection, and notify the physician if emotionally labile.

Modified from Hulvat MC: Multidisciplinary care for patients with breast cancer, *Surg Clin North Am* 87:133-164, 2007; Skidmore-Roth: *Mosby's nursing drug reference,* St Louis, 2010, Mosby.

is being studied for triple-negative breast cancer patients (O'Shaugnessy et al, 2009). The biopsy of patients with triple-negative breast cancer (TNBC) is estrogen and progesterone hormone receptor negative and HER-2/neu negative (Kassam et al, 2009). TNBC is found in younger women, women of African American or Hispanic descent, and women with lower socioeconomic status (Winkeljohn, 2008).

Breast cancer patients are increasingly seeking and using complementary and alternative medicine (CAM) and integrative therapies to enhance their surgical and medical treatment (Table 16-5). (See Chapter 29 for a full discussion of integrative therapies.) Besides using products such as green tea, vitamins E and C, and flaxseed, breast cancer patients are incorporating massage therapy and meditation and enlisting the help of dietitians and nutritionists (Boon et al., 2007) as they battle breast cancer.

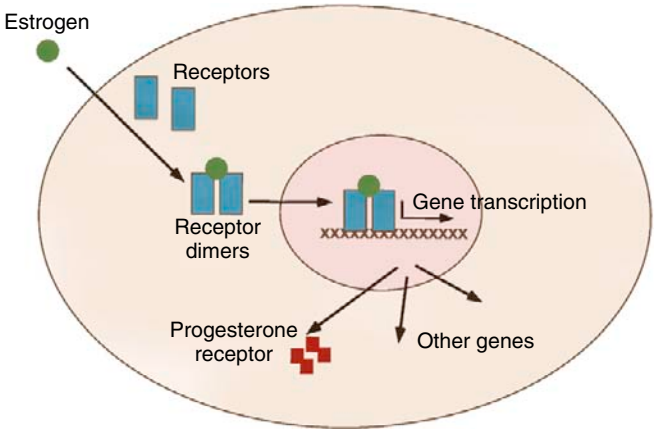


FIGURE 16-8 Physiology of estrogen and the estrogen receptor, shown schematically. Estrogen binds to estrogen receptors, translocates to the nucleus of the cell, and interacts with cellular deoxyribonucleic acid (DNA). This interaction results in the transcription of estrogen-responsive genes, such as the receptor for progesterone. In addition, other genes are induced by the estrogen receptors that influence cell growth and differentiation.

TABLE 16-5

Complementary and Integrative Therapies for Breast Cancer Patients

Symptom	Complementary and Integrative Therapies
PHYSICAL	
Pain	Acupuncture, chiropractic therapy, hypnosis, massage, music, reiki, shiatsu
Nausea/vomiting	Acupuncture, aromatherapy, ginger, hypnosis, progressive muscle relaxation, shiatsu
Fatigue	Acupuncture, massage, meditation, reiki, tai chi, yoga
Hot flashes	Acupuncture, black cohosh, flaxseed
Muscle tension	Aromatherapy, massage, shiatsu
EMOTIONAL	
Anxiety/stress/fear	Aromatherapy, guided imagery, hypnosis, journaling, massage, meditation, music therapy, progressive muscle relaxation, prayer, support groups, tai chi, yoga
Depression	Aromatherapy, yoga, journaling, progressive muscle relaxation

From Ignatavicius DD, Workman ML: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, St Louis, 2010, Saunders.

Perioperative Nursing Considerations

Assessment

A patient undergoing breast surgery will likely be extremely apprehensive about the possibilities of having a malignancy, losing a body part, facing a negative reaction from her spouse and family, and experiencing a negative change in self-image. During a preoperative interview the perioperative nurse should assess the patient's level of anxiety and possible causes, such as the possibility of a cancer diagnosis. Identification of the patient's fears and concerns helps in planning appropriate nursing interventions. The patient should identify the breast (and, if possible, the quadrant of the breast) where the mass is located and participate in surgical site marking. The perioperative nurse should also assess the patient's understanding of the proposed surgical procedure. Reinforcement of knowledge or correction of misunderstandings is possible only if the patient's current level of knowledge is discerned. Identifying the patient's psychologic support system will help to manage anxiety during the patient's stay and enhance the discharge planning process. If the patient has lost a relative or close friend to breast cancer, her coping mechanisms may be affected because of memories of that loss.

Nursing Diagnosis

Based on the nursing assessment, the perioperative nurse uses nursing diagnoses to develop a plan of care. Nursing diagnoses related to the care of patients undergoing breast surgery might include the following:

- Anxiety related to fear of cancer, the surgical intervention, or biopsy results
- Disturbed Body Image related to loss of body part
- Risk for Injury related to use of electrosurgery
- Deficient Knowledge related to unfamiliarity with perioperative routines

Outcome Identification

Outcomes are derived from the nursing diagnoses. They direct the perioperative nurse in selecting nursing interventions that will prevent, or intervene in, the actual or high-risk areas identified in the nursing diagnoses. Outcomes identified for the selected nursing diagnoses could be stated as follows:

- The patient will verbalize a level of anxiety that is personally acceptable.
- The patient will discuss feelings regarding body image changes resulting from the surgical procedure.
- The patient will experience no untoward injury from electrosurgery.
- The patient will verbalize an understanding of perioperative procedures.

Planning

Using nursing diagnoses and desired outcomes, the perioperative nurse can individualize a plan of care for each patient and allow for communication with other colleagues on the patient care team. The plan of care for a patient undergoing

breast surgery can include nursing interventions that allow the patient freedom to express concerns, have specific questions answered, and discuss breast reconstruction options, as appropriate. The Sample Plan of Care below shows such an example. As part of planning patient care, priorities are established and a method of ensuring continuity of care ensured.

Implementation

Before surgery, the perioperative nurse should procure the necessary medical and surgical supplies, instruments, and equipment for the planned operation. The patient's operative site should be marked by the surgeon outside of the OR room before any medications are given. Mammogram films or other imaging studies should be available in the OR for the surgeon's review; their presence may be confirmed during the preop briefing and/or time-out. The facility protocol for identifying the correct surgical site should be followed. Often this consists of a checklist that is initiated during the time-out and includes verbal communication among surgical team members, review of the medical record and the informed consent, confirmation of imaging studies, and direct observation of the marked surgical site. IV antibiotics, started within 1 hour before the incision is made, may be administered (Evidence for Practice). For breast surgery, the site and side must be verbally verified with each member of the surgical team during the time-out. A breast biopsy, performed after the patient has received a local anesthetic, will require adjunct sedation and monitoring equipment (e.g., electrocardiogram [ECG], pulse oximeter, blood pressure apparatus). Patient allergies should be reviewed to avoid allergic or toxic reactions to local anesthetics. For a mastectomy, extra sponges and instrumentation are often needed. An electrosurgical unit (ESU) or a surgical laser is used to provide both hemostasis and tissue dissection. Safe practices when using devices that generate surgical smoke require the use of a smoke evacuation system and accessories in both open and laparoscopic

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Anxiety related to fear of cancer, the surgical intervention, or obtaining biopsy results

OUTCOME
The patient will verbalize a level of anxiety that is personally acceptable.

INTERVENTIONS
- Encourage questions and allow time for verbalization of fear, distress, and anxiety. Use active listening and reflective questions.
- Review the surgeon's explanation of the planned procedure and the reason for it (as appropriate).
- Assess verbal and nonverbal signs of anxiety.
- Provide emotional support and comfort measures (warm blankets, touch as appropriate).
- Maintain quiet, calm environment.
- Demonstrate warmth and acceptance of the patient's anxiety.
- Determine the patient's personally effective coping techniques (or recommend some), such as relaxation, rhythmic breathing, or guided imagery. Support the patient in using these.
- Record patient's reactions.

NURSING DIAGNOSIS
Disturbed Body Image related to loss of body part

OUTCOME
The patient will discuss feelings regarding body image changes resulting from the surgical procedure.

INTERVENTIONS
- Allow patient to discuss concerns about her sexual attractiveness, loss of confidence, and perceived loss of femininity.
- Promote an environment of support, respect, and comfort.
- Discuss available resources and options (external prosthesis, alternatives in garments and dress, reconstructive surgery, as appropriate). Make referrals to nurse on discharge unit or community agency as indicated.
- Maintain patient's privacy.
- Encourage a visit by a *Reach to Recovery* volunteer (as applicable).

NURSING DIAGNOSIS
Risk for Injury related to use of electrosurgery

OUTCOME
The patient will experience no untoward injury from electrosurgery.

INTERVENTIONS
- Position dispersive pad as close to operative site as possible.
- Note any metal implants the patient may have and do not use the dispersive pad over these sites.
- Select a site that is clean and dry, with good muscle mass; note and document the condition of the skin at the selected site.
- Protect pad from fluids and contact with metal objects.
- Ensure that all prep solutions have dried before activating the unit.
- Activate electrosurgical unit after dispersive pad and active electrode are connected.
- Set power setting as low as possible to achieve desired effect. Document power settings used.
- Use holster for active electrode on the sterile field.
- Provide supplies to remove excess char buildup from active electrode (as applicable).
- Check dispersive pad contact and all connections after changes in position or requests to increase power.
- Evaluate and document the condition of the skin on removal of the dispersive pad.

NURSING DIAGNOSIS
Deficient Knowledge related to unfamiliarity with perioperative routines

OUTCOME
The patient will verbalize understanding of perioperative procedures.

INTERVENTIONS
- Assess the patient's experience with previous surgical procedures.
- Review the need for correct site surgery verification protocols.
- Explain that the skin will be cleansed with antiseptic solution at the surgical site and that solution may feel cold.
- Provide clear and concise explanations of all nursing interventions.
- Explain roles of the healthcare team members.
- Encourage questions.
- Describe the types of dressings and equipment that may be used postoperatively. If lymph node dissection is performed, describe the presence of incisional closed wound drainage systems.

procedures (AORN, 2009). (See Chapter 7 for a full discussion of the ESU and surgical smoke evacuation.) The incision site may be drained postoperatively with a closed wound suction device. Ensuring the availability of supplies before the procedure allows the nurse to maintain a comforting presence while supporting, monitoring, and observing the patient.

During the intraoperative phase, the patient is placed supine on the OR bed with the operative side near the edge of the bed. The arm on the involved side, with the palms up and fingers extended, is carefully placed on a padded armboard at no greater than 90 degrees to prevent brachial plexus stretch. If there are surgical reasons to tuck the arms at the side, the elbows are padded to protect the ulnar nerve, the palms face inward, and the wrist is maintained in a neutral position (Denholm, 2009). Depending on the location of the lesion and the planned surgery, a small pad can be placed under the operative side to facilitate exposure of the incision area. Positioning the OR bed in slight Fowler's position with a lateral tilt away from the surgeon can also facilitate exposure.

Skin preparation depends on the location of the lesion and the surgery intended. Skin prep solutions vary, depending on the surgeon's preference. For a breast biopsy, the area prepped is usually the affected breast and the immediate surrounding skin. For a mastectomy, the area prepped can extend from above the clavicle to the umbilicus and from the opposite nipple to the bed line of the operative side, including the axilla, and possibly the upper arm on the operative side. Some surgeons caution against vigorous scrubbing of the surgical site to prevent possible seeding of cancer cells from the main mass. The surgeon may request that only an antiseptic solution be applied to the breast. Appropriate precautions to prevent pooling of solution under the patient and to reduce the risk of surgical fire are taken during skin prep procedures.

Surgical draping exposes the affected breast and the preoperative site mark. For mastectomy, the arm on the operative side is draped free, using a stockinette and drapes that allow free movement of the arm to facilitate access to the axilla. If a breast biopsy is to be immediately followed by a modified radical mastectomy, the surgeon may prefer to repeat the skin prep and surgical draping before proceeding with the definitive surgery.

During implementation of the plan of care, the perioperative nurse continues to collect data, continuously reassesses the patient's needs and the needs of the surgical team, initiates nursing interventions, and documents all care delivered. Formats for documenting perioperative patient care vary from institution to institution. However, documentation of patient problems and nursing interventions addressing these problems is essential. For the patient undergoing breast surgery, consideration should be given to documenting the patient's level of anxiety, the surgical position and accessory positioning devices used, the time-out, the location of the ESU dispersive pad, unit settings and identification number, results of perioperative monitoring, medications administered by the perioperative nurse or from the sterile field, specimens collected, and any closed wound drainage systems inserted into the surgical wound.

Evaluation

Evaluation of the patient before discharge from the OR includes both general observation parameters important for every surgical patient and specific evaluation of the goals of the plan of care. The patient's skin at dependent pressure sites, skin prep sites, and the dispersive pad placement site is assessed and any change in skin integrity documented. The hand-off report to the nurse in the postanesthesia care unit (PACU) includes any unusual events or patient problems during surgery, the incorporation of any closed wound drainage systems in the wound, and achievement of identified patient outcomes. These outcomes, based on the nursing diagnoses selected, should be part of documentation

EVIDENCE FOR PRACTICE

Preventing Surgical Site Infection

Surgical site infections (SSIs) are classified as superficial, which involves only skin or subcutaneous tissue of the incision; deep incisional, which involves fascia and/or muscular layers; and infection of organ and/or space. Approximately 500,000 SSIs occur each year. SSIs are believed to account for up to $10 billion annually in healthcare expenditures. Infection rates for breast surgery are more common than previously believed. In a study by Olsen and colleagues (2008), 5.3% of patients developed infections within 1 year of surgery; the rate increased to 7% for women who had mastectomy followed by breast reconstruction with an implant.

The Centers for Medicare & Medicaid Services created the Surgical Infection Prevention Collaborative (SIPC) in 2002 and their expert panel identified the following three performance measures for quality improvement related to antimicrobial prophylaxis:

- Deliver intravenous antimicrobial prophylaxis within 1 hour before incision (2 hours for vancomycin and fluoroquinolones).
- Use an antimicrobial prophylactic agent consistent with published guidelines.
- Discontinue use of the antimicrobial prophylactic agent within 24 hours after surgery (48 hours for cardiothoracic surgery patients).

Many hospitals that followed SIPC performance measures decreased their SSI rates. An extension of SIPC is the Surgical Care Improvement Project (SCIP), a multiagency collaboration started in 2003. SCIP focused on the three SIPC medication improvements and the following:

- Discontinuation of hair removal from the surgical site (if imperative, however, remove hair with clippers)
- Control of blood glucose levels during postoperative period for cardiac surgical patients
- Maintenance of perioperative normothermia

The Institute for Healthcare Improvement recommends the previously listed six measures (i.e., three SIPC and three SCIP measures) and has included them in the *100,000 and 5 Million Lives* campaign. Other measures to reduce SSIs include, but are not limited to, reduction of patient risk factors; optimal cleaning and disinfection of equipment and environment; preparation and disinfection of operative site; adherence by surgical team members to meticulous hand hygiene; traffic control in the individual OR; timely removal of wound drains; and education of surgeons, perioperative personnel, patients, and families about SSI prevention.

Modified from Anderson DI et al: Strategies to prevent surgical site infections in acute care hospitals, *Infect Control Hosp Epidemiol* 29:S51-S61, 2008; Olsen MA et al: Hospital-associated costs due to surgical site infection after breast surgery, *Arch Surg* 143(1):53-60, 2008; Patterson P: Surgical Care Improvement Project: 4 years later, what's the status? *OR Manager* 25(8):1, 7-9, 2009; McCahill LE et al: Enhancing compliance with Medicare guidelines for surgical infection prevention: experience with a cross-disciplinary quality improvement team, *Arch Surg* 142(4):355-361, 2007.

as well as the nursing report. Outcomes identified for the selected nursing diagnoses could be stated as follows:

- The patient verbalized an acceptable level of anxiety; she communicated her specific anxieties, her facial expression and body structures were relaxed, and her vital signs remained within her normal range.
- The patient discussed feelings regarding possible body image changes resulting from the surgical procedure; her preferred coping strategies were reviewed and supported during the procedure.
- The patient experienced no untoward injury from electrosurgery; there were no skin changes at the site of the dispersive pad.
- The patient verbalized an understanding of perioperative procedures; she cooperated with requests and was provided with ongoing explanations.

Patient and Family Education and Discharge Planning

Discharge planning should begin as soon as the patient is informed of the necessity for surgery or when the nurse first meets the patient. According to the extent of the anticipated surgery, information about appropriate exercises to enhance recovery, prosthetic devices, reconstruction options, and available community support groups should be explained to the patient. The perioperative nurse provides or reinforces information based on the patient's desire for information, readiness to learn, and anxiety level.

The patient is often discharged within hours of or the day after surgery. The patient and other caregivers need to be instructed regarding aseptic wound care, care for the closed wound drainage system (if present), and pain management. Possible signs of complications should be included, along with instructions regarding when and how to notify the physician. Postoperative exercises need to be taught to the patient to facilitate her return to normal activities. Nursing home care may be necessary and should be coordinated with the physician and the patient. A follow-up telephone call to the patient can help the nurse assess the patient's ability to cope with her diagnosis and surgery. The Patient and Family Education box provides sample discharge information for the patient undergoing breast surgery.

Late and long-term effects of breast cancer treatments should be reviewed with the patient. Fatigue, insomnia, loss of appetite, fear of recurrence, anxiety, depression, and "chemobrain" (Research Highlight, p. 601) are common symptoms seen in cancer survivors. These signs and symptoms should be reported to the physician and nurse so intervention can be initiated (Barclay, 2009).

PATIENT AND FAMILY EDUCATION

Discharge Instructions and Home Care for Breast Surgery Patients

Give both the patient and the caregiver *verbal* and *written* instructions. Provide them with the name and telephone number of a physician or nurse to call if questions arise. Use visual aids to assist in instruction.

GENERAL INFORMATION

- Review explanation of the disease, the surgical procedure performed, and adjuvant therapy to be carried out.
- Explain that if the axillary nodes were removed, the affected arm may swell and is less able to fight infection. Discuss measures to prevent lymphedema (see Risk Reduction Strategies, p. 602):
  - Exercise arm daily (provide specific exercises).
  - Report loss of shoulder or joint mobility.
  - When healing is complete, begin strengthening and stretching exercises.

Wound/Incision Care (Select Applicable Education Based on Surgical Procedure Performed)

- Encourage the patient to look at her incisions so she can see what is normal. Teach her how to care for the skin at the site of surgery:
  - Advise the patient that there may be a dry gauze dressing over the incision site and the drain site.
  - Provide information regarding dressing changes, amount of fluid leakage at closed wound drainage system site that is normal, when to change soiled drain-site dressing (including emptying and measuring drain reservoir) and what to report to a physician or nurse.
  - Discuss numbness in the area of surgery and typical sensations (heaviness, tingling, "pins and needles"). These are likely to resolve by 1 year after surgery.
- For modified radical mastectomy:
  - Teach the patient to change the dressing, assess the appearance of the incision and closed wound drainage system site, milk or strip clots through the drainage tubing to maintain patency, empty the drainage container, and record the amount and character of drainage.
  - Caution the patient not to abduct the affected arm or elbow above the shoulder until closed wound drainage systems are removed.
  - Instruct the patient to report any redness or drainage around the closed wound drainage system.
  - Instruct the patient to avoid use of deodorants or antiperspirants until stitches and drains have been removed from the axilla and the wound has healed. If no closed wound drainage system is present, the patient may shower.
  - Caution the patient not to allow injections, placing of intravenous lines, drawing of blood, or taking of blood pressure in the affected arm if axillary dissection was done.
  - Instruct the patient to avoid wearing constricting clothing or jewelry on the affected arm and to carry her handbag on the unaffected arm if axillary dissection was done.
  - Discuss the types of temporary and permanent prostheses available; assist with referral as needed.
  - Advise the patient not to use an external prosthesis or bra pad until swelling has subsided and healing of the incision is complete. Tell her to check with a physician or nurse before getting fitted for a breast prosthesis. This usually occurs about 6 weeks after surgery as long as wounds are healing and any postoperative edema has resolved.
  - Discuss the types of reconstruction available.
  - Stress the importance of continuing breast self-examination and mammography of the unaffected breast.

PATIENT AND FAMILY EDUCATION—cont'd

Discharge Instructions and Home Care for Breast Surgery Patients

Warning Signs

- Review the signs and symptoms that should be reported to a physician or nurse:
  - Swelling of arm
  - Drainage from incision, excessive drainage or blood in drainage unit, difficulty keeping container flat
  - Infection: redness, purulent drainage, pain, incision warm to touch

Medications

- Explain the purpose, dosage, schedule, and route of administration of any prescribed medications, as well as side effects to report to a physician or nurse. If the patient is taking an opioid analgesic, initiate a bowel protocol (including a laxative and stool softener) to prevent constipation.
- Discuss alternative methods of postoperative pain management: visualization, guided imagery, meditation, relaxation, biofeedback, music, other personally effective techniques.

Activity

- Encourage discussion of allowances and limitations with respect to occupation, recreational sports, or activities.
- Encourage resumption of self-care activities (feeding, combing hair) and activities of daily living as tolerated.
- Explain that sexual activity may be resumed when desired. The partner should use a position that does not place pressure on the chest wall.
- Discuss the need to continue post-mastectomy exercises to regain full range of motion (as applicable).

FOLLOW-UP CARE

- Stress the importance of regular follow-up visits. Make sure the patient has the necessary names and telephone numbers.
- Prepare the patient for adjuvant therapies: hormone therapy, chemotherapy, and radiation therapy.

PSYCHOSOCIAL CARE

- Encourage verbalization about feelings and fears regarding diagnosis, adjunctive therapy, actual and perceived changes in body image and sexuality.
- Encourage patient and family to seek individual or group counseling to reduce emotional stress and help with effective coping.

REFERRALS

- Provide referrals for home health services and social services as indicated.
- Assist the patient to obtain referral services to breast cancer survivorship programs (see Research Highlight, p.602) and contact support groups, such as the American Cancer Society's *Reach to Recovery* program, to cope with alterations in body image and other concerns.

Modified from Canobbio MM: *Mosby's handbook of patient teaching,* ed 3, St Louis, 2006, Mosby; Weaver C: Caring for a patient after mastectomy, *Nursing 2009* 39(5):44-48, 2009.

RESEARCH HIGHLIGHT

Understanding "Chemobrain"

Chemobrain refers to a wide range of problems experienced by breast cancer survivors who have received treatment with chemotherapeutic agents. These changes usually first become apparent during chemotherapy (hence the name). Some literature reports that 75% of women with breast cancer experience chemobrain after therapy. These symptoms include short-term memory loss, difficulty concentrating and staying focused, reduced verbal and visual memory, difficulty managing daily activities and multitasking, fatigue, disorganization, and confusion. Some cancer-related causes could include chemotherapy, hormonal treatment, radiation therapy, and surgery; complications of cancer treatment; and emotional reactions to cancer diagnosis, treatment, and medications. The severity and duration of the symptoms differ with the individual. A recent study used magnetic resonance imaging to compare regional brain-volume differences between breast cancer survivors exposed to adjuvant chemotherapy and unexposed controls. It showed that there were physical changes in the brains of breast cancer survivors; parts of their brains were smaller. Also, in a study using positron emission tomography (PET) imaging, breast cancer survivors who had received chemotherapy in the previous 5 to 10 years used more of their brains to perform a short-term memory task than control subjects who never received chemotherapy, a sign that their brains had to work harder to complete tasks. Treatments for chemobrain are in the early stages. Some evidence suggests that central nervous system medications may ease adverse cognitive effects.

Modified from Hafner DL: Lost in the fog: understanding "chemo brain," *Nursing 2009* 39(8):42-45, 2009; Mayo Clinic Staff: *Chemobrain,* Mayo Clinic, 2009, available at www.mayoclinic.com/health/chemobrain/ncbi-n:DS01109. Accessed April 27, 2009; National Cancer Institute: Delving into possible mechanisms for chemobrain, *NCI Cancer Bull* 6(6), March 24, 2009.

RISK REDUCTION STRATEGIES

Decreasing Lymphedema Associated with Breast Surgery

Lymphedema after breast surgery is caused by a disruption of the axillary bed by excision of lymph nodes and/or radiation therapy to the area. Patients are at a lifetime risk of edema in the upper extremity and/or in the ipsilateral upper quadrant and breast tissue. Risk factors that affect the occurrence of lymphedema include axillary node dissection, radiation therapy, tumor in the upper outer quadrant of the breast, stage of cancer at diagnosis, age, obesity, hypertension, chemotherapy, and radiation treatment. Risk reduction starts at the preoperative evaluation with education. Baseline girth and volume measurements of both upper extremities are taken and recorded. Note any factors that put the patient at increased risk for development of lymphedema. Educate the patient about arm and hand precautions. Risk reduction practices also include providing good skin care to prevent infection, preventing injury and muscle strain, avoiding limb constriction, promoting lymph drainage with elevation, using compression garments, avoiding extreme temperatures, and performing regular, light aerobic exercise. If lymphedema is diagnosed, intervention is necessary. Various approaches, including surgery, pharmacotherapy, low-level laser therapy, and complete decongestive treatment (CDT), can decrease and maintain the size of the limb. CDT is a two-phase program that consists of a treatment phase and a maintenance phase. The International Society of Lymphology considers CDT the standard of care for lymphedema. Once a diagnosis of lymphedema is made, the patient must be monitored over the course of her life. Fu's research supports provision of information about lymphedema to improve practice of risk reduction behaviors with breast cancer survivors. Compliance with the maintenance phase is related to better outcomes.

Modified from Fu MR, Ridner SH, Armer J: Post-breast cancer lymphedema, *Am J Nurs* 109(8):34-41, 2009; Johnstone PAS, Mondry TE: *Prevention and treatment of lymphedema related to breast cancer, 2007,* available at www.medscape.com/viewartcle/566471. Accessed April 14, 2008; Mulcahy N: *Recognizing lymphedema is vital in assisting oncology patients, 2009,* available at www.medscape.com/viewarticle /587127. Accessed April 15, 2009.

RESEARCH HIGHLIGHT

Cross-Cultural Relevance of Breast Cancer Survivorship Programs

Breast cancer survivorship programs to assist women in dealing with the multiple concerns they have after breast cancer treatment are important. However, few of these programs have been evaluated for cultural relevance with diverse groups. One such program, Taking CHARGE, is a theory-based self-management program developed to assist women with survivorship concerns that arise after breast cancer treatment. This research appraised both the utility and the cultural relevance of the program for African American (AA) breast cancer survivors, during which they assessed Taking CHARGE program content, format, materials, and the self-regulation process. Content analysis of audiotapes was conducted using an open, focused coding process to identify emergent themes regarding program relevance as well as topics requiring enhancement and/or further emphasis. Although findings indicated that the program's content was relevant to participants' experiences, AA women identified need for cultural enhancements in spirituality, self-preservation, and positive valuations of body image. Content areas requiring more emphasis included persistent fatigue, competing demands, disclosure, anticipatory guidance, and age-specific concerns about body image/sexuality. Suggested improvements to program materials included portable observation logs, additional resources, photographs of AA women, vivid colors, and images depicting strength. These findings can be used for program enhancements to increase the utility and cultural relevance of Taking CHARGE for AA survivors and underscore the importance of evaluating other interventions for racially/ethnically diverse groups.

Adapted from Chung LK et al: Breast cancer survivorship program: testing for cross-cultural relevance, *Cancer Nurs* 32(3):236-245, 2009.

Surgical Interventions

BIOPSY OF BREAST TISSUE

Biopsy removes suspicious breast tissue for pathologic examination. In a *core needle biopsy (CNB),* a disposable, cutting-type needle is introduced and advanced into the breast mass to entrap a core or plug of tissue. The needle is withdrawn, and the tissue specimen sent to a pathologist for diagnostic examination. CNB may also be performed with a vacuum-assisted core biopsy (VACB) device (Breast Health, 2006). In an *incisional biopsy,* a portion of the mass is surgically excised using a curved incision line. The tissue is sent for pathologic examination (Mulholland et al, 2006). In an *excisional biopsy,* the entire tumor mass is excised along with a small margin of normal tissue from adjacent tissue for examination as with incisional biopsy (Cornforth, 2009).

Procedural Considerations

Biopsy is usually performed after the patient has been administered a local anesthetic, a local anesthetic with IV moderate sedation/analgesia, a laryngeal mask airway (LMA), or a general anesthetic with intubation. The short delay between biopsy and further treatment has not been shown to adversely affect survival. However, when an extensive surgical procedure is anticipated in conjunction with the biopsy or when multiple lesions are to be excised and the amount of local anesthetic would exceed the maximum safe dose, general anesthesia is induced. In the instance of anticipated extensive surgery based on pathologic results, the patient must have preoperatively given informed consent to proceed with the more definitive surgery. A new surgical setup will be used. A minor instrument set is used for biopsy; the ESU is often requested. Perioperative staff should be sensitive to the fact that the patient may be alert during the procedure and use caution with oral pathology reports called over a speaker phone. Pathology reports, especially if the report confirms malignancy, should be discussed when the patient is fully awake and has a support system available.

Operative Procedure—Open Breast Biopsy

1. An incision in the direction of the skin lines (curvilinear) or along the border of the areola is made over the tumor mass. The circumareolar incision gives the best cosmetic result. If the lesion is located in an extremely lateral or medial site, a radial incision may be used.

2. Gentle traction is applied to the mass with holding forceps. If the lesion is small, the entire mass and an edge of normal tissue are removed by sharp dissection. If a large lesion is present, a small incisional biopsy of the main mass is done. The specimen should not be placed into a formalin solution if a frozen section is to be done at the time of surgery; instead, it is sent fresh, as exposure to formalin prevents frozen-section examination. The specimen may be marked with a sterile marker as to its orientation in the breast and/or may be placed on a sterile towel that is marked with a sterile marker to orient the specimen. This assists the surgeon in reexcision if the pathologist finds positive margins on the specimen. The tissue is examined by frozen section to determine immediate diagnosis while the patient is still anesthetized. If a 48-hour permanent section is required for definitive diagnosis, the patient is scheduled at a later time for any further surgery that may be necessary.
3. If the lesion is benign, hemostasis is checked and the subcutaneous breast tissue of the wound is approximated with absorbable suture. The skin is closed with fine sutures or skin staples, and a firm pressure dressing is applied.
4. If the lesion is malignant, the incision is tightly closed with a continuous locking suture on a cutting needle.
5. If a more extensive operation is required, it may be performed immediately. Team members regown and reglove to avoid transfer of cancerous cells to healthy tissue. The operative site is again prepped and draped. A separate sterile setup and set of instruments for a more radical procedure are then used.

Operative Procedure—Open Breast Biopsy with Needle (Wire) Localization

A radiologist performs wire placement before the patient's arrival in the OR. Care is taken during transfer to the OR bed and gown removal not to dislodge or bump the wire. Similar care is taken during positioning, prepping, and draping.

1. The skin incision is placed precisely over the expected location of the mammographically determined lesion to minimize tunneling through the breast tissue.
2. Dissection is carried out using the wire as a guide.
3. Tissue around the wire is removed en bloc with the wire and sent for specimen mammography in the radiology department.
4. The patient is kept on the OR bed with the sterile field maintained until confirmation that the lesion has been excised. It is then sent from radiology to the pathology department.

INCISION AND DRAINAGE FOR ABSCESS

Incision of an inflamed and suppurative area of the breast is performed to drain an abscess. Breast abscesses occur most frequently during the first 4 weeks of breastfeeding. Staphylococcal or streptococcal organisms enter the breast through abraded or lacerated nipple surfaces or through the lactiferous ducts. Chronic abscesses are rare. Drainage is required when the breast abscess around the nipple or in breast tissue is apparent. Biopsies may be done for additional diagnosis.

Procedural Considerations

Breast abscess is very painful and may require surgery with the patient administered a general anesthetic. Instruments are the same as those for a biopsy.

Operative Procedure

1. Generally, a radial incision extending outward from the nipple or a circumareolar incision is preferred. A short incision into the thoracomammary fold may be used for deep breast abscesses in the lower or outer quadrant.
2. After skin incision, the wound is deepened until pus is encountered.
3. A curved hemostat is directed into the cavity to determine the extent of the abscess. Specimens for aerobic and anaerobic organisms are usually taken for culture.
4. Loculations are broken up by exploring the cavity with the index finger.
5. The opening is enlarged to ensure adequate drainage, the cavity is irrigated with warm saline solution, and bleeding vessels are ligated with absorbable sutures or coagulated.
6. The wound is drained or loosely packed with gauze. Healing occurs by granulation.

LUMPECTOMY (SEGMENTAL RESECTION)

Lumpectomy is removal of a tumor mass with a margin of 1 to 1.5 mm of normal tissue. Surgical clips may be left in the operative site to assist the radiation oncologist (Lind et al, 2005). Lumpectomy, with subsequent radiation therapy, is often the treatment of choice for small tumors. It is not an option for patients who have two or more cancer sites in separate quadrants of the breast, persistent positive margins after reasonable surgical attempt, or diffuse malignant-appearing microcalcifications, as well as for patients who have undergone previous radiation to the affected breast (Mulholland et al, 2006). A lumpectomy, combined with sentinel node or axillary node dissection (Figure 16-9) and irradiation in stage I and stage II breast cancers, appears to provide results equal to a more radical procedure. If one or more axillary nodes are involved, chemotherapy also is recommended.

Procedural Considerations

In patients with large breasts, increased bleeding may occur, requiring the ESU, a smoke evacuation system, and additional hemostatic clamps.

Operative Procedure

The procedure is as described for excisional biopsy.

SENTINEL LYMPH NODE (SLN) BIOPSY

Identification and microscopic examination of the sentinel lymph nodes (SLNs), the first lymph nodes along the lymphatic channel from the primary tumor site, will help to determine the need for additional or more extensive surgeries and treatments of early-stage invasive breast cancer for patients thought to have low to moderate risk for involvement of lymph nodes (Sentinel Lymph Node Dissection, 2008). It is believed that if the cancer cells have traveled through the lymph nodes, the cells will lodge in the first nodes. The sentinel node is not located in the same site in every patient. If sentinel nodes are negative, no other nodes in the lymph node channel are likely to be involved. Evidence of a positive node requires an axillary node dissection and adjunct therapy (Sentinel Node Biopsy, 2009). Complications of SLN biopsy include risk of allergic reactions to the blue dye (Patient Safety), rare instances of sensory or motor nerve damage, and pain. Contraindications

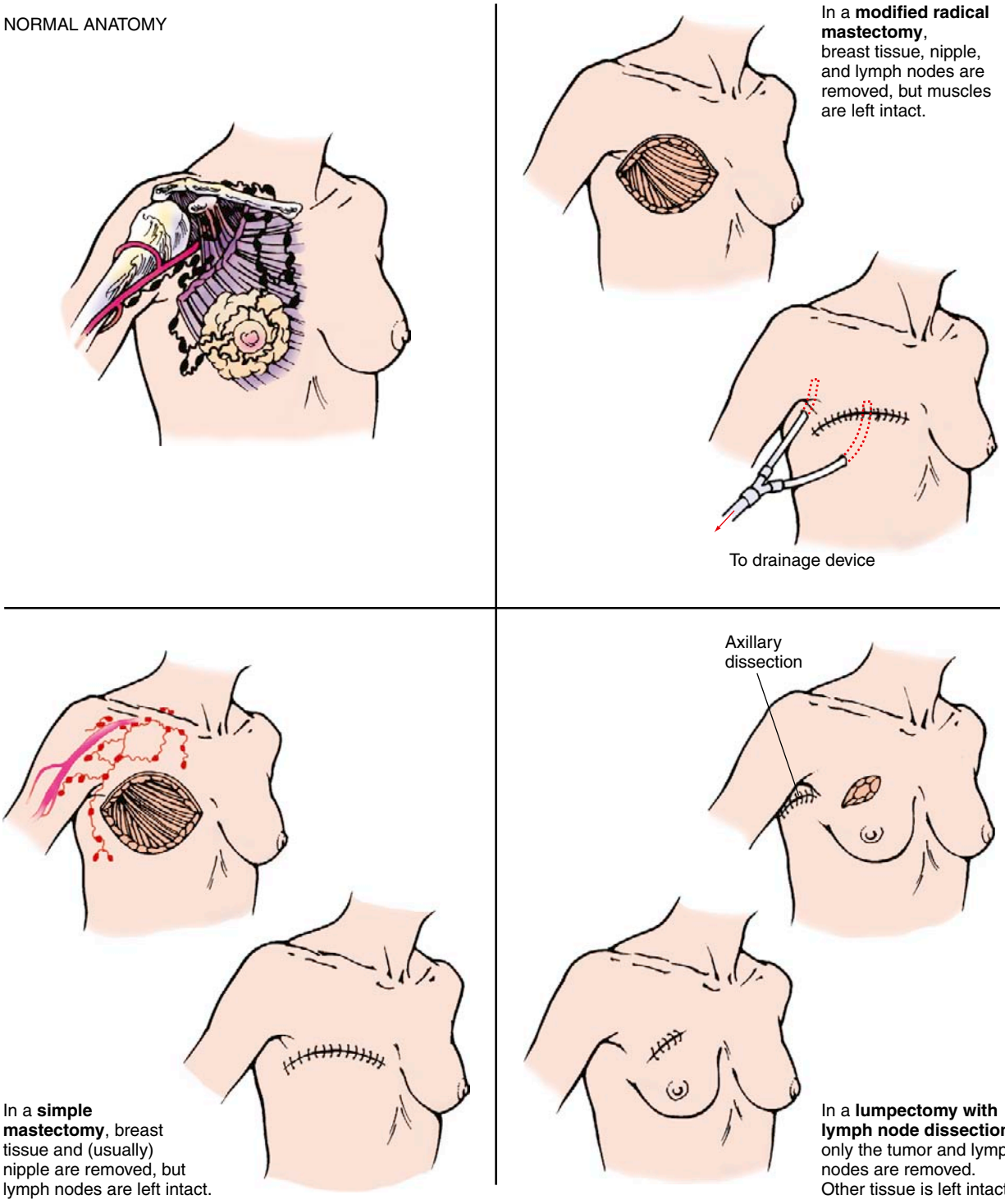


FIGURE 16-9 Surgical management of breast cancer.

to SLN biopsy include palpable axillary nodes, large or locally advanced breast cancers, prior axillary surgery, and pregnancy or lactation (Lind et al, 2005).

Procedural Considerations

The procedure for SLN biopsy is similar to that for breast biopsy. Sentinel node identification is accomplished by injection of either isosulfan blue dye or a radiocolloid (technetium 99 [^{99m}Tc]), a gamma-emitting material. Isosulfan blue is contraindicated in patients with known hypersensitivity to the dye; careful patient monitoring and observation are mandatory, and a crash cart should be available in the instance of severe anaphylactic reaction (Rapid Response Team box). The procedure is coordinated with staff of the nuclear medicine department and requires use of a handheld detector if technetium is used. In addition to a minor instrument set, if isosulfan blue is used, a 5-ml syringe,

a 25-gauge needle, an alcohol wipe, and the dye are required. For technetium, the gamma-tracer probe, counter, and sterile sleeve for the probe are required. Multiple specimen containers should be on hand along with pathology request forms. The surgeon may request that each specimen be numbered on the specimen container and the pathology request form. Safe practices for handling surgical specimens are implemented. A combination of technetium and isosulfan blue can also be used for lymphatic mapping (Mulholland et al, 2006). SLN biopsy is quickly replacing levels I and II axillary lymph node dissection as the standard procedure for staging an axillary lymph node–negative patient (Morrow and Harris, 2009).

PATIENT SAFETY

Sentinel Lymph Node Biopsy and Anaphylactic Reaction

Sentinel lymph node biopsy (SLNB) is the standard procedure for staging of the axilla in patients with clinically node negative breast cancer. The sentinel lymph node is located by intraparenchymal injection of blue dye alone or in combination with intradermal administration of radiolabeled colloid near the tumor site. The combination of blue dye and radiotracer has been shown to increase the sensitivity of SLNB. The most commonly used blue dye in the United States is Lymphazurin 1%. Use of this dye is contraindicated in those people who have a known sensitivity to triphenylmethane or related compounds. Severe allergic reaction and anaphylaxis have been observed in 1% to 3% of patients who received the dye during SLNB. The incidence of anaphylaxis continues to increase. During general anesthesia, the recognition of systemic anaphylaxis depends almost entirely on the observation of clinical symptoms and observations such as urticaria, erythema, respiratory complications, and/or cardiovascular collapse. The patient usually develops symptoms within 30 minutes. Although rare, anaphylactic shock from blue dye is a potentially lethal situation. Early recognition as well as aggressive hemodynamic management can significantly reduce mortality and morbidity. Patients may have a biphasic anaphylaxis to blue dye within 1 hour and up to 6 to 8 hours after surgery. Patients who experience anaphylaxis from blue dye should be observed for up to 24 hours.

Modified from Liang MI, Carson WE: *Biphasic anaphylactic reaction to blue dye during sentinel lymph node biopsy, 2008,* available at www.wjso.com/content/6/1/79. Accessed April 10, 2009; eMedicine Health: *Sentinel node biopsy, 2009,* Web MD, LLC, available at www.emedicinehealth.com/sentinel_node_biopsy/page6_em.htm. Accessed May 18, 2009.

Operative Procedure—Using Isosulfan Blue Dye

1. Dye is injected around or near the tumor, or dye may be injected into the area of the breast mass that has been exposed as part of a breast biopsy (Sentinel Node Biopsy, 2009).
2. This may be followed by a three-stage axillary lymphatic massage (Kirby et al, 2007).
3. The sentinel nodes stained with the blue dye are identified and excised.
4. The nodes are sent fresh to the pathology department for examination.
5. Based on the results, the surgeon proceeds with the planned surgery or may elect breast conservation.

Operative Procedure—Using Technetium

1. The tumor or previous biopsy site is injected with a small amount of radioactive tracer 20 minutes to 8 hours before the surgery. It can also be injected after anesthesia is induced (Sentinel Node Biopsy, 2009).
2. This may be followed by massage.
3. A handheld detector is passed over the top of the patient's chest to identify the area of the sentinel node by a positive reading. The probe may also be used with the addition of a sterile sleeve during excisional biopsy. Isosulfan blue dye may be used in conjunction with technetium during a procedure to enhance visibility of nodes.
4. The surgeon marks the skin with a skin scribe to indicate the reactive area.
5. The area is prepped, and the surgeon proceeds with the planned procedure for excisional biopsy of the sentinel lymph node.

AXILLARY NODE DISSECTION

Axillary node dissection (Figure 16-10) is removal of axillary nodes through an incision in the axilla after determining that the sentinel node is malignant. Removal and examination of the axillary nodes allow staging (see Figure 16-7) of the disease. Adjunct treatment can be more accurately planned when the pathologic stage is determined.

Procedural Considerations

The patient is placed supine on the OR bed with the operative side near the bed edge. The arm on the operative side is extended to less than 90 degrees on an armboard. The skin is prepped and draped as previously described.

RAPID RESPONSE TEAM

Anaphylactic shock from Lymphazurin 1% can occur 6 to 8 hours after the first episode of anaphylaxis. At this time, the patient may be in the ambulatory surgery recovery (see Patient Safety) or the medical-surgical unit. A rapid response team may be called when the symptoms of anaphylactic shock are observed, such as oxygen desaturation, systolic blood pressure in the range of 30 to 40 mm Hg, and urticaria. These teams are part of a formal interdisciplinary system to reduce death or disability through early identification, assessment, and stabilization of patients with a deteriorating medical condition before the patient's condition requires resuscitation or transfer to a higher level of care. The patient in anaphylactic shock is treated appropriately, admitted to the hospital for observation, and, when fully recovered, discharged with appropriate medications and instructions, especially with information about the allergy to Lymphazuin. The patient should inform all medical personnel of this allergy and wear a medical alert bracelet.

Modified from Liang MI, Carson WE: *Biphasic anaphylactic reaction to blue dye during sentinel lymph node biopsy, 2008,* available at www.wjso.com/content/6/1/79. Accessed April 6, 2009; Administrative Policy and Procedure Manual, Taylor Hospital, effective date April 2006.

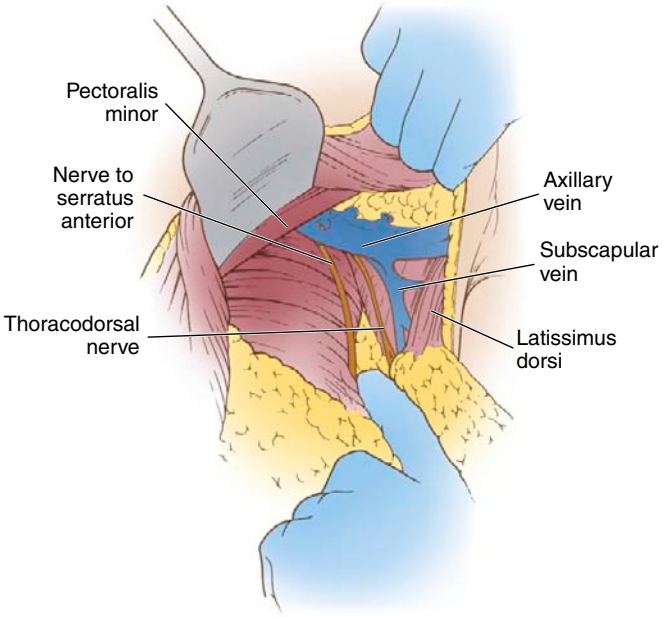


FIGURE 16-10 Axillary dissection.

Operative Procedure

1. An incision is made slightly posterior and parallel to the upper lateral border of the pectoralis major muscle or transversely across the axilla.
2. The fascia is incised over the pectoralis muscle and the pectoralis minor muscle is exposed. Major blood and lymphatic vessels are clamped and ligated. The use of electrosurgery is avoided around the axillary vessels and nerves to reduce the risk of inadvertent injury and subsequent impaired muscle function.
3. The tissue over the axillary vein is incised.
4. Lymph nodes between the pectoralis major and pectoralis minor muscles are removed. Care is taken not to injure the medial and lateral nerves of the pectoralis major muscle.
5. Axillary fat and lymph nodes are freed from the axillary vein and chest wall. The long thoracic nerve is identified along the chest wall near the axillary vein, and the thoracodorsal nerve posteriorly is dissected free from the specimen.
6. The fat and nodes are removed. The incision is closed with sutures and staples, and a dressing is applied. A closed wound drainage system is usually placed through a separate stab incision for lymphatic drainage.

SUBCUTANEOUS MASTECTOMY

Subcutaneous mastectomy is removal of all breast tissue with the overlying skin and nipple left intact. This procedure is recommended for patients who have central tumors of noninvasive origin, chronic cystic mastitis, hyperplastic duct changes, or multiple fibroadenomas or who have undergone several previous biopsies. Breast reconstruction may be undertaken at the time of mastectomy or at a later date if desired.

Procedural Considerations

The patient is positioned as for a biopsy. If reconstruction is to be undertaken, appropriate equipment and supplies (see Chapter 21) are also required.

Operative Procedure

1. An incision is usually begun in the inframammary crease and may be made on the medial or the lateral aspect of the breast. Some surgeons initially remove and preserve the nipple areola complex by employing lateral extensions of wide circumareolar incisions.
2. Blunt dissection is performed to elevate the breast from the pectoral fascia.
3. The breast tissue is separated from the skin with an attempt made to remain in a plane between the subcutaneous tissue and the breast. Dissection is carried out toward the axilla. With care, 90% or more of the breast tissue, including the tail of Spence, can be removed. Some lymph nodes in the axillary area also may be removed. Bleeding vessels are clamped and ligated.
4. If a preoperative decision was made for immediate reconstruction, that procedure follows at this time. Provided that the subareolar tissue shows no signs of tumor, as verified by a pathologist, the salvaged areolar complex is placed on a deepithelialized dermal bed.
5. A closed wound suction catheter typically is inserted. The wound is closed, and a light pressure dressing is applied.

SIMPLE MASTECTOMY

Simple mastectomy is removal of the entire involved breast without lymph node dissection (see Figure 16-9). A simple mastectomy is performed to remove extensive benign disease, if malignancy is believed to be confined only to the breast tissue, or as a palliative measure to remove an ulcerated advanced malignancy.

Procedural Considerations

The patient is positioned as for a biopsy.

Operative Procedure

1. Through a transverse elliptic incision (Figure 16-11, *A*), using a knife, curved scissors, and the ESU, the skin edges are freed from the fascia. Bleeding vessels are clamped with hemostats and ligated with sutures or electrocoagulated.
2. The skin edges of the wound can be protected with warm, moist laparotomy pads; the breast tissue is grasped with Allis forceps and is dissected free from the underlying pectoral fascia with curved scissors, a knife, or an ESU.
3. The tumor and all breast tissue are removed. Bleeding vessels are clamped and ligated or electrocoagulated.
4. A closed wound drainage catheter is inserted and anchored to the skin with a fine suture. The wound is closed with fine sutures or staples; a dressing is applied.

MODIFIED RADICAL MASTECTOMY

Modified radical mastectomy is performed after a tissue biopsy with a positive diagnosis of malignancy and removes the involved breast and axillary contents (all three levels of nodes—axillary, pectoral, and superior apical) (see Figure 16-9). The underlying pectoral muscles are not removed before or after removal of axillary nodes. A modified radical mastectomy is done to remove the involved area with the hope of decreasing the spread of the malignancy. This surgery's elliptic incision encompasses the nipple-areolar complex, a biopsy scar if an

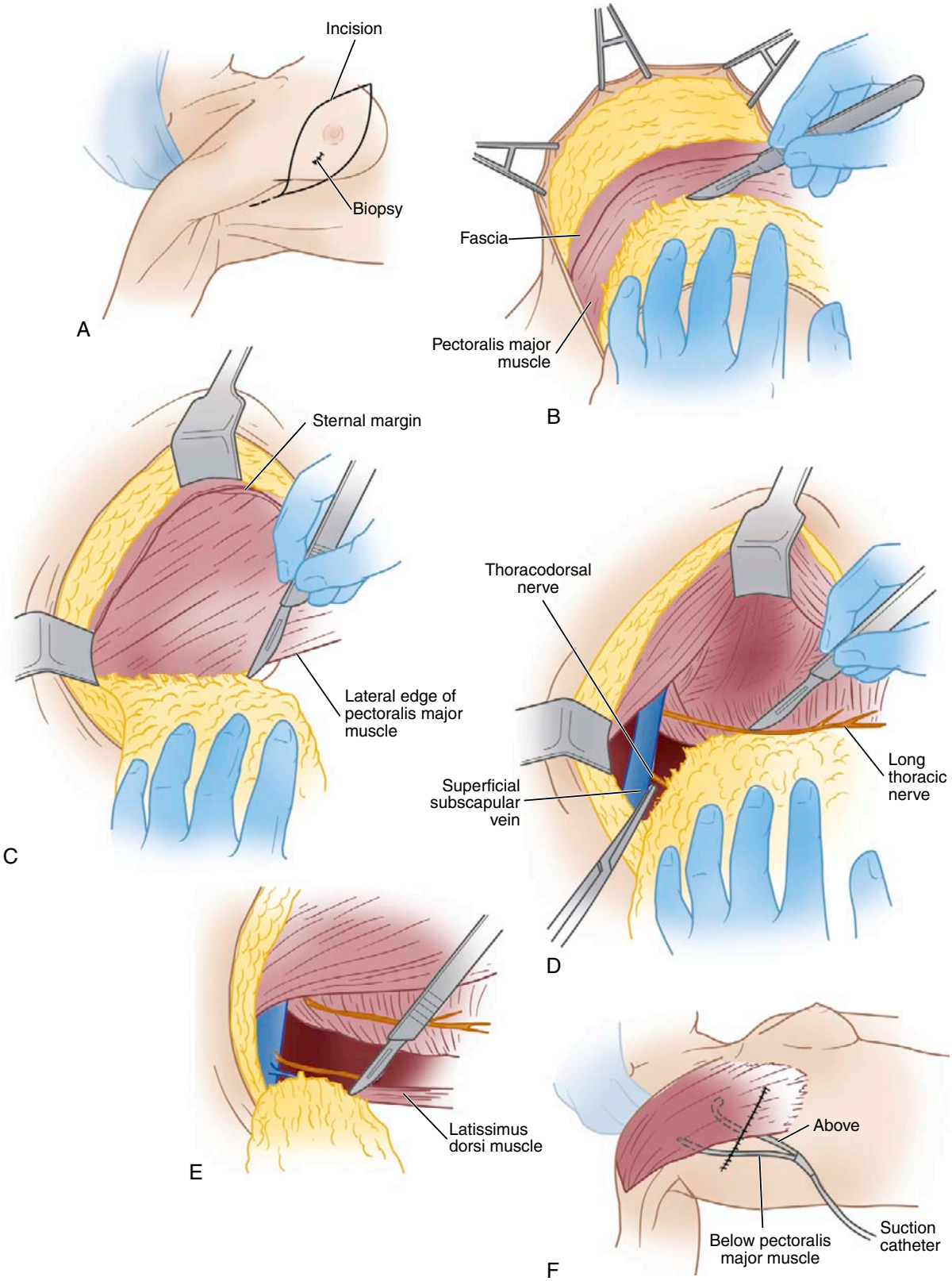


FIGURE 16-11 Modified radical mastectomy. **A**, Lines of incision. **B**, Resection of breast from lateral edge of pectoralis major muscle. **C**, Dissection of breast from lateral edge of pectoralis major muscle. **D**, Thoracodorsal and long thoracic nerves identified. **E**, Resection from latissimus dorsi muscle. **F**, Incision is closed, and closed wound drainage systems are placed.

open biopsy has been performed, and excess skin of the breast. If skin is needed for reconstruction (see Chapter 21), it can be preserved and exposure obtained through incision rather than excision (Mulholland et al, 2006).

Procedural Considerations

The patient is placed supine on the OR bed with the operative side near the bed edge. The arm on the operative side is extended to less than 90 degrees on a padded armboard. The skin is prepped and draped as previously described. Tissue removed during surgery will be submitted for microscopic analysis to further classify it (type, tumor size, grade, invasion, lymphocytic response, clean margin size). Additional analysis such as hormone receptor status (estrogen and progesterone positive or negative) and HER-2/neu (human epidermal growth factor receptor 2) expression may also be performed. This information assists the oncologist in planning subsequent adjuvant therapies (Ignatavicius and Workman, 2010).

Operative Procedure

1. An oblique elliptic incision with lateral extension toward the axilla is made through the subcutaneous tissue (see Figure 16-11, *A*). The bleeding points are controlled with hemostats and ligatures or electrocoagulation.
2. The skin is undercut in all directions to the limits of the dissection by means of a #3 knife handle with a #10 blade, curved scissors, or the ESU. Knife blades need to be changed frequently to ensure precise dissection.
3. The margins of the skin flaps are covered with warm, moist laparotomy pads and then retracted. The fascia and breast are resected from the pectoralis major muscle (Figure 16-11, *B*), starting near the clavicle and extending down to the midportion of the sternum. The pectoralis muscle is left intact.
4. The intercostal arteries and veins are clamped and ligated.
5. The axillary flap is retracted for dissection of the axilla. Careful attention is directed to preventing injury to the axillary vein and to the medial and lateral nerves of the pectoralis major muscle.
6. The fascia is dissected from the lateral edge of the pectoralis muscle (Figure 16-11, *C*). Vessel ligation is performed in the axilla and adjacent to the sternum. The fascia is then dissected from the serratus anterior muscle. The thoracic and thoracodorsal nerves are preserved (Figure 16-11, *D*).
7. The breast and axillary fascia are freed from the latissimus dorsi muscle and suspensory ligaments (Figure 16-11, *E*). The specimen is then passed off the field.
8. The surgical area is inspected for bleeding sites, which are ligated and electrocoagulated. The wound is irrigated with normal saline. Closed wound suction catheters are inserted into the wound through stab wounds and secured to the skin with a nonabsorbable suture on a cutting needle (Figure 16-11, *F*).
9. A few absorbable sutures may be used in the subcutaneous tissue to approximate the skin edges. The incision is closed with interrupted nonabsorbable sutures, staples, or a running subcuticular stitch for a better cosmetic result.
10. The dressing can be a simple gauze dressing, a bulky dressing held in place by a Surgi-Bra, or a gauze or elastic bandage wrap.

REFERENCES

American Cancer Society: What are the risk factors for breast cancer? 2009, available at www.cancer.org/docroot/CRI/content/CRI_2_4_2X_what_are_the_risk_factors_for_breast_cancer_5asp?sitearea. Accessed April 2, 2009.

Association of periOperative Registered Nurses: Recommended practices for a safe environment of care. In *Perioperative standards and recommended practices,* Denver, 2009, The Association.

Barclay L: Cancer Survivorship Care: An Expert Interview with Miriam E Slavin, RN, MS, OCN, Oncology Nursing Society 34th Annual Congress, 2009, available at www.medscape.com. Accessed June 1, 2009.

Bland KL et al: Radiofrequency, cryoablation and other modalities for breast cancer ablation, *Surg Clin North Am* 89:539–550, 2009.

Boon HS et al: Trends in complementary/alternative medicine used by breast cancer survivors: comparing survey data from 1998 and 2005, *BMC Womens Health*, 2007; 7:4. Published online.

Breast Health: *Diagnostic Procedure Options (Clinical Study Guide),* Washington, DC, 2006, AORN 53rd Congress.

Cornforth T: Breast Biopsy-Excisional-Incisional-Fine Needle Aspiration-Core Needle, 2009, available at www.womenshealth.about.com/cs/breastlumps/a/brstlumpbiopsy.htm. Accessed May 18, 2009.

Denholm B: Tucking patient's arms and general positioning, *AORN J* 89(4):755–757, 2009.

Fearmonti RM et al: Integrating partial breast irradiation into surgical practice and clinical trials, *Surg Clin North Am* 87:485–498, 2007.

Hormonal therapy changes, 2007, available at www.breastcancer.org/search.jsp?terms=estrogen+receptor+%28ER%29+down-regulators+. Accessed August 7, 2009.

Hulvat M et al: Multidisciplinary care for patients with breast cancer, *Surg Clin North Am* 89:133–176, *2009.*

Ignatavicius DD, Workman ML: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, St Louis, 2010, Saunders.

Kassam F et al: Survival outcomes for patients with metastatic triple-negative breast cancer: Implications for clinical practice and trial design, *Clin Breast Cancer* 9(1):20–33, 2009.

Kirby RM et al: Three stage axillary lymphatic massage optimizes sentinel lymph node localisation using blue dye, International Seminars in Surgical Oncology, 2007, available at www.issoonline.com/content/4/1/30. Accessed May 15, 2009.

Lind DS et al: Breast procedures, ACS Surgery Principles and Practice, 2005, available at www.medscape.com/viewarticle/503006. Accessed May 27, 2009.

Martinez-Cecilia D: Preoperative MRI can change surgical approach to breast cancer. 6th European Breast Cancer conference (EBBC), 2008. Medscape Medical news online at www.medscape.com/viewarticle/573066. Accessed August 9, 2009.

Mikula C: Mammography and biopsy, *Adv Nurses* 10(9):21–23, 2008.

Morrow M, Harris JR: Comprehensive Management of Regional Breast Lymph Nodes, 2009, available at cme.medscape.com/viewarticle/590749. Accessed August 8, 2009.

Mulholland M et al: *Greenfield's surgery*, ed 4, Philadelphia, 2006, Lippincott Williams & Wilkins.

National Cancer Institute: What You Need to Know About Breast Cancer, 2007, available at www.cancer.gov/cancertopics/wyntk/breast. Accessed April 5, 2009.

Nelson R: Women with BRCA Mutation Most Likely Opt for Prophylactic Mastectomy, 2009, Medscape Medical News, available at www.medscape.com/viewarticle/589280. Accessed May 6, 2009.

O'Shaughnessy J et al: Efficacy of BSI-201, a poly (ADP-ribose) polymerase-1 (PARP1) inhibitor, in combination with gemcitabine/carboplatin in patients with metastatic triple negative breast cancer: results of a randomized phase 11 trial, *J Clin Oncol* 27(155), 2009:Abstract 3.

Re-excision for close margins? 2008, available at www.breastcancer.org/symptoms/path_report/ask_expert/question_03.jsp. Accessed August 7, 2009.

Sentinel Lymph Node Dissection, 2008, available at www.breastcancer.org/treatment/surgery/lymph_node_removal/sentinel_dissection/index.jsp. Accessed August 7, 2009.

Sentinel Node Biopsy, 2009, e-Medicine Health, Web MD, LLC. available at www.emedicinehealth.comsentinel_node_biopsy/page6_em.htm. Accessed May 18, 2009.

Stephan P: Stereotactic Breast Biopsy for Breast Abnormalities, 2009, available at www.breastcancer.about.com/od/breastbiopsy/p/stereotactic.htm. Accessed May 18. 2009.

U.S. Department of Health and Human Services: New Screening Catches More Breast Cancers, 2008, available at www.hhs.gov/diseases/indexhtml. Accessed April 10, 2009.

Weaver C: Caring for a patient after mastectomy, *Nursing* 39(5):44–48, 2009.

Winkeljohn DL: Oncology nursing 101 Triple Negative Breast Cancer, *Clin J Oncol Nurs* 12(6):861–863, 2008.

Zuckerman D: 2007 Update: When Should Women Start Regular Mammograms? 40? 50? National Research Center for Women & Families 2007, available at www.center4research.org/wmnshlth2007/mam04.07.html. Accessed May 25, 2009.

CHAPTER 17

Ophthalmic Surgery

VICTORIA DREGER

Statistics about vision loss are staggering: throughout the world, more than 161 million people have significant vision loss and that number is expected to double by 2020; more than 37 million people are completely blind, with someone going blind every 5 seconds. Ninety percent of eye accidents, thousands of which occur daily, are preventable with the use of proper safety eyewear (Prevent Blindness America [PBA], 2005). Preventable or treatable conditions cause 80% of blindness worldwide (Lighthouse International, 2007).

Early detection of eye disease through regular eye exams can provide the most effective treatment and ultimately preserve vision (Figure 17-1). However, a national telephone survey of more than 3000 adults found that most Americans are not aware of risks and warning signs of the diseases that could blind them. Over 70% said that losing their eyesight would have the greatest impact on their daily life. Many considered losing their eyesight to be worse than losing an arm or leg, or losing hearing or the ability to speak (National Eye Institute [NEI], 2008a). As a result of the survey, the National Eye Institute is increasing its efforts to educate healthcare professionals about methods of communicating with patients to better maintain eye health (NEI, 2008a). At the same time, outpatient surgeries have been increasing: cataract is the leading diagnosis for ambulatory surgery visits, with more than 3 million lens extractions performed yearly (Cullen et al, 2006). The perioperative nurse must keep abreast of changes in technology, procedural techniques, safety issues, and patient education resources to provide optimal care to ophthalmic surgery patients (Research Highlight).

Surgical Anatomy

The major eye structures and normal eye function will be reviewed here; conditions requiring surgery will be discussed under Surgical Interventions. The perioperative nurse uses this combined knowledge to understand the surgeon's plan of treatment and to prepare the patient, instrumentation, supplies, and equipment for the procedure.

Bony Orbit

The two orbital cavities are situated on either side of the midvertical line of the skull between the cranium and the skeleton of the face. The seven bones that form the orbit are the maxilla, palatine, frontal, sphenoid, zygomatic, ethmoid, and lacrimal bones.

Each orbit is in the shape of an irregular, four-sided pyramid, with its base at the front of the skull and its axis pointing posteromedially toward the apex. The orbit contains the globe; orbital fat; extraocular muscles, nerves, and blood vessels; and part of the lacrimal apparatus. The orbit also acts as a distribution center for certain vessels and nerves that supply the facial areas around the orbital aperture.

The *orbital septum* is a sheet of connective tissue that descends from the periosteum of the orbital margin to the eyelid retractors near the skin surface. The septum protects the contents of the bony orbit, and divides the area into anterior (preseptal) and posterior (postseptal) spaces.

Lacrimal Apparatus

The lacrimal apparatus effectively functions like a sink, with a faucet (main and accessory lacrimal glands) and drain (lacrimal puncta, canaliculi, sac, and nasolacrimal duct). The lacrimal gland produces tears and secretes them through a series of ducts onto the anterior ocular surface, thereby keeping the cornea moist and washing away any debris. The tears then flow inward to the puncta, from which they are conducted by the canaliculi to the lacrimal sac and finally pass into the nasolacrimal duct (Figure 17-2).

Eyelids

The palpebral fissure refers to the space between the margins of the two eyelids (Figure 17-3). When the eye is closed, the fissure becomes a mere slit and the cornea is completely covered by the upper eyelid. The upper eyelid is more mobile and larger than the lower. The upper and lower lids meet at the medial and lateral angles (canthi) of the eye. The eyelids are closed by the orbicularis oculi muscle, innervated by the seventh cranial nerve. The upper lid is opened by the levator muscle, which is innervated by the third cranial nerve.

The anterior eyelid layers contain the eyelid skin, ocular adnexa (eyelashes and associated glands), and subcutaneous tissue, lymphatics, and muscles.

The tarsus is a plate of dense fibrous tissue that forms the main scaffolding of the eyelids. The tarsus is anchored to the walls of the orbit by the medial and lateral palpebral ligaments. Within the tarsus are the meibomian glands, which secrete the oily component (sebum) of the tear film. The orifices of these sebaceous glands are found at the eyelid margin just posterior to the eyelashes.

Conjunctiva

The conjunctiva is a thin, transparent mucous membrane divided into a palpebral portion (lining the inside of the eyelids) and a bulbar portion (lining the surface of the globe) (see Figure 17-3). The junction between the palpebral and bulbar conjunctivae forms a forniceal sac.

RESEARCH HIGHLIGHT

Review of Impaired Vision Among Midlife Adults and Geriatric Patients

Existing nursing research on low vision and blindness is scarce, and of those studies that exist, most have a small sample size and tend to be qualitative in nature. One article reviewed nursing research regarding blindness and impaired vision among midlife adults and geriatric patients. In contrast, the number of American patients in this age range with visual impairment is expected to double by the mid-2020s, with an eventual 1.6 million blind Americans and 3.9 million Americans with low vision. Visual impairment is associated with decreased quality of life and shortened life expectancy.

The authors suggest that the limited number of nursing research studies involving this population is of concern considering the number of persons affected. They suggested four broad categories for research endeavors:

1. Questions within the context of holistic nursing frameworks (e.g., How does visual impairment affect capacity for self-care, coping, adaptability, socialization, economic security, access to care, self-esteem, and/or spiritual well-being?)
2. The capacity of advanced practice nurses to assess and refer visually impaired patients (e.g., developing an evidence base regarding common age-related eye diseases)
3. Efficacy testing for how all health conditions are managed and adapted for accessibility by blind or low vision patients
4. Availability and testing of reengineered work designs for nurses with visual impairment, to retain valuable and experienced workers during an upcoming nursing shortage; a related issue is whether electronic medical records enhance the functioning of visually impaired health professionals because the font size can be enlarged and darkened

Another review suggested other future research to assess the relationship between age-related macular degeneration and involvement in motor vehicle collisions. Certain programs, such as those in which patients utilize miniature telescopes mounted into ophthalmic corrective lenses (e.g., bioptic telescopes) while driving, should also be explored. The authors state that well-designed studies would be important to inform both clinical and policy audiences about safety and quality of life, while using bioptics for driving.

Nurse scholars are called upon to expand the nursing knowledge base for the anticipated surge in patients with low vision and blindness and those who suffer from those conditions. Are you ready for the challenge?

Modified from Owsley C, McGwin G: Driving and age-related macular degeneration, *J Vis Impair Blind* 102(10):621-635, 2008; Sharts-Hopko N: Low vision and blindness among midlife and older adults: a review of the nursing research literature, *Holist Nurs Pract* 23(2):94-100, 2009.

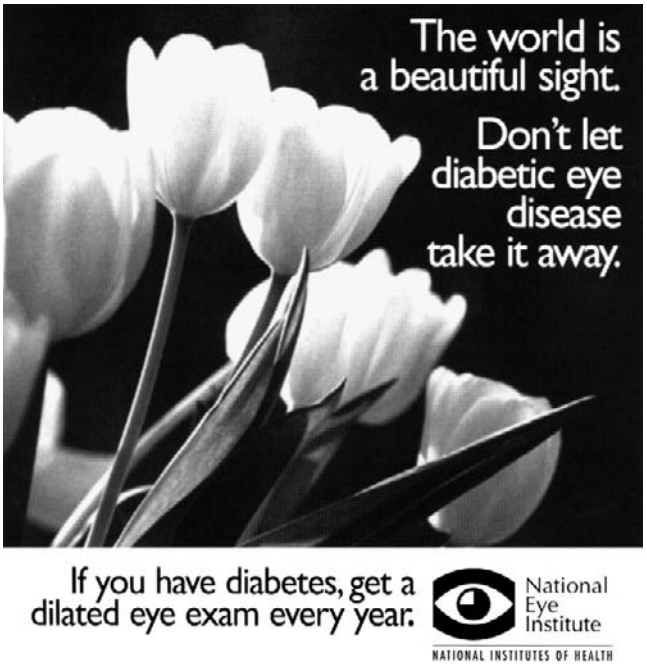


FIGURE 17-1 Public service announcement on prevention of diabetic eye disease.

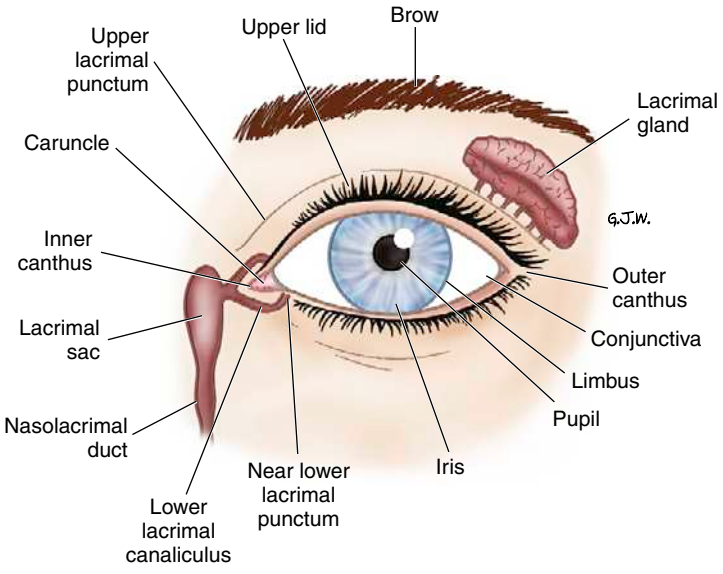


FIGURE 17-2 Lacrimal apparatus.

Muscles

Named according to their relative position on the eyeball, the extraocular muscles of the eyeball include the four recti (the *superior rectus, inferior rectus, medial rectus, and lateral rectus*) and two oblique muscles (the *superior oblique and inferior oblique*) (see Figure 17-3). Except for the inferior oblique muscle, these muscles originate from the back of the orbit. The muscles work in yoked pairs, with ocular movements generated by an increase in the tone of one set of muscles and a decrease in the tone of the antagonistic muscles. The extraocular muscles are supplied by cranial nerves III (oculomotor, supplying the superior, inferior and medial recti), IV (trochlear, supplying the superior oblique), and VI (abducens, supplying the lateral rectus).

Globe

The eyeball (globe) is supported in the orbital cavity on a cushion of fat and fascia. The fibrous external layer includes the clear cornea and white sclera; the middle, vascular pigmented layer comprises the iris, ciliary body, and choroid; and the internal layer is the sensory retina. The globe is filled with two clear liquids: the aqueous humor (anterior to the lens) in the

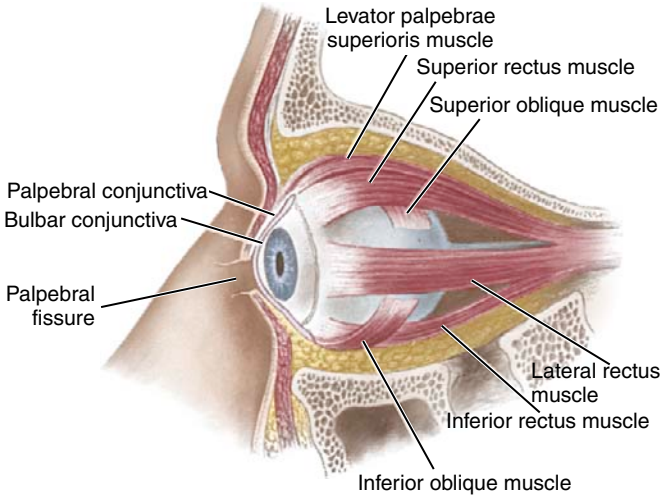


FIGURE 17-3 Orbit and muscles. Medial rectus is located on nasal side of globe.

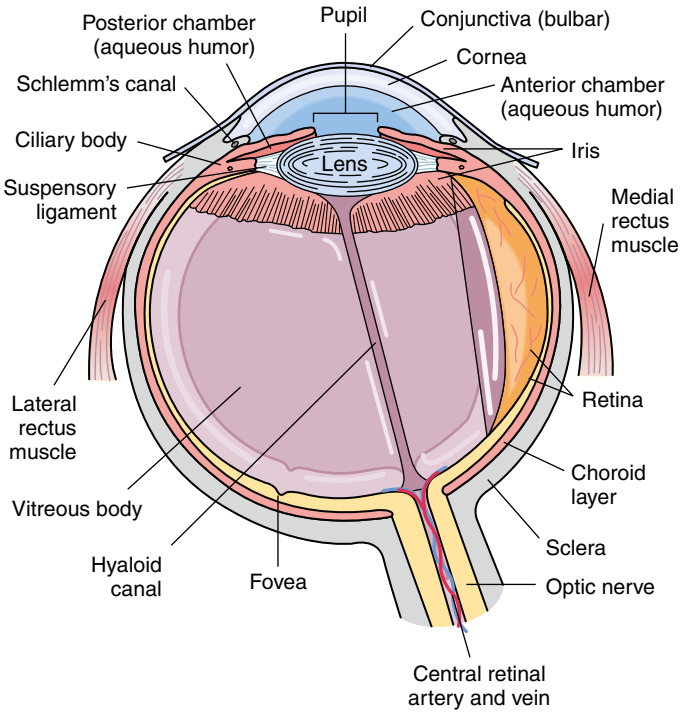


FIGURE 17-4 Horizontal section through left globe.

anterior segment and the vitreous humor (behind the lens) in the *posterior segment*. Light and images are focused *(refracted)* by the lens, suspended behind the pupillary opening of the iris, and the cornea (Figure 17-4).

Refractive Apparatus

Cornea. The *cornea* is the transparent, avascular window through which light rays pass to the retina; it joins the sclera at a transitional zone called the *limbus*. Corneal sensation is provided via ophthalmic branches of the fifth cranial nerve. The cornea is composed of five layers: the epithelium, Bowman's membrane, the stroma, Descemet's membrane,

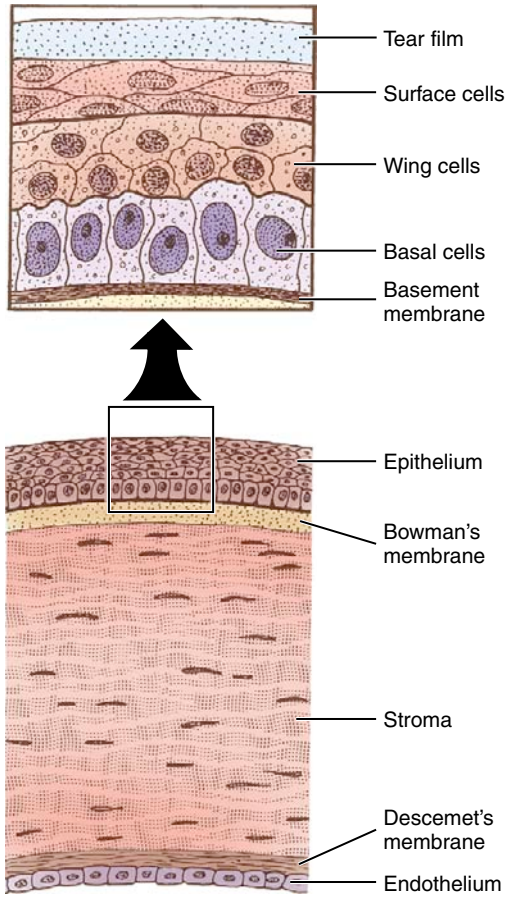


FIGURE 17-5 Five layers of cornea. *Inset,* Layers of epithelium.

and the endothelium (Figure 17-5). The epithelium consists of constantly renewing cell layers with many nerve endings, accounting for the cornea's great sensitivity to foreign bodies and abrasions. Bowman's membrane is connective tissue thickening that forms a barrier to trauma and infection under the epithelium. If damaged, Bowman's membrane does not regenerate and a permanent scar is formed. The stroma accounts for 90% of the corneal thickness and is composed of precisely layered fibers. If this layering is disrupted (for example, by edema), the corneal clarity decreases. Descemet's membrane is a thin layer between the endothelial layer of the cornea and the stroma. The corneal endothelium is a single layer of hexagonal cells that acts as a fluid pump to keep the cornea clear by maintaining the proper level of stromal dehydration. Because corneal endothelial cells do not regenerate, damage to this layer may cause persistent corneal edema and loss of transparency.

The *sclera* is the opaque "white" part of the external layer, and is made up of collagenous fibers loosely connected with fascia. The sclera receives attachments of the extraocular muscle tendons, and is pierced by the ciliary arteries and nerves posteriorly by the optic nerve.

Visual images are refracted (focused) by the cornea, the aqueous humor, the lens, and the vitreous body. The cornea has the greatest refractive power of the ocular structures. Variations in the curvature of the cornea change its refractive power (Figure 17-6).

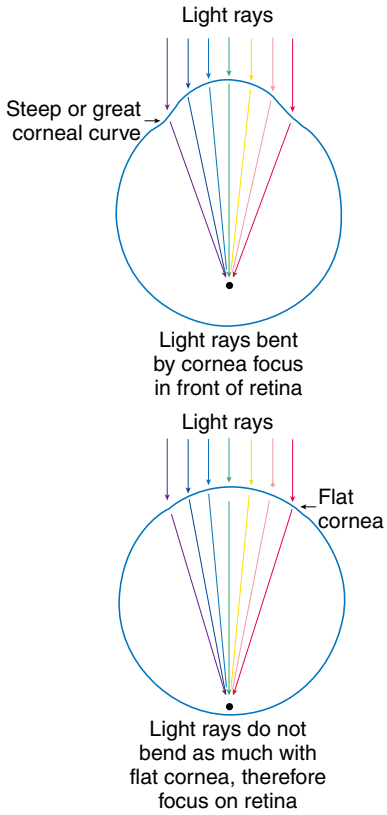


FIGURE 17-6 Variations in the curvature of the cornea change its refractive power.

Lens. The biconvex lens is suspended behind the iris and connected to the ciliary body by delicate collagenous strings called *zonules* (Figure 17-7). The lens changes shape and focus (accommodation) by relaxation and tightening of the zonular fibers. Over time (particularly after age 40), the lens and lens zonules become progressively less elastic, resulting in *presbyopia*. This loss of accommodative power is typically corrected with reading glasses or bifocals.

Vitreous. The vitreous body is a glasslike, transparent, gelatinous mass composed of 99% water and 1% collagen and hyaluronic acid. It fills the posterior four fifths of the eyeball and is adherent to the retina at the vitreous base.

The eye functions similarly to a camera. Light rays from an object pass through the system of refractory devices—the cornea, aqueous humor, lens, and vitreous—and are refracted (bent) so that the rays strike the retina. For information to be received correctly and sent to the cerebral cortex, all structures must function together to focus the light rays. The lens must be able to bend the light waves correctly and bring an object into clear focus. Refractive errors, or errors in focusing ability, occur when the cornea is misshapen or when the lens cannot appropriately change shape to focus images.

Nerve and Blood Supply

The optic nerve (second cranial nerve) extends between the posterior eyeball and the optic chiasm. This cranial nerve carries visual impulses, as well as the sensations of pain, touch, and temperature, from the eye and its surrounding structures

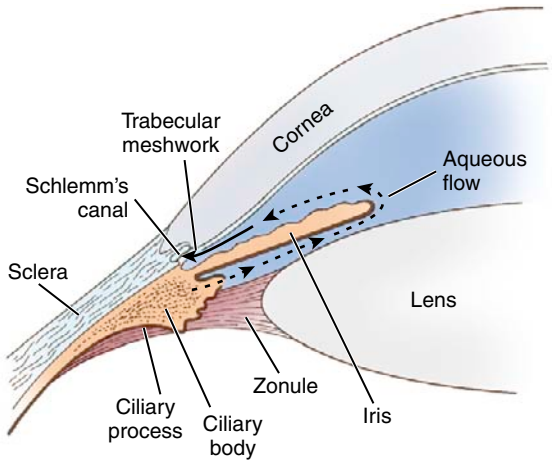


FIGURE 17-7 Anterior chamber, ciliary body, and aqueous circulation.

to the brain. The third cranial nerve (oculomotor) is the primary motor nerve to the inferior oblique as well as all rectus muscles except the lateral rectus, which is innervated by the sixth cranial nerve (abducens). The fourth cranial nerve (trochlear) innervates the superior oblique muscle.

The ophthalmic artery, the main arterial supply to the orbit and globe, is a branch of the internal carotid artery. It divides into branches supplying the globe, muscles, and eyelids. The central retinal artery and central retinal vein travel through the optic nerve and provide a separate blood supply for the retina.

Physiology of Vision

Clear vision requires all of the following: healthy, functioning eye structures; adequate light; intact neurovascular communication with the brain; and the brain's effective interpretation of the images relayed. Since the eye is similar to a camera with a lens system, the following cycle, if completed in the full sequence, leads to accurate visual images:

1. Light rays emanate from an object in the field of vision and transmit to the eye.
2. Iris muscles control the size of the pupil, thereby determining the intensity of light (similar to the shutter of a camera).
3. These light rays pass through the optical system (cornea—"window of the eye"), aqueous fluid, lens, vitreous to reach the retina (which is similar to the film in a camera). The flexible lens bends the light rays to form the image on the retina, ideally striking at the macula, the area of highest sensitivity for details.
4. The visual sensory nerve endings of the retina pass the images as nerve impulses through nerve fibers of the optic nerve to the brain, where the occipital area interprets the images.

Since early treatment for various eye diseases can potentially save sight, people 60 years of age or older should have a comprehensive dilated eye exam every 2 years as a minimum (NEI, 2008b). Any condition that disrupts eye health or the process of these steps impairs vision. Other structures within the eye exist, but it is beyond the scope of this chapter to adequately cover all details of the complex organ of sight. Specific conditions requiring surgical intervention will be explained under Surgical Interventions.

Perioperative Nursing Considerations

Assessment

Patients undergoing eye surgery range from premature infants with retinopathy of prematurity or congenital conditions to elderly patients whose conditions result from the aging process. These patients need assessment of both their vision and their general health status. A preoperative visit to the eye clinic or surgeon's office typically completes the diagnostic testing and physical exam pertinent to the presenting eye condition subsequently requiring surgery. Communication with the physician's office staff to coordinate patient preparation and teaching and to collate preoperative test results increases the efficiency and effectiveness of preoperative procedures. Perioperative nurses contact patients preoperatively by phone to provide needed information concerning the day of surgery and to obtain initial preoperative assessment information. The perioperative nurse reviews the data provided from the office chart and conducts additional interviewing/history-taking in conjunction with the physical exam to complete the assessment process.

The perioperative nursing staff must be prepared to meet the specific needs of each patient and family, collaborate and communicate effectively for continuity of patient care, and prepare the patient for home care. Most patients are admitted through an ambulatory admission area adjacent to the surgical suites (Ambulatory Surgery Considerations). On admission, a staff member should fully orient the patient to the physical surroundings. Constant description and reinforcement are important to visually impaired patients. Approaching the patient from the unaffected side increases the patient's independence and decreases the possibility of startling the patient.

The assessment is designed to collect and disseminate pertinent information and must be carried out in a comprehensive, yet efficient, manner. A standard set of parameters should provide enough information to facilitate appropriate care in the event of an emergency. Physiologic information (e.g., height, weight, vital signs), psychosocial factors (e.g., support systems, fears, anxiety), and environmental, education, and self-care needs are assessed. The general health history includes completing a comprehensive list of current medication therapy (often the patient is asked to bring currently prescribed medications to the appointment). The medical history is very important in cueing the nurse to evaluate for ocular manifestations of systemic disease. For example, the patient may present for retinal surgery as a consequence of retinopathy related to diabetes mellitus. Additional discharge planning factors are also explored.

Data may be collected from family or significant others and/or directly from physicians or their office staff. Throughout the assessment process, the nurse encourages the patient toward self-actualization and assuming an active role in his or

AMBULATORY SURGERY CONSIDERATIONS

Ophthalmic Surgery in Elderly and Team Communications/Hand-Off

Anesthetic management impacts the success of eye surgeries. Safe outpatient surgery, especially in the elderly population, depends on patient selection, preoperative evaluation, preparation, monitoring, and local anesthesia techniques. In addition to standard preoperative evaluation, special considerations apply for anesthesia in ophthalmic surgery. For example, elderly patients scheduled for eye surgeries may have co-morbidities of congestive heart failure, hypertension, diabetes, angina, chronic lung disease, senility, parkinsonism, and/or arthritis, any of which may disrupt the surgical procedure. Some patients with Alzheimer's disease, head tremor in Parkinson's disease, claustrophobia, chronic cough, or shortness of breath while lying flat may benefit from general anesthesia because of difficult management with regional anesthesia and light sedation. Patients may benefit from leaving dentures in place since they may even breathe easier.

It is essential that the patient understand the procedure and routine. Thorough explanations (technique, monitoring, and safety precautions) regarding regional anesthesia for eye surgery can relieve patient anxiety and enhance cooperation. Most importantly, the preoperative anesthesia interview can set the tone and obtain patient acceptance. Premedication can serve as an adjunct to decrease anxiety and provide amnesia during injection of the block. Monitoring and titration of IV medications selected should achieve proper sedation levels and effect. Narcotic doses must be adjusted (decreased) in the elderly because increasing age alters pharmacodynamics.

Established regimens of cardiac medications should be continued in the perioperative period with beta-blocker use considered to prevent complications associated with increased heart rate; regional anesthesia is generally safe, even for elderly patients with a history of myocardial infarction. Following outpatient surgery, the patient needs to have the services of a responsible adult (assistance with walking, eating, and home care) for up to 24 hours after discharge.

Amato-Vealey and colleagues (2008) state, "Care provided in all phases of the perioperative process is driven by the need for rapid turnover; for increased volume and efficiency; to improve physician satisfaction; and to accelerate throughput for the surgical patient." Such a hurried environment can lead to communication errors and mistakes that could be fatal. Errors can occur throughout multiple phases of perioperative care. Active communication should be used to verify and clarify accurate exchange of information (e.g., correct person, correct site, correct procedure, special concerns) between all healthcare personnel, such as at the following transition of care points:

- Between the surgeon's office scheduling and the healthcare facility
- Between the healthcare facility scheduling and the preoperative area
- Between preoperative and intraoperative areas
- From intraoperative to phase I PACU
- From phase I to phase II recovery and discharge

"Effective and standardized communication between care providers at hand-off points during the perioperative process will help them facilitate safety and anticipate and limit complications. Communication that is timely, accurate, complete, unambiguous, and understood by the recipient reduces error and results in improved patient safety" (Amato-Vealey et al, 2008).

Modified from Amato-Vealey EJ et al: Hand-off communication: a requisite for perioperative patient safety, *AORN J* 88(5):763-770, 2008; Donlon JV et al: Anesthesia for eye, ear, nose and throat surgery. In Miller RD, editor: *Miller's anesthesia,* ed 4, Philadelphia, 2005, Churchill-Livingstone.

her healthcare needs (Patient Safety). All information should be documented so that it is readily available to others. Some healthcare systems have computerized health records (electronic medical records and health information technologies) that are accessible to appropriate healthcare providers in various locations. This supports continuity of care and can prevent errors (omissions), which are more likely when information is not readily available.

PATIENT SAFETY

Asking Questions

Various healthcare organizations have emphasized the importance of patient safety considerations. The Joint Commission's 2009 *National Patient Safety Goal* #13 states, "Encourage the patient's active involvement in their care as a patient safety strategy." Since 2002 The Joint Commission and the Centers for Medicare & Medicaid Services have encouraged patient participation through the "SPEAK UP" initiative (each letter of the acronym denotes a safety-related activity). Suggestions include basics of speaking up about any questions or concerns, emphasizing the right to know information about one's own care and the importance of asking again if one does not understand explanations given.

Various initiatives are intended to help prevent errors, such as avoiding mistakes during surgery, preventing infection, and accurately administering medications. Patients are encouraged to know their rights, understand instructions from healthcare providers, and be active in their pain management plan. A majority of healthcare institutions using the initiatives adds value to accreditations and certification processes; in fact, some institutions even advertise their accreditations.

The National Institutes of Health also provides information about *Talking to Your Doctor.* Questions pertaining to diseases, treatments, and tests along with general communication tips are available on the internet to help patients participate in and understand their care plan. Of course, "an eye care professional who has examined the patient's eyes and is familiar with his or her medical history is the best person to answer specific questions" (NEI Health Information, 2008).

Besides patient information, nurses need to be actively engaged in activities promoting safety; this influence can be exercised in many ways. Siefert (2008) notes "One of the simplest and most effective [ways] is to verbalize that something does not seem right. Motivate novice nurses to articulate concerns, encourage experts to scrutinize assumptions, and promote a workplace that respects curiosity and inquiry. The question not asked may lead to an error not prevented." Speaking up might take the form of strictly adhering to institutional policies concerning time-outs, patient identification, or sponge and instrument counts or even questioning a drug order, such as when Diamox is ordered for a patient who has a sulfa allergy.

Modified from Blanchard J: Clinical issues: National Patient Safety Goals update, *AORN J* 88(5):822-823, 2008; Seifert PC: Want to improve safety? Ask questions, *AORN J* 88(5):707-708, 2008; The Joint Commission: *Speak up*: *facts about speak up initiatives,* 2008, available at www.jointcommission.org/GeneralPublic/Speak+Up/about_speakup.htm. Accessed March 25, 2009; National Eye Institute, National Institutes of Health: *NEI health information*: *Talking to your doctor,* 2009, available at http://nei.nih.gov/health/talktodoc. Accessed March 25, 2009; National Eye Institute, National Institutes of Health: *NEI health information*: *Facts about cataracts,* 2008, available at www.nei.nih.gov/health/cataract/cataract_facts.asp. Accessed March 25, 2009.

An ocular history, which includes the patient's primary problem, history of the present condition, symptoms, and visual limitations, is collected from the patient's initial visit to the eye care provider's office, and the nurse confirms these findings. Some common forms of ocular examination are shown in Figure 17-8.

An external examination of the eye, including lids, lashes, conjunctiva, and lacrimal apparatus, should have been performed to detect any deviations from normal. The corneal reflex should have been tested and the cornea inspected for superficial irregularities. Pupil size and contour, as well as pupillary reaction, both direct and consensual, should be noted. Shallow anterior chamber depth alerts staff members to the potential for high pressures resulting from angle closure with dilation of the pupil.

The function of the extraocular muscles should have been determined. Movement should be synchronous, and visual lines should meet on a fixed object. Documentation of this examination must be descriptive, accurate, and concise. It is of value later in assessing the outcome of the procedure. The following observations are also important:

- General appearance of the eye (edema, asymmetry, redness, condition of conjunctiva, sclera, and skin around eyes)
- Symptoms of irritation (itching, burning)
- Position of eyelids (opened and closed), condition of upper and lower lid surfaces, eyelid spasm
- Visual acuity, pupillary dilation (note if pupils are equal, round, reactive to light, and accommodative), visual fields
- Extraocular muscle movement
- Drainage from eye
- Current and significant past medical problems (eye disease, diabetes, cardiovascular disease, hypertension, allergies)
- Current medication history, including anticoagulants, analgesics, herbs, and nutritional supplements
- General: vital signs; restlessness, discomfort, anxiety; limitations in mobility; presence of prosthesis

Laboratory Studies. The specific laboratory studies requested are derived from the more general standards for preanesthesia care established by the American Society of Anesthesiologists (ASA) (ASA, 2005). Although some eye procedures are completed with only local anesthesia, many, if not most, are performed in collaboration with an anesthesia care provider. Thus the results of laboratory studies that were performed should be reviewed during the nursing assessment. Deviations from normal should be noted, documented, and reported, verifying the anesthesia care provider's awareness of the same. The following tests might be routinely ordered; they are typically based on each facility's preanesthesia guidelines (delineating the age at which testing is needed) or the provider's medical judgment (relating to the patient's medical history):

- Serum enzymes, blood count, and other blood work: hemoglobin: males 14 to 18 g/dl, females 12 to 16 g/dl, elderly values slightly decreased; hematocrit: males 42% to 52%, females 37% to 47%, elderly values slightly decreased (Pagana and Pagana, 2009).
- Blood glucose: 70 to 105 mg/dl; increase in normal range after age 50 years; may be higher or lower depending on intake; critical levels are less than 50 mg/dl or more than 400 mg/dl in adult males and less than 40 mg/dl or more

FIGURE 17-8 **A**, A direct ophthalmoscope allows the eye care professional to examine the retina and optic nerve. **B**, After the eyes are dilated, an indirect ophthalmoscope provides the eye care professional with a wider view of the retina. **C**, A slit lamp, with its high magnification, allows the eye care professional to examine the front of the eye.

than 400 mg/dl in adult females. Some facilities may postpone surgery at a certain maximum level for elective cases. Urgent cases may be allowed insulin drip administration according to protocol (Pagana and Pagana, 2009).

- Serum potassium: adults, including elders: 3.5 to 5 mEq/L; critical values are less than 2.5 mEq/L or greater than 6.5 mEq/L. Some facilities may require that results were obtained within 24 hours; usually mandatory for renal failure or hemodialysis patients (Pagana and Pagana, 2009).
- Coagulation studies (prothrombin time [pro-time, PT])—for patients taking warfarin (Coumadin): 11.0 to 12.5 seconds, critical value more than 20 seconds; INR: 0.8 to 1.1, with possible critical value greater than 5.5; activated partial thromboplastin time [APTT]—for patients taking heparin: 30 to 40 seconds, critical value more than 70 seconds; desired ranges for therapeutic anticoagulation are 1.5 to 2.5 times normal, or around 70 seconds; partial thromboplastin time [PTT]—for patients taking heparin: 60 to 70 seconds, critical value more than 100 seconds. Coagulation studies may also be ordered for patients recently discontinued from taking anticoagulants (Pagana and Pagana, 2009).

Electrocardiogram and Chest X-ray Examination. In older adults, chest x-ray examination and an electrocardiogram (ECG) may be prescribed; if so, these reports should be included in the patient's record. The older adult is more predisposed to respiratory tract infection from less elastic alveoli, decreased heart size (unless there is enlargement associated with hypertension or heart disease), and ECG changes secondary to cellular alteration, conduction system fibrosis, and neurogenic changes. The physician team (surgeon, anesthesia provider) caring for the patient may determine further need for medical, pulmonary, or cardiac workup and/or clearance by a specialist. All decisions are made for safety and risk reduction according to medical judgment.

After the assessment information has been compiled, nursing diagnoses are identified and the plan of care for the entire perioperative period is developed.

Nursing Diagnosis

Nursing diagnoses related to the care of patients undergoing ophthalmic surgery might include the following:

- Deficient Knowledge or Readiness for Enhanced Knowledge related to diagnosis, surgical intervention, and home care management
- Anxiety related to vision loss, surgical intervention, awake status during surgical intervention, fear of the unknown and surgical outcome
- Disturbed Sensory Perception related to visual impairment, surgical intervention, and patching of operative eye or both eyes
- Acute and/or Chronic Pain related to increased intraocular pressure and surgical intervention
- Risk for Infection related to surgical intervention

Outcome Identification

Outcomes identified for the selected nursing diagnoses could be stated as follows:

- The patient, family, or significant others will verbalize knowledge of the diagnosis, planned surgical intervention, medication management, and requirements for home care maintenance before discharge.

- The patient will verbalize an acceptable level of anxiety and use personally effective coping mechanisms.
- The patient will demonstrate ability to safely adapt to visual sensory perception disturbances.
- The patient will remain comfortable during surgical intervention as determined by response on a verbal pain scale
- The patient will be free from signs and symptoms of postoperative infection.

Planning

Plans of care are the framework for organizing activities in the perioperative period. Although ophthalmic surgery is often perceived as minor because of the small incision site and because many procedures generally are not lengthy, the perioperative nurse must be fully prepared for potential complications or emergencies (Rapid Response Team box). Patients who are admitted for ophthalmic surgery often have complex medical histories. After a review of the patient's record, supplemented by a patient or family interview or collaboration with colleagues, data collected are incorporated into an individualized perioperative plan of care. A Sample Plan of Care for a patient undergoing ophthalmic surgery can be found on p. 618.

Implementation

Managing and Monitoring Patient Safety Needs. A key aspect of the perioperative nurse's role is patient safety. Because many ophthalmic procedures are performed with local anesthesia, the circulating nurse or an additional perioperative nurse must be prepared to monitor the patient according to the *Perioperative Standards and Recommended Practices* (AORN, 2009) and provide supportive care. Reassurance is especially important for patients who are awake. Ophthalmic patients, like other surgical patients, have increased sensitivity to noise and activities within the room. The room should be kept quiet and peaceful to decrease anxiety and increase cooperation, thereby reducing the need for deep sedation.

Both the scrub person and the perioperative nurse must also manage additional patient safety needs. Foreign substances must not be introduced intraocularly. Lint-free drapes should be used to create the sterile field. If powder-free gloves are not used, gloved hands must be wiped with moistened gauze sponges to remove starch powder particles before the procedure begins. Gloved hands should not touch the portion of an instrument used in an intraocular wound, and debris should be cleansed from instruments with cellulose sponges. The entire surgical team must be knowledgeable about their roles and be prepared to function quickly in the event of a complication or emergency.

Members of the perioperative nursing team have several important responsibilities in the preparation of the room and the equipment (History box). Technologic advances in ophthalmic surgery require that perioperative nurses be familiar with equipment and check each piece carefully before the patient arrives in the OR. The availability of specially ordered implants or prostheses needs to be checked to prevent delay or cancellation of the procedure. Scrupulous attention to aseptic technique is essential in preventing endophthalmitis (infection within the eye). Safety-focused communication within the perioperative nursing team includes the following:

1. Identification: The perioperative nurse asks the patient to state his or her name and compares the name on the wristband with the name on the chart and surgical schedule while verbally confirming it with the patient or a family member. The use of two identifiers, such as birth date or medical record number, is recommended.
2. Verifications: The patient or family member should also state which eye is the operative site and which procedure is being performed. The nurse reviews the surgical consent, surgeon's preoperative orders, and OR schedule to determine if the correct operative eye has been prepared (including verification of operative eye using the word "right" or "left" [abbreviations are not accepted], marking of operative site, and dilation, if appropriate) and other procedures have

RAPID RESPONSE TEAM

The goal of a rapid response team is to intercede in a clinical situation before the patient deteriorates and requires advanced life support. The underlying principle of the rapid response team, proactive intervention, has applicability in the care of patients undergoing ophthalmic procedures.

The oculocardiac reflex (OCR) is a trigeminal-vagal response that can occur during eye surgery in response to traction on extraocular muscles, pressure on the globe, or retrobulbar block. The most common symptom of OCR is sinus bradycardia, which can lead to asystole. The patient may become hypotensive and may experience a wide range of other dysrhythmias attributable to negative inotropic and conduction effects. The incidence of OCR reported ranges from 32% to 90%; in as many as 1 in 2200 strabismus surgeries, transient cardiac arrest may ensue.

The goal in treating OCR is to prevent progression to sinus arrest, which coincides with the philosophy of the rapid response team—intervening before the patient becomes critical and requires cardiopulmonary resuscitation. Heightened awareness of the patient's overall status is imperative for safe eye surgery.

Gentle surgical technique in traction on eye muscles is one method of preventing OCR. When OCR develops and treatment is required, the surgeon should immediately stop stimulating the eye and release the traction. The surgeon may also inject lidocaine near the eye muscle in an effort to block the response. Depending on the dysrhythmia noted, the anesthesia provider may administer atropine 0.007 mg/kg IV, ensure adequate depth of anesthesia and adequate ventilation (as hypoventilation and hypercarbia significantly increase the incidence of bradycardia in strabismus surgery), and request that the surgeon stop all operative manipulation. The perioperative nurse provides supportive assistance as required by the situation. Teamwork and communication during critical times (such as during an episode of cardiac dysrhythmia) in conjunction with prevention, vigilance, and early intervention can help avoid a more urgent emergency rescue.

Modified from Donlon JV et al: Anesthesia for eye, ear, nose and throat surgery. In Miller RD, editor: *Miller's anesthesia,* ed 4, Philadelphia, 2005, Churchill-Livingstone; McGoldrick KE, Gayer SI: Anesthesia and the eye. In Barach PG et al, editors: *Clinical anesthesia,* ed 5, Philadelphia, 2006, Lippincott Williams & Wilkins.

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Deficient Knowledge or **Readiness for Enhanced Knowledge** related to diagnosis, surgical intervention, and home care management

OUTCOME
The patient, family, or significant others will verbalize knowledge of the diagnosis, planned surgical intervention, medication management, and requirements for home care maintenance before discharge.

INTERVENTIONS
- Determine knowledge level.
- Identify barriers to communication.
- Assess readiness to learn.
- Identify psychosocial status.
- Assess coping mechanisms.
- Implement measures to provide psychologic support.
- Develop individualized plan of care.
- Evaluate psychosocial response to plan of care.
- Elicit perception of surgery.
- Encourage patient participation in decision-making and planning for postoperative care.
- Reinforce physician's explanations and clarify any misconceptions.
- Provide instructions based on age and identified needs.
- Include family members in preoperative teaching.
- Evaluate response to instructions.
- Evaluate environment for home care.
- Identify expectations of home care.
- Ensure continuity of care.

NURSING DIAGNOSIS
Anxiety related to vision loss, surgical intervention, awake status during surgical intervention, fear of the unknown and surgical outcome

OUTCOME
The patient will verbalize an acceptable level of anxiety and use personally effective coping mechanisms.

INTERVENTIONS
- Allow the patient time to verbalize concerns.
- Assist the patient in identifying sources of anxiety.
- Help the patient identify existing personal strengths and external resources; reinforce personally effective coping mechanisms.
- Offer alternative methods to minimize anxiety (e.g., music, humor).
- Encourage independence by having the patient participate in his or her plan of care; involve patient in identifying diversional activities.
- Observe for increased anxiety demonstrated through behavior (e.g., hand tremor, shakiness, restlessness, facial tension, voice quivering, increased perspiration).
- Broadly classify the patient's level of anxiety, based on nursing observation (low, moderate, high).
- Offer comfort measures (e.g., warm blankets, a pillow for under knees).
- Provide emotional support; reinforce information the patient has been previously given.
- Use touch (as appropriate) to communicate reassurance.
- Control environmental stimuli in the OR.
- Introduce staff members.
- Orient patient to environment and routines.
- Assure patient that a member of the staff is nearby.
- Provide information and answer questions honestly.
- Provide status reports to family members.

NURSING DIAGNOSIS
Disturbed Sensory Perception related to visual impairment, surgical intervention, and patching of operative eye or both eyes

OUTCOME
The patient will demonstrate ability to safely adapt to visually disturbed sensory perception.

INTERVENTIONS
- Note sensory impairments.
- Introduce self and other team members so that patient can recognize voices.
- Familiarize and orient patient to immediate surroundings; continuously reorient patient.
- Approach patient from unaffected side.
- Before discharge, review and have the patient repeat back in his or her own words safety measures to prevent falls and other injuries.
- Make referral to appropriate agency if home assistance is required.

NURSING DIAGNOSIS
Acute Pain and/or **Chronic Pain** related to increased intraocular pressure and/or surgical intervention

OUTCOME
The patient will remain comfortable during surgical intervention as determined by response on a verbal pain scale.

INTERVENTIONS
- Instruct patient to verbalize pain during procedure performed using local anesthetic or sedation; use a validated pain rating scale.
- Identify cultural and value components related to pain.
- Observe for physical signs of pain, such as facial grimacing, groaning, muscle tightening, or changes in vital signs.
- If using local anesthesia, alert physician to any patient reports of significant pain from the injection or signs of toxicity (e.g., tinnitus, tingling around the mouth).
- During procedure, make sure patient understands what is happening (e.g., stinging or pressure from local anesthetic injection) and how long it will last.
- Monitor the presence of or an increase in eye pain, pain around orbit, blurred vision, reddened eye, abdominal pain, nausea, vomiting, neurologic changes, and changes in visual fields; initiate appropriate action.
- Implement measures to provide psychologic support.
- Implement pain guidelines; administer medications as prescribed.
- Instruct the patient to refrain from excessive exertion, such as crying, coughing, straining, overlifting, bending, rubbing the eyes, and blowing the nose postoperatively.
- Discuss other methods to promote patient comfort, such as music, guided imagery, relaxation techniques.

NURSING DIAGNOSIS
Risk for Infection related to surgical intervention

OUTCOME
The patient will be free from signs and symptoms of surgical site infection.

INTERVENTIONS
- Preoperatively, document whether the patient has a preexisting infection, is immunocompromised, or has other conditions that compromise resistance to infection.
- Maintain an aseptic perioperative environment.
- Adhere to good handwashing practices.

SAMPLE PLAN OF CARE—cont'd

- Minimize length of invasive procedure by planning care.
- Initiate traffic control.
- Maintain continuous surveillance.
- Determine and record the wound classification.
- Instruct the patient and family in self-care, including postoperative antibiotic therapy if prescribed.
- Teach the patient and family to wash hands before the instillation of any ophthalmic medications.
- Instruct the patient and family to watch for redness, pain, swelling, drainage, and changes in visual acuity postoperatively and to report these problems promptly to the physician.

HISTORY

Developments in Ophthalmic Nursing as a Specialty

Journal articles from the 1960s offered perspectives from both nurses and surgeons on the perioperative nurse's role in ophthalmic surgery. Both perspectives are interesting, especially in illustrating how some attitudes have changed and other principles still remain the same.

The nursing perspective at the time emphasizes, "Our precious gift of sight oftimes is taken for granted. We give little thought to the truly wondrous gift that it is. A patient coming to the hospital, however, is acutely aware of this gift, and sight becomes a valued possession as he contemplates eye surgery. This patient temporarily entrusts in our care God's great gift to him. Unfortunately not all OR nurses enjoy assisting on eye surgery. There is a vast difference in the skills applied to ophthalmic surgery and the needed skills in general surgery.... The time and effort spent by a nurse to learn the proper approach to patient care during eye surgery can be rewarding."

"The role of the circulating nurse requires that she maintain an atmosphere of efficient, peaceful tranquility.... Extreme care must be taken in regard to the instillation of eye drops. The RIGHT drug in the RIGHT strength in the CORRECT eye is of paramount importance. The exact number of drops at the correct interval and number of times designated by the surgeon must be carefully carried out.... A good ophthalmic nurse gives herself ample time to set up [instrumentation] .... The eye is a delicate organ and everything related to the operation should be delicate and precise. Sharp points and cutting edges must be carefully handled. Perfect approximation of teeth on closing edges of the instruments is absolutely necessary. All eye instruments are precision manufactured and one has to develop a light touch in regard to their handling. Such instruments should never be tossed on top of one another, thrown together in a basin during or after the operation or in any way allowed to become entangled with one another. It is best to place instruments for sterilization in a carrier or tray that is large enough to accommodate all the instruments side by side without any overlapping."

A surgeon's perspective from the same time period states: "The fact that ophthalmic surgery differs from all other types of surgery in many ways is well established.... The adult eye patient...enters the hospital to preserve vision or restore lost vision. He is rational, awake and alert and, in many cases because of his diminished vision, peculiarly sensitive to sounds and odors that surround him.... The nurse should be familiar with the type of surgery and be knowledgeable about the local anesthesia.... A patient who is admitted for an enucleation...has a tremendous psychological problem. He knows that after surgery he will be missing an eye, which is a great loss in his mind, even though he knows that the eye is painful and blind. Many times the question of disfigurement is not discussed with the surgeon, but the patient may speak of it to the nurse. The nurse should say the removal of the eye would provide relief from pain and worry and the artificial eye will be satisfactory cosmetically.... The nurse must be acquainted with the various types of eye medications and their actions and the more common surgical procedures, so that she can function more intelligently and efficiently. A well informed nurse can explain the reasons for the medications and the procedures which are experienced by the patient.... The following should be checked prior to surgery: ...(very important again) the eye to be operated.... An operating room which is noisy and in which the personnel are inordinately garrulous is a very disturbing and tension-producing area for the eye patient who is under sedation. If he cannot doze quietly and is wakened fitfully with a start, he is not well-prepared for the operation. The patient should be kept quiet until the time for his positioning in the operating room...quiet and decorum should be maintained in the operating room...the circulating nurse should assist the surgeon in getting the appropriate medications and treatments accomplished rapidly. The equipment used in ophthalmic surgery has recently become much more sophisticated. New instrumentation includes laser units, operating microscopes with camera or television attachments, light coagulator, etc. All equipment should be tested prior to surgery. The door to the operating room should be kept closed and the surgeon should not be disturbed during the procedure. During a moment which is not critical, messages may be given.... The surgeon's entire attention at this point is directed to the area enclosed by the drape. The assistant is responsible for giving instructions to the scrub nurse who will then transmit those that are appropriate to the ever-attentive and constantly present circulating nurse.... The paperwork should have been done during the surgery by the circulating nurse so that at the end of the procedure the surgeon need only sign the various forms.... Nurses who are interested in this specialty and who have gained experience in the field will perform much more effectively than those who have only general nursing experience.... Intraocular infection is so devastating that infected cases should never be done in such a room. The highest peak of efficiency is reached when a team has been assigned to the eye service alone and can anticipate the needs of ophthalmic surgeons."

Modified from Ballen PH: Ophthalmic surgery: the nurse's role, *AORN J* 8:35-38, 1967; Rogers C: Nursing skills in ophthalmic surgery, *AORN J* 8:39-45, 1967.

been carried out according to facility policies on correct-site surgery. Such a policy may require that, before the administration of eyedrops or medication, the nurse asks the awake patient which eye is the operative site. If there is any discrepancy among the patient's response, the informed consent, the physician's orders, ophthalmic history, and exam, the discrepancy is corrected during the preoperative verification process. Immediately before the incision, this information, along with any implants or special needs, is reconfirmed during the time-out (Menke, 2008).

Safety Measures in Administering Medications. Medications used in the perioperative period are extremely important to the outcome of the procedure and the safety of the patient. Drugs for diagnosing and treating eye disorders are potent. One error could result in total, irreversible blindness.

The patient's medical and ocular histories determine the selection of an appropriate ophthalmic agent. The perioperative nurse should be knowledgeable about the specific medication ordered, including purpose, strength, action, duration, adverse reactions, route of administration, and contraindications. This information should be included in the patient's initial assessment. For example, mydriatic and cycloplegic eyedrops may be contraindicated in narrow-angle glaucoma.

The nurse checks the medication label for name, strength, and expiration date during preparation and before medication administration. This precaution is especially important because many ophthalmic drugs are distributed in single-dose units that closely resemble one another. The patient must be positively identified, and the site of the administration must be clearly translated from the physician's orders. Abbreviations should not be used. The words "right eye," "left eye," or "both eyes" should be used in writing orders. Handwashing between patients when administering eyedrops is imperative, and Standard Precautions should be followed. The nurse ensures that intraocular solutions are separated from those not used intraocularly.

All solutions on and off the sterile field must be clearly labeled. To meet The Joint Commission's *2009 National Patient Safety Goals,* medications in a procedural setting must have labels that include drug name, strength/concentration, and amount (TJC, 2009). Medication errors are the most common medical errors. Compliance with requirements can be an issue. One facility found that staff are more likely to label medications when preprinted labels are provided (Jennings and Foster, 2007). Preprinted labels are commercially available. Sterile waterproof pens and labels are also available to avoid smearing from liquids.

Instillation of Eyedrops. Before administering eyedrops, the perioperative nurse should perform hand hygiene. The patient may be supine or sitting, with the head tilted back slightly. The nurse instructs the patient to look upward and then gently pulls the lower eyelid open to expose the lower conjunctival sac (Figure 17-9). The prescribed number of drops is then administered without touching the tip of the dropper to the eye or the nurse's fingers. The natural blinking of the lids distributes the drug evenly onto the eye surface. When anesthetic eyedrops are instilled for topical anesthesia, they are placed on the cornea.

To minimize systemic absorption of certain eyedrops, such as atropine, the nurse may instruct the patient to press on the nasolacrimal duct for 1 minute to prevent absorption into the circulatory system. When a toxic drug is instilled, the nurse uses a tissue or clean cotton ball to dry the inner corners of the patient's eyelids after each drop to minimize systemic absorption of the drug.

The nurse provides teaching about the expected effect of each medication so the patient is able to evaluate its effectiveness, detect signs and symptoms of adverse reactions, and know when to notify the perioperative personnel concerning problems. The patient should also be well-informed of the special considerations associated with specific medications so that appropriate safety precautions can be taken.

FIGURE 17-9 An eye care professional applies eyedrops to dilate a patient's pupils.

Ophthalmic Pharmacology. Numerous medications are used during ophthalmic surgery. See the Surgical Pharmacology table on pp. 621-623 for the purpose and description of each.

Anesthesia

GENERAL ANESTHESIA. Youth, deafness, language barriers, dementia, severe anxiety, specific systemic diseases, known sensitivity to local anesthetics, potential of blood entering the airway (such as in tear duct procedures), and long duration of the operative procedure are among the conditions that may dictate use of general anesthesia.

LOCAL ANESTHESIA. Local anesthesia or monitored anesthesia care (MAC) is used for most eye surgery. Consideration must be given to the patient's age, systemic condition, and discharge plan in determining whether to use preoperative sedation, such as sublingual or oral midazolam hydrochloride (Versed). Intraoperative sedation, when indicated, may be prescribed and managed by either the anesthesia provider or the surgeon. The perioperative nurse, however, is often accountable for monitoring the patient's response to the sedation and the local anesthetic in the perioperative period.

The perioperative nurse assembles the sterile local anesthesia setup as required by the surgeon before the patient enters the OR, checking to ensure correct medications, proper concentrations and dosages, and appropriate sizes and gauges of needles and syringes. Local anesthetics should not be mixed far in advance of the time of intended use, because they may deteriorate, producing a reduced effect for the patient. The addition of epinephrine prolongs the duration of action of most local anesthetics and the vasoconstrictive effect can reduce bleeding, often present in eyelid procedures.

Administration Methods of Local Anesthesia. The *topical method* of local anesthesia has gained popularity for cataract-extraction procedures. A combination of anesthetic eyedrops

SURGICAL PHARMACOLOGY

Medications Used During Ophthalmic Surgery

Drug/Name	Purpose/Description
MYDRIATICS	
Phenylephrine (Neo-Synephrine, Mydfrin), 2.5%, 10%	Mydriasis (dilates pupil but permits focusing); used for objective examination of retina, testing of refraction, easier removal of lens; used alone or with a cycloplegic
CYCLOPLEGICS	
Tropicamide (Mydriacyl), 0.5%, 1%	Cycloplegia (paralysis of accommodation; inhibits focusing); dilates pupil; anticholinergic, used for examination of fundus, refraction
Atropine, 1%	Anticholinergic, dilates pupil, inhibits focusing; potent, long duration (7-14 days)
Cyclopentolate (Cyclogyl), 0.5%, 1%, 2%	Anticholinergic, dilates pupil, inhibits focusing
Scopolamine hydrobromide (Isopto Hyoscine), 0.25%	Anticholinergic, dilates pupil, inhibits focusing
Homatropine hydrobromide (Isopto Homatropine), 2%, 5%	Anticholinergic, dilates pupil, inhibits focusing
Epinephrine (1:1000) preservative free (PF)	Dilates pupil; added to bottles of balanced salt solution for irrigation to maintain pupil dilation during cataract or vitrectomy procedure
MIOTICS	
Carbachol (Miostat), 0.01%	Potent cholinergic, constricts pupil, used intraocularly during anterior segment surgery
Carbachol (Isopto Carbachol), 0.75%, 1.5%, 2.25%, 3%	Potent cholinergic, constricts pupil, used topically for lowering intraocular pressure in glaucoma
Acetylcholine chloride (Miochol-E), 1%	Cholinergic, rapidly constricts pupil, used intraocularly during anterior segment surgery; reconstitute immediately before using
Pilocarpine hydrochloride, 1%, 4%	Cholinergic, constricts pupil, used topically for lowering intraocular pressure in glaucoma
TOPICAL ANESTHETICS	
Tetracaine hydrochloride (Pontocaine), 0.5%	*Onset:* 5-20 sec; *duration of action:* 10-20 min
Proparacaine hydrochloride (Ophthaine), 0.5%	*Onset:* 5-20 sec; *duration of action:* 10-20 min
INJECTABLE ANESTHETICS	
Lidocaine (Xylocaine), Lidocaine MPF,* 1%, 2%, 4%	*Onset:* 4-6 min; *duration of action:* 40-60 min, 120 min with epinephrine; MPF solution is preservative free
Bupivacaine (Marcaine, Sensorcaine), Bupivicane MPF, 0.25%, 0.50%, 0.75%	*Onset:* 5-11 min; *duration of action:* 480-720 min with epinephrine; often used in 0.75% combination with lidocaine for blocks; MPF solution is preservative free
Mepivacaine (Carbocaine), 1%, 2%	*Onset:* 3-5 min; *duration of action:* 120 min; duration of action greater with epinephrine
Etidocaine (Duranest), 1%	*Onset:* 3 min; *duration of action:* 300-600 min
ADDITIVES TO LOCAL ANESTHETICS	
Epinephrine 1:50,000-1:200,000	Combined with injectable local anesthetics to prolong anesthesia and reduce bleeding
Hyaluronidase	Enzyme mixed with anesthetics (75 units/10 ml) to increase diffusion of anesthetic through tissue, improving effectiveness of block; contraindicated if skin inflammation or malignancy present
VISCOELASTICS	
Sodium hyaluronate (Healon, Amvisc, Provisc, Vitrax) in a sterile syringe assembly with blunt-tipped cannula	Lubricant and support; maintains separation between tissues to protect endothelium and maintain anterior chamber intraocularly; removed from anterior chamber to prevent postoperative increase in pressure; should be refrigerated (except Vitrax); allow 30 min to warm to room temperature
Sodium chondroitin/sodium hyaluronate (VisCoat) in a sterile syringe assembly with blunt-tipped cannula	Maintains a deep chamber for anterior segment procedures, protects epithelium of cornea, and enhances visualization; may be used to coat intraocular lens before implantation; should be refrigerated
DuoVisc	Packages of separate syringes of Provisc and VisCoat in same box
VISCOADHERENTS	
Hydroxypropyl methylcellulose 2% (Occucoat) in a sterile syringe assembly with blunt-tipped cannula	Maintains a deep chamber for anterior segment procedures, protects epithelium of cornea, and may be used to coat intraocular lens before implantation; removed from anterior chamber at end of procedure; stored at room temperature
Hydroxyethylcellulose (Gonioscopic Prism Solution); Hydroxypropyl methylcellulose 2.5% (Goniosol)	Used as coupling solution for gonioscopy; stored at room temperature

Continued

SURGICAL PHARMACOLOGY

Medications Used During Ophthalmic Surgery—cont'd

Drug/Name	Purpose/Description
IRRIGANTS	
Balanced salt solution (BSS, Endosol)	Used to keep cornea moist during surgery; also used as internal irrigant into anterior or posterior segment
Balanced salt solution enriched with bicarbonate, dextrose, and glutathione (BSS Plus, Endosol Extra)	Used as internal irrigant into anterior or posterior segment; need to reconstitute immediately before use by addition of part I to part II with transfer device
HYPEROSMOTIC AGENTS	
Mannitol (Osmitrol)	Intravenous osmotic diuretic; increases osmolarity of plasma, causing osmotic pressure gradient to pull free fluid from eye to plasma, and reduces intraocular pressure
Glycerin (Osmoglyn, Glyrol)	Oral osmotic diuretic given in chilled juice or cola; increases osmolarity of plasma, causing osmotic pressure gradient to pull free fluid from eye to plasma, and reduces intraocular pressure
ANTIINFLAMMATORY AGENTS	
Betamethasone sodium phosphate and betamethasone acetate suspension (Celestone)	Glucocorticoid; injected subconjunctivally after surgery for inflammation prophylaxis; also used to treat severe allergic and inflammatory conditions
Dexamethasone (Decadron)	Adrenocortical steroid; injected subconjunctivally after surgery for inflammation prophylaxis; also used to treat severe allergic and inflammatory conditions and intraocularly for endophthalmitis
Methylprednisolone acetate suspension (Depo-Medrol)	Glucocorticoid; injected subconjunctivally after surgery for inflammation prophylaxis; also used to treat severe allergic and inflammatory conditions
ANTIINFECTIVES	
Polymyxin B/bacitracin (Polysporin ointment)	Topical treatment of superficial ocular infections of conjunctiva or cornea; used prophylactically after surgery
Polymyxin B/neomycin/bacitracin (Neosporin ointment)	Topical treatment of superficial infections of external eye; used prophylactically after surgery; potential hypersensitivity to neomycin
Neomycin and polymyxin B sulfates and dexamethasone (Maxitrol ointment or suspension)	Topical treatment of steroid-responsive inflammatory ocular conditions or bacterial infections of external eye; potential hypersensitivity to neomycin
Tobramycin/dexamethasone (TobraDex)	Topical treatment or prevention of superficial infections of external part of eye; also has antiinflammatory properties
Cefazolin (Ancef, Kefzol)	Prophylactically injected subconjunctivally after procedure; also topically, intraocularly, and systemically for endophthalmitis
Gentamicin sulfate (Garamycin)	Prophylactically injected subconjunctivally after procedure; also topically, subconjunctivally, and intraocularly for endophthalmitis
Ceftazidime (Fortaz, Tazicef, Tazidime)	Injected subconjunctivally and intraocularly for treatment of endophthalmitis
MISCELLANEOUS	
Cocaine, 1%-4%	Topical use, never injected; used on cornea to loosen epithelium before debridement and on nasal packing to reduce congestion of mucosa
5-Fluorouracil (5-FU)	Antimetabolite used topically to inhibit scar formation in glaucoma-filtering procedures; handle and discard in compliance with Occupational Safety and Health Administration (OSHA) and facility policies for safe use of antineoplastics
Mitomycin (Mutamycin)	Antimetabolite used topically to inhibit scar formation in glaucoma-filtering procedures and pterygium excision; handle and discard in compliance with OSHA and facility policies for safe use of antineoplastics
Tissue plasminogen activator (TPA) (Activase)	Thrombolytic agent; used to treat fibrin formation in postvitrectomy patients; lysis of clots on retina
Fluorescein	Yellowish-green fluorescence of this IV diagnostic aid is used in fluorescein angiography to diagnose retinal disorder; topical stain—fluorescein strip temporarily stains cornea yellow-green in areas of denuded corneal epithelium

SURGICAL PHARMACOLOGY

Medications Used During Ophthalmic Surgery—cont'd

Drug/Name	Purpose/Description
Timolol maleate (Timoptic)	Beta-adrenergic receptor blocking agent; treatment of elevated intraocular pressure in ocular hypertension or open-angle glaucoma
Acetazolamide sodium (Diamox)	Carbonic anhydrase inhibitor; given IV to decrease secretion of aqueous humor and results in a drop in intraocular pressure; diuretic effect

**MPF,* Methylparaben free.
Modified from Hodgson BB, Kizior RJ: *Saunders nursing handbook 2009,* St Louis, 2009, Saunders; Epocrates online, available at https://online.epocrates.com. Accessed May 28, 2009.

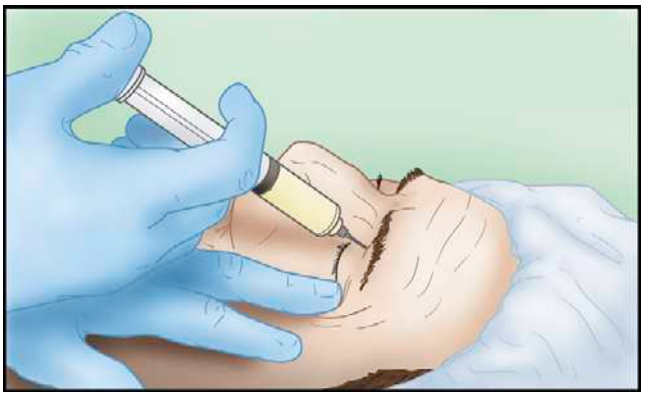


FIGURE 17-10 Peribulbar block.

is instilled into the eye and may be supplemented with infiltration of preservative-free anesthetic into the anterior chamber. Selection of patients for the topical method requires that they can cooperate and follow verbal commands to keep their eyes open and look up or down. Conditions that render the patient a poor candidate for topical anesthesia include inability to tolerate eyedrops, Alzheimer's disease, extreme anxiety, and communication problems (e.g., language barriers, hearing impairment, auditory aphasia).

The *infiltration method* involves the surgeon injecting the anesthetic solution beneath the skin, beneath the conjunctiva (subconjunctival), or into Tenon's capsule, depending on the type of surgery.

The most common technique for regional anesthesia in eye surgery is a *peribulbar block*. The anesthetic is injected around the soft tissue of the globe after the needle is directed to the floor (inferior) or roof (superior) of the orbit (Figure 17-10).

Retrobulbar block is injection of anesthetic solution into the base of the eyelids at the level of the orbital margins or behind the eyeball to block the ciliary ganglion and nerves (Figure 17-11). The surgeon administers the retrobulbar injection 10 to 15 minutes before surgery to produce temporary paralysis of the extraocular muscles. Since the tip of the needle cannot be visualized, training and experience are key. Potential complications of retrobulbar injection are brainstem anesthesia and death, oculocardiac reflex, perforation of the globe, and retrobulbar hemorrhage (Bollinger and Langston, 2008). Additional risks include ptosis, conjunctival or eyelid bruising, optic nerve damage, and central vein and artery occlusion.

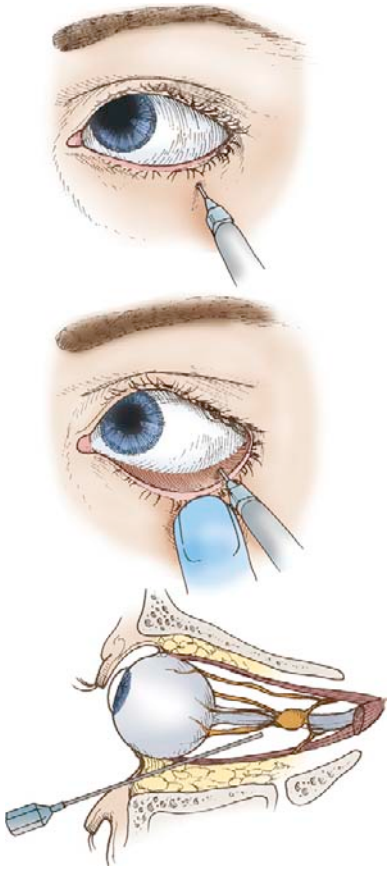


FIGURE 17-11 Retrobulbar block.

A systematic review found no evidence of difference in pain perception in surgery with retrobulbar or peribulbar anesthesia; both were largely effective. Similarly, the review found no evidence of difference in complete akinesia or need for further injections of the local anesthetic. Retrobulbar hemorrhage was uncommon; severe local or systemic complications were rare in both approaches. Overall, retrobulbar and peribulbar anesthesia were found to be equal in efficacy and safety, including acceptability to patients (Alhassan et al, 2008).

For eyelid repairs, the surgeon injects the solution through the upper or lower lid. For operations on the lacrimal apparatus, the anesthetic is injected at the level of the anterior ethmoidal

foramen to anesthetize the internal and external nasal nerves. Injection of local anesthetic into the lateral adipose compartment from an inferior temporal needle insertion blocks the nasociliary, lacrimal, frontal, supraorbital, and supratrochlear branches of the ophthalmic division of the trigeminal nerve and infraorbital branch of the maxillary division; this may be used before retrobulbar block.

Positioning. Positioning the patient for ophthalmic surgery generally requires additional devices for stabilizing the head, protecting bony prominences, and providing appropriate alignment to prevent peripheral neurovascular injury. The ophthalmology stretcher, which is a combination transport device and OR bed, is often used for convenience and comfort as the surgical bed. This special bed, with a tapered head end, allows for closer access to the patient's face and eliminates several transfers for the patient. The perioperative nurse positions the patient with a foam donut or headrest under the head and a pillow under the knees. The nurse tucks the patient's arms at the side, padding the elbows to protect the ulnar nerve, facing the palms inward and maintaining the wrists in a neutral position (Denholm, 2009). A drape secures the arms. It should be tucked snuggly under the patient, not under the mattress. This prevents the arm from shifting downward intraoperatively and resting against the OR bed rail.

If patients are to be sedated, the nurse asks if they are comfortable and offers reassurance that there are ways to increase comfort. Some elderly patients prefer not to discuss their discomfort for fear of being bothersome.

Intraocular surgery is usually carried out with the use of a microscope. A special wrist rest may be used to stabilize the surgeon's hands and may include a perforated tubing or bar to provide oxygen under the drapes. The nurse should attach it to the bed and secure it approximately 2.5 cm below the patient's lateral canthus before draping. The wrist rest may be placed unilaterally or may encircle the head. A strip of tape may be placed over the patient's forehead (avoiding the eyebrows) and secured to the operative bed to stabilize the head.

Prepping. The operative site is prepped under aseptic conditions, usually after the anesthetic is administered. A sterile prep tray commonly contains sterile normal saline solution, irrigation bulb, basins, gauze sponges, cotton-tipped applicators, towels, and antimicrobial skin disinfectant.

Some surgeons order one or two drops of 5% povidone-iodine solution administered to the eye surface before the prep of the face and eyelids to decrease the number of surface microbes. Unless the patient has been administered a general anesthetic, a topical anesthetic drop is placed to minimize the stinging sensation. Povidone-iodine solution may be contraindicated in patients with allergic reactions to *topical* iodine. For these patients, hexachlorophene can be used as the agent for the facial prep; however, it is not applied directly to the ocular surface because of its surface toxicity.

The nurse cleans the patient's lid margins by everting the lids and cleaning with cotton-tipped applicators moistened with antimicrobial skin disinfectant, taking care to prevent the solution from entering the patient's ears. The eye or eyes may be then irrigated with normal saline solution using an irrigating bulb. When toxic chemicals or small particles of foreign matter must be removed, the eye surface and conjunctival sac are thoroughly flushed with tepid sterile normal saline solution using an irrigation bulb or an Asepto syringe. The nurse dries the prep area so the drape will adhere.

Draping. Special concerns for eye surgery draping include repelling water, eliminating lint and fiber particles, and providing adequate air exchange for patients receiving local anesthetics. A cardboard bridge that adheres to the sides of the patient's face may be used to support the drape above the patient's mouth and nose. The surgeon may request that the nurse place a Mayo stand above the patient before the draping process to provide a platform to decrease the weight of the drapes and surgical handpieces/tubing on the patient. The use of a one-piece disposable drape, with a self-adherent, fenestrated plastic section for the eye, eliminates the need to lift the patient's head during draping and facilitates drape removal at the end of the procedure. The eyelids may be separated when applying the self-adherent plastic eye drape to keep the eyelashes out of the operative eye. A fluid drainage bag with wicking strip may also be adhered to the plastic eye drape.

In an alternative method, the surgeon may drape the head with a half-sheet and two towels, use a large sheet or U-drape/split sheet to cover the patient and OR bed, and place a fenestrated plastic eye drape over the operative site.

Instrumentation. Basic eye instruments are shown in Figure 17-12. Additional instruments, depending on the type of procedure, can be added to the basic instrument set. Special surface finishes are used to reduce light reflection. Instruments are designed with round handles for smoother motion and rotation under the microscope. The instruments to be placed on the Mayo stand and the order of their use can also be listed on the preference card or computerized picklist.

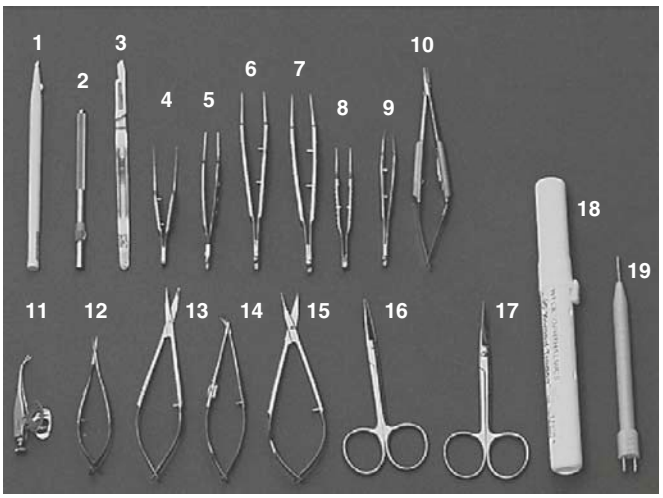


FIGURE 17-12 Basic eye instrument setup. *1,* Super blade (disposable); *2,* Beaver knife handle; *3,* #9 Bard-Parker knife handle; *4,* Colibri corneal forceps; *5,* Bishop-Harmon suturing forceps; *6,* Castroviejo suturing forceps, 0.5 mm; *7,* Castroviejo suturing forceps, 0.12 mm; *8,* Castroviejo tying forceps; *9,* Kelman-McPherson suturing forceps; *10,* Harper needle holder; *11,* Barraquer iris scissors; *12,* Vannas iridocapsulotomy scissors; *13,* Westcott tenotomy scissors; *14,* Castroviejo corneal scissors; *15,* Westcott stitch scissors; *16,* Knapp strabismus scissors; *17,* iris scissors; *18,* eye electrosurgical unit, disposable; *19,* bipolar eraser-tip eye electrosurgical unit, disposable.

A variety of ophthalmic forceps are designed for specific use with different tissues of the eye. Fixation forceps, used to hold tissue firmly in place or provide traction before incision, have an angled tooth that overlaps for secure fixation. Suturing forceps, used to pick up wound edges for dissection or suturing, are single-toothed forceps with the tooth at a right angle to the shank of the forceps. Tying forceps have a flat platform for holding suture as it is tied. The tips of the most commonly used forceps are illustrated in Figure 17-13.

CARE AND HANDLING. To maintain the quality and precision of all ophthalmic instruments, including microsurgical instruments, strict criteria for care and handling must be followed. Storage cases protect instrument tips and cutting surfaces. The instruments should be inspected under magnification when purchased and before and after each use, observing for burrs on tips, nicks on cutting surfaces, and alignment of jaws. Eye instruments should be cleaned during use with nonfibrous sponges to avoid damaging delicate instrument tips. Personnel handling instruments should know the name and purpose of each instrument. Tissue can be damaged by the use of an inappropriate instrument, and instruments can be damaged by inappropriate use. After use, the instruments should be cleaned, thoroughly dried, and terminally sterilized before storage in protective containers. A broader and more rigorous look at the entire flash sterilization process—from cleaning, decontaminating, and sterilizing to transporting—is found in The Joint Commission's focus on optimal patient outcomes. This coincides with the *AORN Perioperative Standards and Recommended Practices* (AORN, 2009) in that "flashing or abbreviated cycles should not be performed for convenience, as an alternative to purchasing additional instrument sets or to save time" (Mitchell, 2009).

It is recommended that microsurgical instruments undergo ultrasonic cleaning with distilled water and an appropriate enzymatic cleansing agent. They can be individually handheld or immersed together in the ultrasonic cleaner as long as they are not touching each other. Instruments should be rinsed with distilled water and thoroughly dried. A hot air blower (never a towel) should be used for drying instruments. Instrument lubricant should not be used on irrigating cannulae because residue can be introduced into the eye and cause damage (Risk Reduction Strategies).

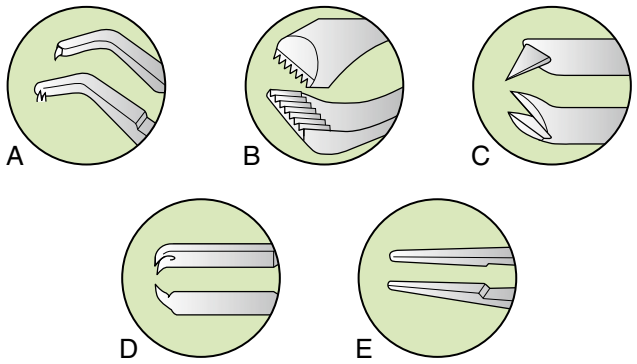


FIGURE 17-13 Close-up of tips of micro instruments used in phacoemulsification procedures and for inserting intraocular lenses (IOLs). **A**, Colibri forceps. **B** and **C**, Fixation forceps. **D**, Suturing forceps. **E**, Tying forceps.

In addition to basic care and handling, a routine preventive maintenance program should be established for sharpening, realigning, and adjusting the precision eye instruments. Keeping an instrument in good repair is much less expensive than buying a new one. Disposable instruments (Figure 17-14) are becoming popular with surgeons because of accessibility and quality assurance; for example, forceps are properly aligned for each use because they have not been used on other procedures. Benefits for the institution include elimination of costs related to repairs. Knives are available that have safety features of retractable blades to be in compliance with the Needlestick Safety and Prevention Act, requiring implementation of safer medical devices to minimize occupational exposure to bloodborne pathogens from accidental sharps injuries, which remains a serious problem (Harris, 2008).

RANGE OF EQUIPMENT USED. A wide range of equipment is used in ophthalmic surgery. The perioperative team's knowledge of proper functioning and troubleshooting should be confirmed through inservice education and training specific to new equipment. For safety, all items must be used according to the manufacturer's directions and tested for proper performance before the patient enters the OR. Although the products and manufacturers may vary, the following are some of the typical pieces of equipment and accessories used in ophthalmic surgeries:

- *Phacoemulsification machines:* Similar to the action of a jackhammer, these machines use ultrasound to break up the cataract. Irrigation and aspiration ("I&A") handpieces are used as well. Bipolar electrosurgical unit (ESU) and anterior vitrectomy handpieces may also be attached when needed. The surgeon controls the foot pedal and chooses one of the following modes by depressing the pedal to a certain position: irrigation alone; irrigation and aspiration; and irrigation, aspiration, and phacoemulsification combined. Some machines also have an anterior vitrector. As the surgeon manipulates the handpiece and operates the foot pedal to emulsify the lens nucleus, the perioperative nurse is responsible for monitoring the function of the instrument and operating the console controls to change settings such as irrigation bottle height. Displays may show cumulative density of energy and other settings, even video input of the procedure.
- *Posterior vitrectomy machines:* Functions on these machines may include vitrectomy with cutter handpieces for removal of vitreous; extrusion for gentle aspiration near sensitive retina and macula; oil infusion; bipolar electrosurgery/diathermy;

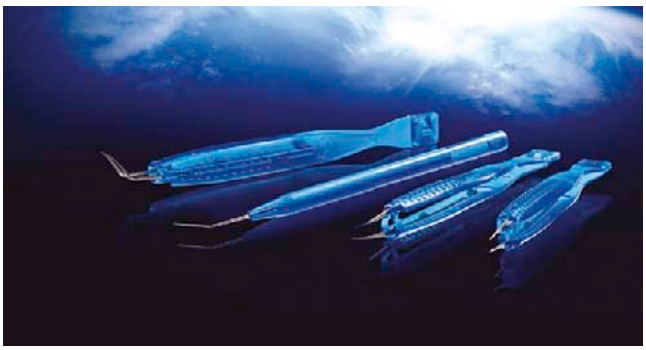


FIGURE 17-14 Disposable ophthalmic (cataract) instruments.

RISK REDUCTION STRATEGIES

Prevention of Toxic Anterior Segment Syndrome

Toxic anterior segment syndrome (TASS), also known as sterile endophthalmitis, is a sterile noninfectious form of acute inflammation that occurs after eye surgery (typically cataract surgery). The onset of the syndrome typically begins within 24 hours after surgery and is characterized by decreased vision, significant corneal edema, and moderate to severe inflammation in the anterior chamber of the eye. Patients may report blurred vision, eye pain, and eye redness. The cornea is most often affected by TASS because the corneal epithelium is the most sensitive tissue in the anterior chamber. Complications of TASS may include permanent iris damage, in which the pupil does not dilate or constrict appropriately, or ocular hypertension or glaucoma. Overall, TASS can be a very serious and sight-threatening condition.

TASS is thought to be a response to the introduction of a noninfectious, toxic substance into the anterior segment of the eye during surgery. Substances that have been implicated include irrigating solutions and other agents such as anesthetics and antibiotics. TASS may also be related to the improper cleaning or sterilization of instruments.

The perioperative nurse plays a key role in implementing risk reduction strategies for TASS, not only in prevention through the vigilant implementation of recommended practices for the use, cleaning, disinfection, and sterilization of equipment and instrumentation, but also in the provision of effective patient education. Timing is critical with TASS, and treatment must be initiated quickly to prevent permanent damage; therefore the perioperative nurse must ensure that discharge instructions for the patient include a directive to contact the surgeon immediately at the first indication of visual disturbance, no matter how mild.

Members of professional organizations (including cataract surgeons and ophthalmic and surgical nurses), infection control personnel, manufacturers of cataract surgical instruments, the Centers for Disease Control and Prevention (CDC), and the U.S. Food and Drug Administration have provided the following recommendations for the prevention of TASS:

- Basic principles for cleaning and sterilization must be followed to prevent TASS.
- Manufacturer directions for use should be followed. For example, directions for use of many intraocular instruments require or recommend sterile distilled or sterile deionized water for most cleaning steps. Sterile distilled or sterile deionized water is required for final rinsing. Rinsing serves the purpose of removing all cleaning solutions along with debris loosened during the cleaning process. (NOTE: Agitation in a basin of water is not considered a final rinse.)
- Manufacturer recommendations for sterilizer maintenance must be followed.
- All steps of cleaning and sterilization should be completed; adequate time should be allotted for the task.
- Sufficient numbers of instrument sets (including phacoemulsification, irrigation and aspiration handpieces, and lens inserters) should be available to allow sufficient time for cleaning and sterilization between procedures.
- Precise measurements of water and detergent should be used in mixing cleaning solutions.
- Disposable cannulae and tubing should be used if possible and discarded after use.
- Instruments used in the eye should be cleaned separately from nonophthalmic surgical instruments.
- Ultrasonic cleaning machines must be emptied, cleaned, disinfected, rinsed, and dried daily at minimum, but preferably after each use.
- Cleaning tools (e.g., syringes, brushes) should be discarded after each use.
- Cleaning solutions should be discarded after each use.
- Rinse water flushed through an instrument should be discarded and not reused.
- Only lint-free materials should be used in cleaning/drying and on the sterile field.
- Surgeons should check instruments under the microscope before use and reject any with notable debris or defect.
- The minimum interval for verifying quality of water used in a facility's steam sterilizing system is yearly.
- Staff involved in the cleaning and sterilization process of ophthalmic instruments should undergo competency testing and performance evaluation through direct observation and with a competency checklist so that all staff are evaluated consistently.
- Each healthcare facility should develop and write specific procedures for instrument cleaning and sterilization.

Modified from American Society of Cataract and Refractive Surgery, Ad Hoc Task Force on Cleaning and Sterilization of Intraocular Instruments: *ASCRS, ASORN Special Report: Recommended practices for cleaning and sterilizing intraocular surgical instruments,* Fairfax, Va, 2007, Author; Conner RL: Clinical issues: Toxic anterior segment syndrome, *AORN J* 84(5):841-844, 2006; Forster DJ: Phacogenic uveitis. In Yanoff M, Duker JS, editors: *Yanoff & Duker: Ophthalmology,* ed 4, St Louis, 2008, Mosby; Johnston J: Toxic anterior segment syndrome—more than sterility meets the eye, *AORN J* 84(6):969-984, 2006.

and motorized cutting with electric scissors attachment. Foot pedal or manual control can set eye pressure and cut and suction rates.

- *Cryotherapy machine:* The cryotherapy machine is generally used to cause an inflammatory reaction in the retinal tissue that seals a break or tear. The unit uses nitrous oxide as the freezing agent. Adequate pressure settings are needed for acceptable levels of freeze. Either external or intraocular handpieces are available.
- *Lasers:* Lasers are used for various applications in eye procedures, whether for clearing an opacified posterior capsule after cataract surgery, for reshaping or creating a flap of the cornea, or for direct use inside the eye during posterior vitrectomy. Settings must be confirmed with the surgeon. All persons present in the OR when the laser is in use must wear appropriate protective eyewear according to the laser's wavelength. Warning signs are posted on doors and windows are covered to avoid scatter outside the room.
- *ESU units:* Bipolar or monopolar ESU may be used. The return electrode monitor placement must follow manufacturer guidelines. Fire precautions must be observed, especially in the presence of oxygen.
- *Operating microscope:* Proper care and maintenance of the operating microscope are essential to ensure optimal functioning and durability of this sophisticated, expensive piece of equipment typically used for intraocular procedures (Figure 17-15). The perioperative nurse must be familiar with how to adjust pupillary distance (PD—distance between pupils

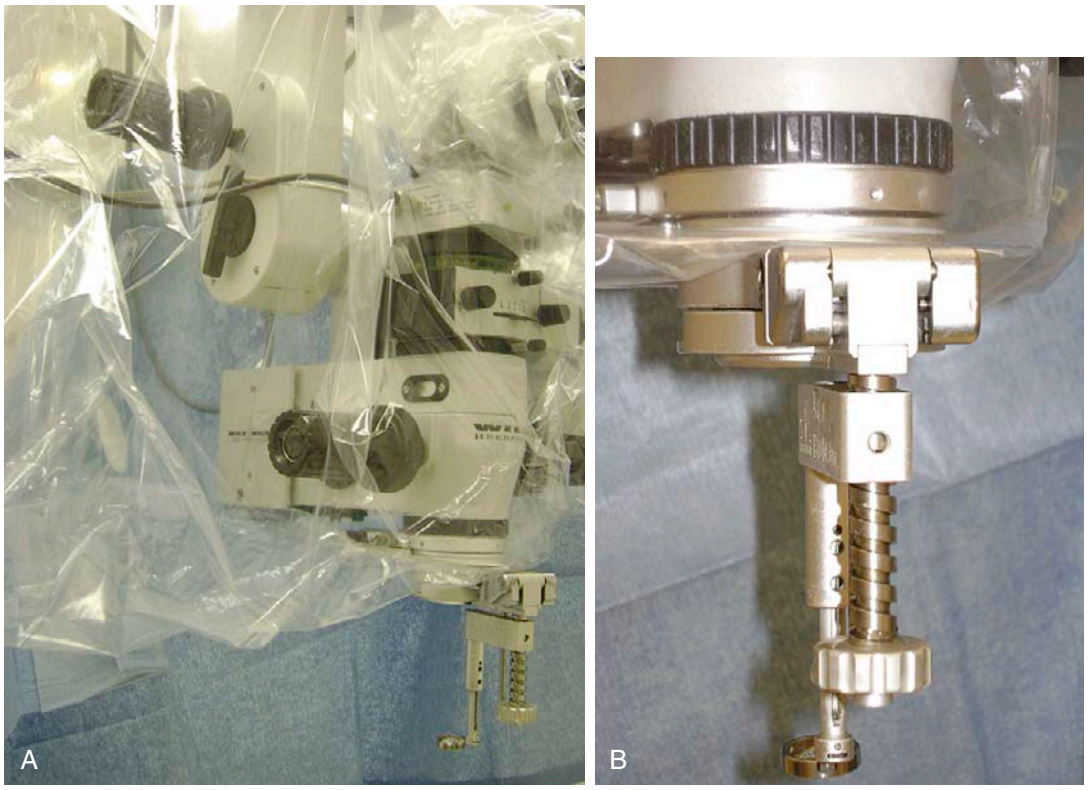


FIGURE 17-15 **A**, Draped microscope with attachment for wide-angle view inside the eye. **B**, Close-up of wide-angle attachment that can swing out of the way to use contact lens on eye.

FIGURE 17-16 Oculars of microscope set for surgeon's pupillary distance and diopter adjustments for clear viewing.

of the user's eyes) and diopter settings on the oculars (eyepieces) for operator vision correction to work without eyeglasses (Figure 17-16). Users who have astigmatism should wear their eyeglasses and set the oculars at zero. Some microscopes used for other applications such as plastic surgery may utilize light sources that are so bright they can damage the retina. The nurse must ensure that the microscope used in ophthalmic surgery is specifically intended and safe for use in eye surgery.

FIGURE 17-17 A patient wearing a protective eye patch.

Ophthalmic Sutures. Sutures used in ophthalmic surgery are very fine and range in size from 4-0 to 10-0. Handling and arming these sutures can be a challenge for the perioperative nurse with uncorrected presbyopia. Fine eye sutures produce minimum reaction and discomfort for the patient. They should be handled as little as possible to avoid weakening and fraying. Ophthalmic needles also are very delicate and must be handled with extreme care and inspected for evidence of burrs before use.

Ophthalmic Dressings. At the completion of the operation, the operative eye area is cleansed with saline sponges. After plastic procedures on the lids or lacrimal ducts, antibiotic

ointment may be thinly spread over the skin and eyelashes to prevent adhesion of the bandage.

The initial dressing is a sterile eye pad secured with nonallergenic tape (Figure 17-17). After intraocular operations, when external pressure on the eyes might be harmful, the initial dressing is covered with a protecting, perforated aluminum plate or plastic eye shield. Postcataract dressings range from traditional eye pads, to collagen corneal shields rehydrated in an antiinfective-antiinflammatory solution, to no dressing at all. A pressure bandage, consisting of a folded eye patch covered with a second single-layer eye patch, may be used when a compression effect is desired.

Evaluation

The nurse evaluates the patient's general condition before transport to the postanesthesia care unit (PACU) or observation unit. The general appearance of the skin is assessed, with areas around the face and bony prominences noted for redness or other changes from the preoperative condition.

A hand-off report to the receiving nurse in the PACU or observation area should include postoperative positioning requirements, potential problems specific to the patient, and preoperative anxiety level and use of coping mechanisms. Eye patching may produce disturbed sensory perception.

Evaluation should address whether the patient met the desired perioperative nursing outcomes; the patient's responses may be documented as outcome statements. The following examples are based on the nursing diagnoses identified in the plan of care:

- The patient, family, or significant others verbalized knowledge regarding the diagnosis, planned intervention, medication management, and requirements for home care maintenance.
- The patient verbalized an acceptable level of anxiety and used coping mechanisms that were effective.
- The patient safely adapted to visually disturbed sensory perception.
- The patient remained comfortable during the intervention as determined by pain scale response.
- The patient will remain free from signs and symptoms of surgical site infection.

Patient and Family Education and Discharge Planning

Patient education is one of the nurse's greatest contributions. Some facilities have programs with group teaching for patients; in other settings, education is provided individually. Depending on the setting, the nursing role in patient education may include review of preoperative expectations, individual patient needs, surgeon's instructions, cataract procedure, intraocular lens (IOL) choices, and cataract surgery explanations and overview of the surgery experience (Burlew-Quartey, 2008).

Implementation of the plan of care actually begins during the patient interview. Planning to meet the patient's educational needs should play an equal role with meeting other needs. Verbal review and reinforcement of information initially provided in the physician's office ensures consistency in teaching. Written material and audiovisual media (closed circuit television, videocassettes, photos, and patient information websites) may be used to enhance patient education programs but do not eliminate the need for direct interchange with patients and feedback from them.

Family members or friends should be included to add support and increase understanding of the planned surgery. The loss of sight produces the same staged coping behaviors of grieving that move the individual from denial to acceptance. Thorough preoperative preparation of the patient and in most cases the family, who will assist with care at home in the postoperative period (Patient and Family Education), plays a vital role in the successful outcome of the surgical procedure.

Patient and family education for the patient undergoing ophthalmic surgery should include the following:

- Purpose and desired results of preoperative eyedrops and sedation
- Explanation of what to expect from the anesthetic
- Activities and routines of the intraoperative period
- What to expect immediately after surgery
- Designated driver after procedures using sedation
- Verbal and written instructions for use of eyedrops and other medications
- Any limitations on activities (bending, lifting, eye rubbing, special positioning)
- Wound care, protective sunglasses
- Signs and symptoms of complications
- Follow-up postoperative phone calls from the ambulatory surgery center, as applicable
- Who to call with questions or concerns
- Follow-up appointments

See the Patient and Family Education box for additional examples of instructions specific to cataract surgery. The National Quality Forum describes truly high-quality care as also culturally competent care. Provision of culturally appropriate care can increase efficiency and improve patient satisfaction besides improving outcomes. One of the guidelines that NQF developed suggests translating written materials into languages that reflect the local community demographics (NQF, 2009).

Surgical Interventions

SURGERY OF THE GLOBE AND ORBIT

Surgery of the globe (eyeball) and orbit is usually performed because of trauma. Rupture of the eyeball may be direct at the site of injury or, more frequently, indirect from an increase in intraocular pressure that causes the wall of the eyeball to tear at weaker points, such as the limbus. When the intraocular contents have become so deranged that useful function is prohibited or the blind eye becomes painful, removal of the eye contents (evisceration procedure) or of the entire eyeball (enucleation) is indicated. If either procedure is required, an inert globe or a coralline hydroxyapatite (coral) implant may be inserted as a space filler and to aid in the movement of a prosthesis (artificial eye). Fractures of the orbit are discussed in Chapter 21.

Enucleation

Enucleation is removal of the entire eyeball, with the severing of its muscular attachments and optic nerve. This life-altering procedure is indicated for a blind, painful eye; intraocular tumors; and as a last resort after trauma (Dodge-Palomba, 2008). Usually, a round implant is inserted into the socket to replace the globe and provide support for a prosthetic eye.

PATIENT AND FAMILY EDUCATION

Discharge Instructions and Home Care after Cataract Surgery

HOME CARE

- Give both the patient and the caregiver *verbal* and *written* instructions. Provide them with the name and telephone number of a physician or nurse to call if questions arise.
- Advise the patient to avoid squeezing the eyelids shut or touching the eyes postoperatively; encourage elderly patients to wear glasses during the day to avoid rubbing the eyes.
- Review the signs and symptoms that should be reported to a physician or nurse such as:
  - Increased intraocular pressure: sudden onset of eye pain, photophobia, sudden decrease in vision, sudden severe headache
  - Infection: redness and watering of eyes, swelling, blurred vision, pain
- Special instructions
  - Discuss the need to wear an eye shield at night for 2 to 6 weeks to avoid eye injury.
  - Warn that depth perception may be lost and that 50% of peripheral vision will be lost because of the eye patch.
  - Review safety precautions, especially with elderly patients.
    - Instruct the patient to avoid falls by turning the head fully to the affected side to view objects.
    - Advise the patient to use up-and-down head movements to judge stairs and oncoming objects and to move slowly.
  - Discuss the need to wear dark glasses during the day to avoid pupil constriction and glare, since the eye is sensitive to light after surgery.
  - If the patient had cataract surgery without a lens implant, warn that vision will be diminished in one or both eyes until prescription eyeglasses or contact lenses are obtained (in about 4 to 8 weeks).
  - If the patient is receiving eyeglasses, explain that images will be magnified 30%, peripheral vision will be impaired and distorted, and lenses will be bifocal or trifocal. Review safety precautions.
    - Advise the patient to turn the head side-to-side to see peripherally.
    - Advise the patient to judge distances when descending stairs or viewing oncoming objects.
  - If the patient is receiving contact lenses, explain that images will be magnified 7% to 10%, peripheral vision will be intact, and reading glasses may also be prescribed.
  - Review the care, insertion, and removal of lenses. Advise the patient of the importance of routine appointments with the physician for removal, cleansing, and reinsertion of extended-wear lenses.
  - If the patient is receiving an intraocular lens implant, explain that the lens implant aids in focusing but that glasses will be prescribed for close vision in 8 to 12 weeks; there will be no loss in depth perception.
- Medications
  - Review the name, purpose, dosage, schedule, and route of administration of all prescribed drugs; the length of time to take the prescribed medication; and the side effects to report to a physician or nurse.
  - Review the correct procedure for instilling eyedrops and ointments and applying an eye shield (without touching or applying pressure on the eyeball) to avoid self-inflicted injury.
  - Advise the patient to avoid over-the-counter medications, eyedrops, or ointments without checking with the physician.
  - Encourage the patient to share the list of medications with all providers of care, including primary care and specialist physicians, nurses, pharmacists, and other caregivers.
- Activity
  - Explain the need to avoid activities that can increase intraocular pressure: heavy lifting, straining with elimination, bending over at the waist, coughing, vomiting.
  - Instruct the patient to take medications for nausea and constipation as ordered.
  - Instruct the patient to avoid sleeping on the operative side.
  - Explain the need to avoid any strenuous exercise for 6 weeks; tell the patient to check with the physician before resuming occupational or recreational activities.
  - Explain that it will be necessary to adjust to mild magnification when performing daily activities.

FOLLOW-UP CARE

- Stress the importance of regular follow-up visits. Make sure the patient has the necessary names and telephone numbers.

Modified from Canobbio MM: *Mosby's handbook of patient teaching,* St Louis, 2006, Mosby; Using medication reconciliation to prevent errors, *Joint Commission Sentinel Event Alert,* issue 35, January 23, 2006, available at www.jointcommission.org/sentinelevents/sentineleventalert/sea_35.htm. Accessed May 28, 2009.

Sphere implants may be coralline (hydroxyapatite) or synthetic though glass and silicone implants are still commonly used. Hydroxyapatite, a lightweight, coral-like material, may be used as the foundation for a prosthetic eye because its porous structure encourages fibrovascular ingrowth. The hydroxyapatite implant is wrapped in human donor sclera or Silastic sheeting before insertion into the orbital space. New porous polyethylene implants have the advantage of allowing the rectus muscles to be sutured directly to the implant, thus eliminating the wrapping and expense of donor sclera. Suturing rectus muscles to the orbital implant enables improved postoperative movement of the ocular prosthesis.

The patient typically consults with an ocularist 4 to 6 weeks after enucleation or evisceration surgery for a prosthetic eye. A temporary prosthesis may be inserted while a custom-made prosthesis is fabricated. Ocularists may belong to an international professional and educational organization for professionals who specialize in fabricating and fitting custom-made ocular prosthetics (artificial eyes). The American Society of Ocularists (ASO) promotes research in the development of

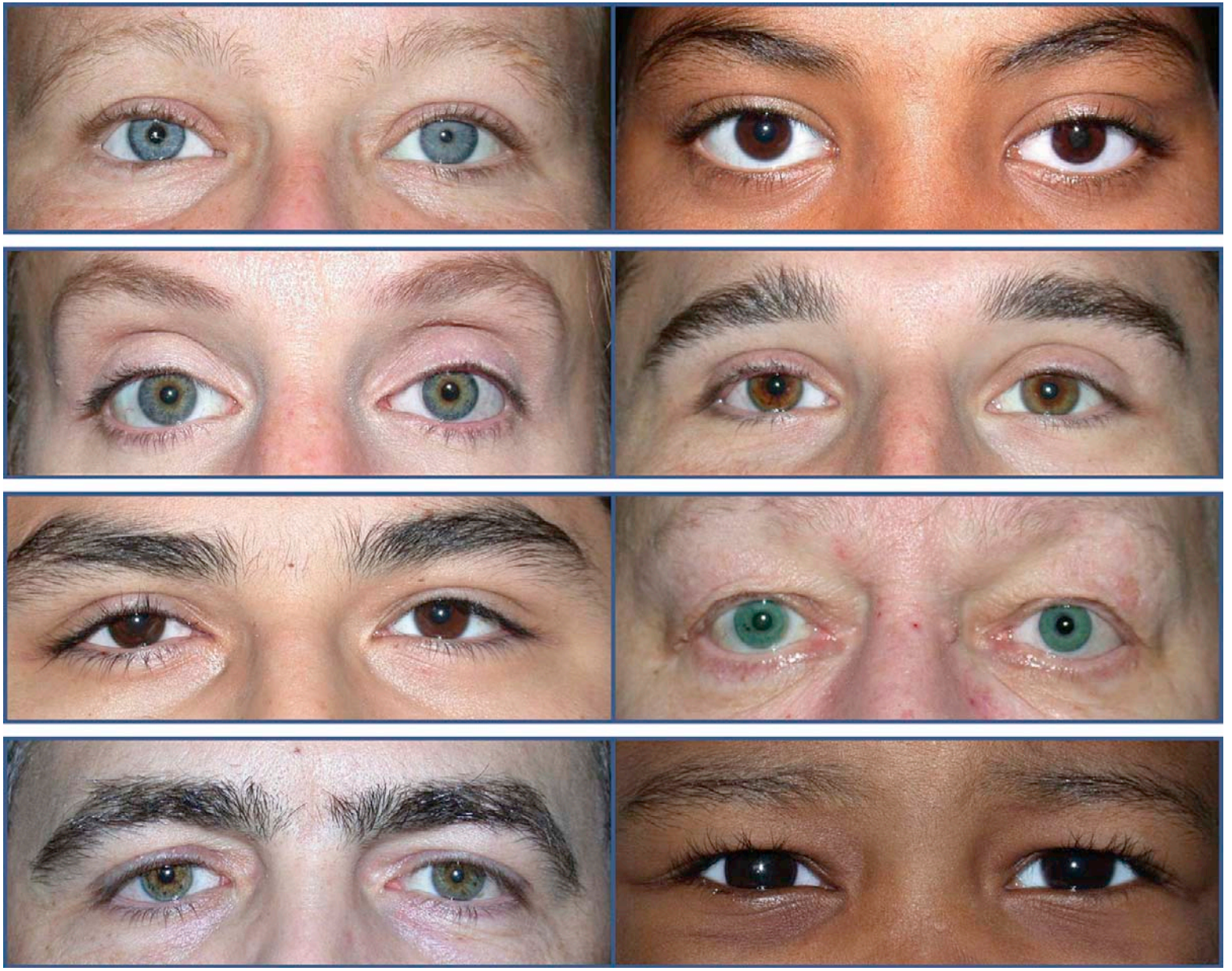


FIGURE 17-18 Patients who have an enucleation can have excellent cosmetic results when fitted with an ocular prosthesis designed by a board certified ocularist.

ophthalmic prosthetics and advancement of the methods, techniques, and skills of its members, thereby providing the public with continual improvements (ASO, 2009). Figure 17-18 provides examples of patients using ocular prostheses made by an ocularist certified by the National Examining Board of Ocularists. Medicare and most insurance companies in the United States provide benefits for prosthetic devices. Ready-made or mass-produced eyes are for short-term use (less than 3 months) only. After the prosthesis is created and fitted, the patient will follow up with the ocularist every 1 to 6 months to evaluate its size and to resurface (polish) the prosthesis to maintain the health of surrounding socket tissue. An appointment is warranted if the prosthesis becomes uncomfortable, feels rough to the touch, or changes in appearance, such as the lids appearing droopy or the eye turning in, out, up, or down (Nichols, 2009). The nurse should stress the importance of protecting the visually viable eye, such as using safety eyewear when participating in sports (Dodge-Palomba, 2008).

Operative Procedure

1. The surgeon places a speculum retractor into the palpebral fissure.
2. The conjunctiva is divided around the cornea with sharp and blunt dissection.
3. The medial, lateral, inferior, and superior rectus muscles are divided, leaving a stump of medial rectus muscle. If a coralline hydroxyapatite implant with donor sclera will be used, the four rectus muscles and two oblique muscles are identified and secured with 6-0 suture (to be used to reattach muscles to cut-out areas in donor sclera) before the muscles are disinserted. The two oblique muscles are similarly detached, but are often not subsequently secured to the orbital implant.
4. Using blunt-pointed curved scissors, retractors, hemostats, and forceps, the surgeon separates the globe from Tenon's capsule. The eye is rotated laterally by grasping the stump of the medial rectus muscle.
5. A large, curved hemostat is passed behind the globe, and the optic nerve is clamped for 60 seconds. The hemostat is removed, the enucleation scissors are passed posteriorly, and the optic nerve is transected. The oblique muscles are severed as the eye is lifted out of the socket by the stump of the medial rectus muscle.
6. Hemostasis is provided with either pressure via a sterile test tube or packing with saline-soaked sponges.
7. The muscle cone is filled with an implant, and the rectus muscles may then be sutured to the surface. Tenon's capsule and the conjunctiva are carefully closed over the implant in separate layers.
8. A plastic socket conformer is placed into the cul-de-sac.
9. A pressure dressing is applied.

Evisceration

Evisceration is removal of the contents of the eye, leaving the sclera and the attached muscles intact.

Operative Procedure

1. The conjunctiva is not separated from the sclera as it is for enucleation. A sharp-pointed knife is inserted through the limbus anterior to the iris.
2. The surgeon removes the contents of the eye (iris, vitreous, lens).
3. The choroid adhering to the sclera is removed with curettes.
4. Bleeding is controlled with delicate hemostatic forceps, electrocoagulation, and sutures.
5. A plastic or coral implant is placed within the empty shell.
6. Using nonabsorbable 4-0 or 5-0 sutures, the surgeon approximates the conjunctival and scleral edges.
7. A pressure dressing is applied.

Exenteration

Exenteration is removal of the entire orbital contents, including the periosteum, for certain malignancies of the globe or orbit. The procedure may also include removal of the external structures of the eyelids.

Procedural Considerations. General anesthesia is usually administered.

Operative Procedure

1. Depending on circumstances, exenteration of the eye may include the removal of the lids. An incision is made down to the orbital rim, through the periosteum, and around the entire orbit.
2. The surgeon frees the periosteum from the orbital walls and apex of the orbit with periosteal elevators.
3. The optic nerve is clamped, and the entire contents of the orbit are removed en bloc.
4. Hemostasis is obtained using the ESU and bone wax.
5. A skin graft or temporal muscle implant may be used to fill the orbital cavity or iodoform gauze is used to fill the cavity.
6. A pressure dressing is applied. The cavity is allowed to granulate.

SURGERY OF THE LACRIMAL GLAND AND APPARATUS

Surgery of the lacrimal gland is usually performed for treatment or diagnosis of tumors of the lacrimal fossa or to correct epiphora, which is abnormal overflow of tears related to a congenital or acquired obstruction of the lacrimal drainage system.

Surgery of the Lacrimal Fossa

Surgery of the lacrimal fossa is performed for biopsy of any structure in the lacrimal fossa.

Operative Procedure. The lacrimal fossa, which is in the upper temporal quadrant of the orbit, may be approached directly through the lid or through the conjunctiva by everting the upper lid. The lacrimal gland is divided into a palpebral and an orbital part by the orbital septum. Surgery on the palpebral portion may produce a dry eye.

Nasolacrimal Duct Procedures

Operative Procedure

SIMPLE PROBING

1. Using a punctual dilator the surgeon widens the tear duct opening along the medial aspect of the upper and lower eyelids.
2. A lacrimal probe (sizes vary from 00 to 4) is passed through the punctum, canaliculus, lacrimal sac, and nasolacrimal duct into the nasal cavity (under the middle meatus)

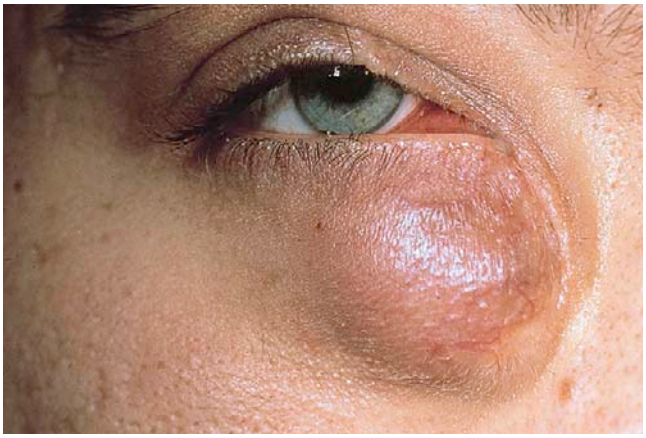


FIGURE 17-19 Chronic infection of lacrimal sac (dacryocystitis) causes swelling of inner lower corner of eye socket.

3. Adequacy of the duct opening is confirmed via metal-on-metal contact with the probe within the nasal cavity or via irrigation of fluorescein-tinged saline through the tear duct, aspirated in the nose.

PROBING WITH INTUBATION

1. After opening the duct as described in the previous procedure, the surgeon may place a Silastic tube or stent in one or both canaliculi to reduce the chance of postoperative reobstruction.
2. The surgeon threads the polyglactin leader on the stent through a stylet inserted in the punctum and retrieves it from the nasal cavity in the nose with a hook. Bicanalicular stents may employ a pliable metal rod attached to the Silastic tube. Such Crawford tubes require a special hook to engage the terminal bulb within the nose before removal.

Dacryocystorhinostomy

Dacryocystorhinostomy (DCR) is the establishment of a new tear passageway for drainage directly into the nasal cavity. The minimally invasive approach to DCR surgery includes the use of a transconjunctival incision, lasers, and endoscopic techniques.

Dacryocystitis (Figure 17-19) is an infection in the lacrimal sac, which may result in a localized cellulitis. Chronic or recurrent dacryocystitis in adults may necessitate probing or DCR because of resistant obstruction of the nasolacrimal duct related to infection-associated scarring, dacryolith (calculus in the duct), or trauma. Another indication for DCR surgery may be intolerable epiphora (tearing) resulting from tear duct laceration following medial orbital wall fracture.

Procedural Considerations. The nasal cavity is anesthetized topically with cocaine just before surgery. The surgery is performed after the patient has been administered a local or general anesthetic.

Operative Procedure

1. An external incision is made in the medial canthal area or inside the nose when an internal approach is used (Figure 17-20).
2. Blunt dissection is carried through the orbicularis down to the nasal bone. The orbicularis is separated from the bone with a Freer elevator. The lacrimal fossa sac is exposed.

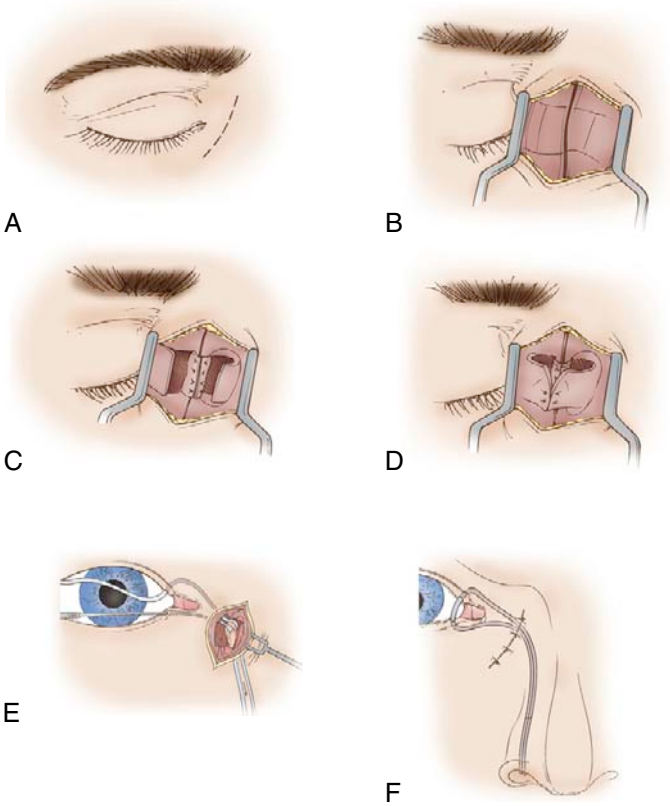


FIGURE 17-20 Dacryocystorhinostomy. **A**, Skin incision for dacryocystorhinostomy or dacryocystectomy. **B**, Lacrimal sac and lacrimal bone exposed. Opening made in lacrimal bone and lacrimal crest. **C**, Posterior flap of wall of sac sutured to posterior flap of nasal mucosa. **D**, Anterior flap of wall of sac sutured to anterior flap of nasal mucosa (drawing is somewhat distorted for visualization of relative positions). **E**, Canaliculi are intubated with Silastic tubes. **F**, Tubes are secured to lateral nasal wall and allowed to slide back into nose.

3. The surgeon uses a hemostat to press an opening through the lacrimal bone. If this is unsuccessful, the anterior lacrimal crest is perforated with a power burr or mallet and chisel. The opening is enlarged to a 10-mm circle with a Kerrison rongeur, and hemostasis is obtained with bone wax if necessary.
4. The inferior punctum is dilated, and a probe is passed into the lacrimal sac.
5. The lacrimal sac and nasal mucosa are incised with H flaps. The surgeon sutures the posterior nasal mucous membrane flap to the posterior lacrimal sac flap with 4-0 absorbable sutures.
6. The surgeon passes the first end of the wire stylet of a Silastic lacrimal duct intubation set through the upper canaliculus, through the opening, and out through the nose (under the inferior meatus). The procedure is repeated for the lower canaliculus.
7. The anterior nasal mucous membrane flap is sutured to the anterior lacrimal sac flap with 4-0 absorbable sutures to create a bridge over the Silastic tubing. The tubing remains in place until the sutures become absorbed, thereby acting as a stent around which epithelial union between the lacrimal and nasal mucosa can occur.

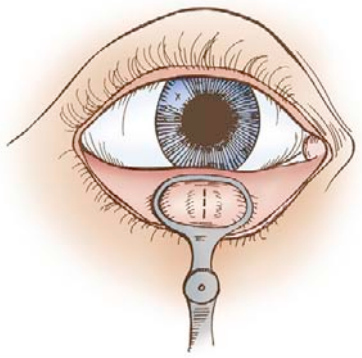


FIGURE 17-21 Transconjunctival approach. Clamp everts eyelid during surgery for chalazion. Viscous contents of chalazion will be removed with curette.

8. The orbicularis is closed with 6-0 absorbable sutures. Skin margins are approximated and closed with nonabsorbable 6-0 sutures. Antibiotic ointment is applied to the incision.
9. The surgeon cuts the wire stylets off the Silastic tubing, and ties the ends of the tubing together. The tubing is sutured to the lateral nasal wall with 6-0 nonabsorbable suture. The tubing is cut so that it retracts into the nostril. An absorbent sponge may be taped under the nostrils.

SURGERY OF THE EYELIDS

Oculoplastic procedures performed on the eyelids include treatment of chalazion, entropion, ectropion, dermatochalasis, and ptosis; biopsy and excision of eyelid tumors; and repair and reconstruction of eyelid trauma or post-biopsy damage.

Removal of Chalazion

Obstruction of meibomian gland secretion may lead to a chalazion, manifesting as a variably firm bump in the eyelid. Although chalazia can become infected, this is not primarily an infectious process. If persistent, incision of the chronic chalazion may be warranted.

Procedural Considerations. Incision of chalazion is often performed in an office setting, but pediatric and very anxious patients may require intravenous sedation. Local anesthesia, with 1:100,000 epinephrine in the local anesthetic, is usually employed. The majority of chalazia are surgically approached from the conjunctival side of the tarsal plate, but cutaneous incisions or repair of friable cutaneous tissue may be required (Figure 17-21).

Operative Procedure (Transconjunctival Approach)

1. Using a chalazion clamp, the surgeon everts the affected lid to expose the chalazion.
2. A vertical incision is made on the inner lid surface with a sharp blade; the small lesion is curetted, or the chalazion wall is excised, in part or in toto.
3. Hemostasis is achieved through use of the bipolar ESU.
4. The wound is left open for drainage. Cutaneous sutures are placed when needed. Pressure eye patching may be performed.

Repair of Entropion

Entropion occurs when the eyelid margin inverts. It may cause significant corneal irritation, attributable to rubbing of inturned eyelashes against the ocular surface. The most common type is *involutional entropion,* when laxity and degeneration of facial attachments between the pretarsal muscle and the tarsus permit the pretarsal muscle to override the lid margin during contraction. *Cicatricial entropion* is attributable to contraction of either the upper or the lower tarsus and its conjunctiva, causing inturned lashes (trichiasis) to abrade the cornea. Commonly employed surgical techniques for entropion repair include lateral tightening of a lax eyelid via either a *tarsal strip* procedure or a *pentagonal wedge resection,* and suture eversion (via either a *Wies* or a *Quickert suture technique*).

Procedural Considerations. The causes of entropion vary, and corrective procedures also vary depending on the pathologic process. Local anesthetic is typically used, and antiinfective ointment is applied postoperatively.

Operative Procedures

BLEPHAROPLASTY OF LOWER LID FOR INVOLUTIONAL ENTROPION

1. The surgeon injects local anesthetic into the lower lid through the conjunctiva using an angled needle.
2. The skin is marked, and an incision is made in the lateral canthus.
3. The orbicularis is dissected off the orbital septum.
4. The skin excision is extended across the lower lid.
5. The orbital septum is incised to expose fat pockets.
6. The surgeon removes extra fat, and hemostasis is achieved.
7. After incising the lateral canthus, the surgeon pulls the lower lid laterally and shortens (tightens) it to correct entropion.
8. The tarsus is reattached to the lateral canthal tendon, and the lower lid fascia is reattached to the orbicularis.
9. The excess skin is pulled up, marked, and excised.
10. The skin incisions are closed.

WIES PROCEDURE FOR CICATRICIAL ENTROPION

1. A marking pen is used to draw a parallel line 4 mm below the lower lid margin; the local anesthetic is then injected.
2. The surgeon places a double-armed 4-0 nonabsorbable retraction suture through the conjunctiva and lower lid 4 mm from the lateral canthus and 4 mm from the medial canthus.
3. A lid plate retractor is placed behind the lower lid as it is pulled up with the traction suture. The surgeon uses a #15 blade to make the skin incision on the marked line.
4. The lid plate retractor is placed in front of the lid, and the lower lid is everted using the traction suture. The conjunctiva is incised with the #15 blade.
5. A full-thickness blepharotomy is extended laterally and medially with scissors.
6. The surgeon passes one end of the double-armed 4-0 suture through the conjunctiva and lower lid tendons and between the orbicularis and tarsus on the medial aspect of the lower lid. This process is repeated approximately 4 mm laterally with the other end of the 4-0 suture.
7. Six mattress sutures are placed and tied to evert the lower lid (Figure 17-22).
8. Excess skin is excised, and the skin incision is closed with 7-0 nonabsorbable sutures.

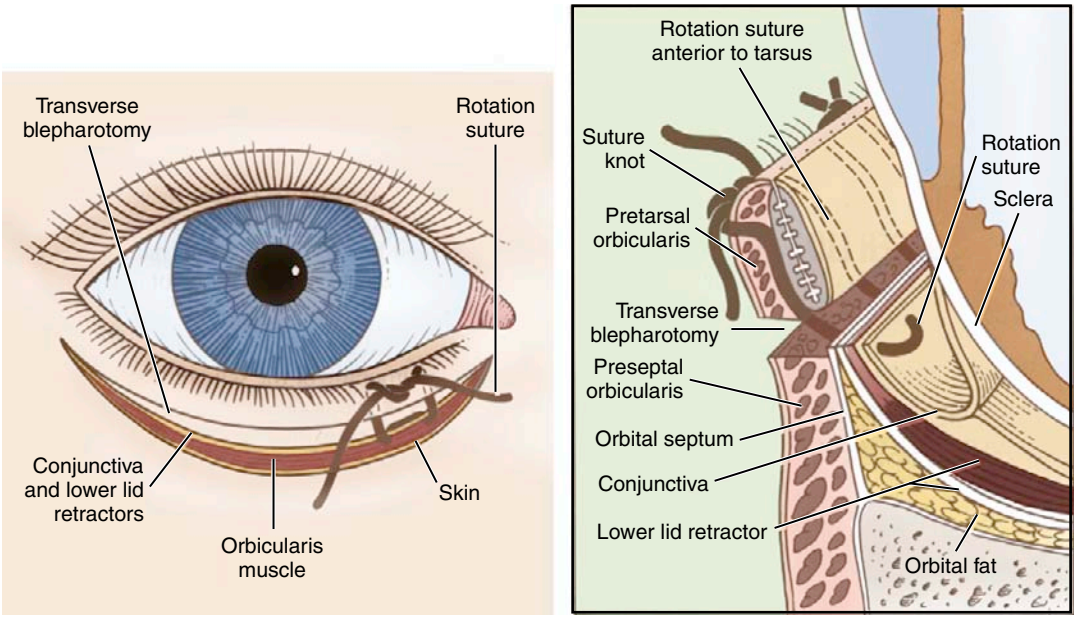


FIGURE 17-22 Wies procedure for entropion. Placement of an everting mattress suture across a transverse blepharotomy.

Repair of Ectropion

Ectropion (sagging and eversion of the lower lid), usually bilateral, is common in older persons (Figure 17-23). Ectropion may be caused by the relaxation of the orbicular muscle and canthal tendons. Symptoms include tearing, conjunctival infection, irritation, and inadequate corneal protection leading to injury to the cornea. Surgery is indicated when facial paralysis is permanent or when scarring follows lacerations, lesions, or penetrating injuries and the cornea becomes exposed, resulting in ulceration and photophobia.

Procedural Considerations. The causes of ectropion vary, and corrective procedures also vary depending on the pathologic process. Local anesthetic is typically used, and antiinfective ointment and ice compresses are applied postoperatively.

Operative Procedure

LATERAL CANTHAL SLING PROCEDURE

One method of correction for ectropion is the lateral canthal sling procedure (Figure 17-24), which repositions and tightens the lower lid in a horizontal direction.

1. The lateral canthus is incised, and a strip of tarsus and lateral canthal tendon is isolated.
2. The surgeon sutures the tarsus/tendon to the periosteum along the inner surface of the lateral wall of the orbit, thereby tightening the lid and correcting the ectropion.

Plastic Repair for Dermatochalasis

Dermatochalasis is a condition of drooping skin and herniated fat of the upper and lower lids that causes the skin of the upper eyelids to hang down over the palpebral fissure, sometimes obscuring vision. It may occur in older persons who have lost normal elasticity in the skin of their upper lids or in persons who have persistent angioneurotic edema with stretching of the skin of the eyelids. If ptosis is present, it accentuates the condition.

FIGURE 17-23 Ectropion, or eyelid eversion (turning out of lid), is most commonly caused by relaxation of eyelid framework.

Procedural Considerations. Dermatochalasis is corrected with blepharoplasty of the redundant skin of the upper or lower eyelids. A segment of skin and fat is removed. In the lower lid, a transconjunctival excision that leaves no external incision may be performed. Brow droop, or ptosis, may also be corrected alone or in combination with blepharoplasty to correct dermatochalasis. Procedures for correcting brow ptosis include direct brow lift, coronal brow lift, and endoscopic brow lift. Most procedures are performed using a local anesthetic with IV sedation.

Operative Procedure

BLEPHAROPLASTY OF UPPER LID FOR DERMATOCHALASIS

1. The surgeon marks the amount of skin to be excised in the upper lid above the lid crease and injects local anesthetic.
2. Stretching the skin of the upper lid tautly, the surgeon incises along the predrawn lines.

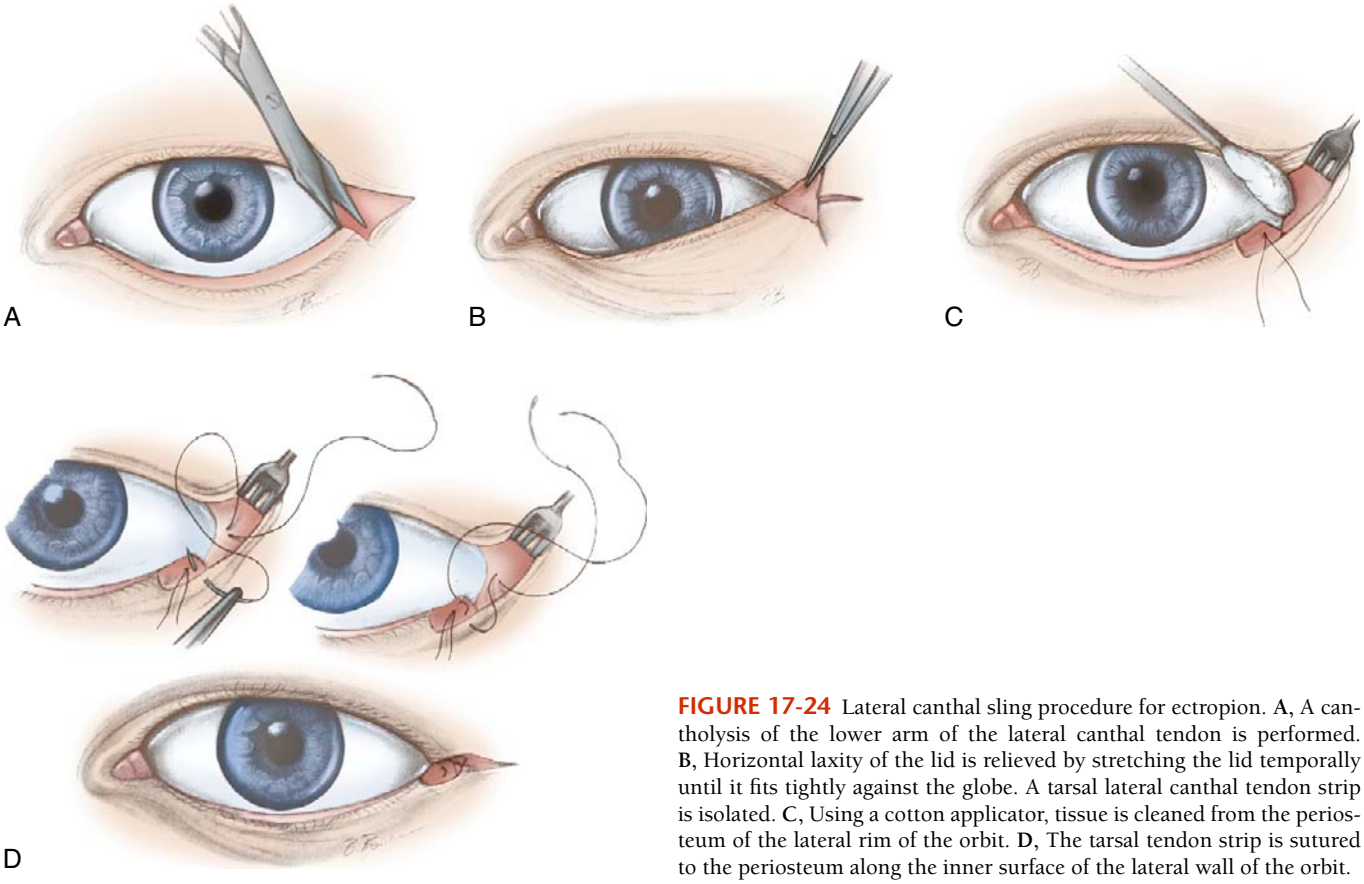


FIGURE 17-24 Lateral canthal sling procedure for ectropion. **A**, A cantholysis of the lower arm of the lateral canthal tendon is performed. **B**, Horizontal laxity of the lid is relieved by stretching the lid temporally until it fits tightly against the globe. A tarsal lateral canthal tendon strip is isolated. **C**, Using a cotton applicator, tissue is cleaned from the periosteum of the lateral rim of the orbit. **D**, The tarsal tendon strip is sutured to the periosteum along the inner surface of the lateral wall of the orbit.

3. The skin between the marked lines is excised, the orbicularis between the incision edges is excised, and hemostasis is achieved.
4. The surgeon incises the septum; applies finger pressure on the globe; and clamps, cuts, and electrocoagulates the bulging fat.
5. If fat is found in the temporal pocket, it may contain a prolapsed lacrimal gland. The lacrimal gland should be resuspended with 5-0 nonabsorbable suture.
6. The surgeon restores the lid crease by suturing the lower skin muscle incision line to the levator at the upper edge of the tarsus.
7. The skin is closed with 6-0 nonabsorbable suture in a continuous running fashion.

TRANSCONJUNCTIVAL BLEPHAROPLASTY OF LOWER LID

1. The surgeon injects local anesthetic into the lower lid through the conjunctiva using an angled needle.
2. Finger pressure is placed on the upper lid while the lower lid is being retracted to expose the conjunctiva of the inferior cul-de-sac.
3. The surgeon incises the conjunctiva and exposes the fat pockets. Prolapsed fat is clamped and removed, and hemostasis is achieved.

Surgery for Unilateral or Bilateral Ptosis

Ptosis is true drooping of the upper lid and may be congenital or acquired. In congenital ptosis there usually is developmental weakness of the levator muscle. The condition may be unilateral or bilateral. The child often compensates by raising the eyebrow or tilting the chin upward.

Acquired ptosis can be neurogenic, myogenic or involutional, which is manifested by a gradual stretching or dehiscence of the levator aponeurosis. The eyelid crease may be high or absent.

Procedural Considerations. The objective of ptosis surgery is to achieve a good cosmetic result, expand the superior visual field, and restore function with elevation of the lid. Many surgical procedures have been devised, directed at the levator aponeurosis, frontalis muscle, or the levator-Müller muscle complex. These muscles are the elevating forces of the upper lids. Local anesthesia may be preferred in cooperative individuals so that intraoperative adjustments can be made. Frontalis suspension uses fascia lata or synthetic materials to attach the tarsus to the frontalis, bypassing the ineffective levator muscle. Harvesting fascia lata requires an additional incision in the leg.

Operative Procedure

LEVATOR APONEUROSIS REPAIR

1. The surgeon marks the existing or potential eyelid crease. With the skin of the upper lid held taut, the skin incision is made (Figure 17-25).
2. An incision is made through the orbicularis. The surgeon dissects the orbicularis off the orbital septum and the levator aponeurosis anterior to the tarsus.

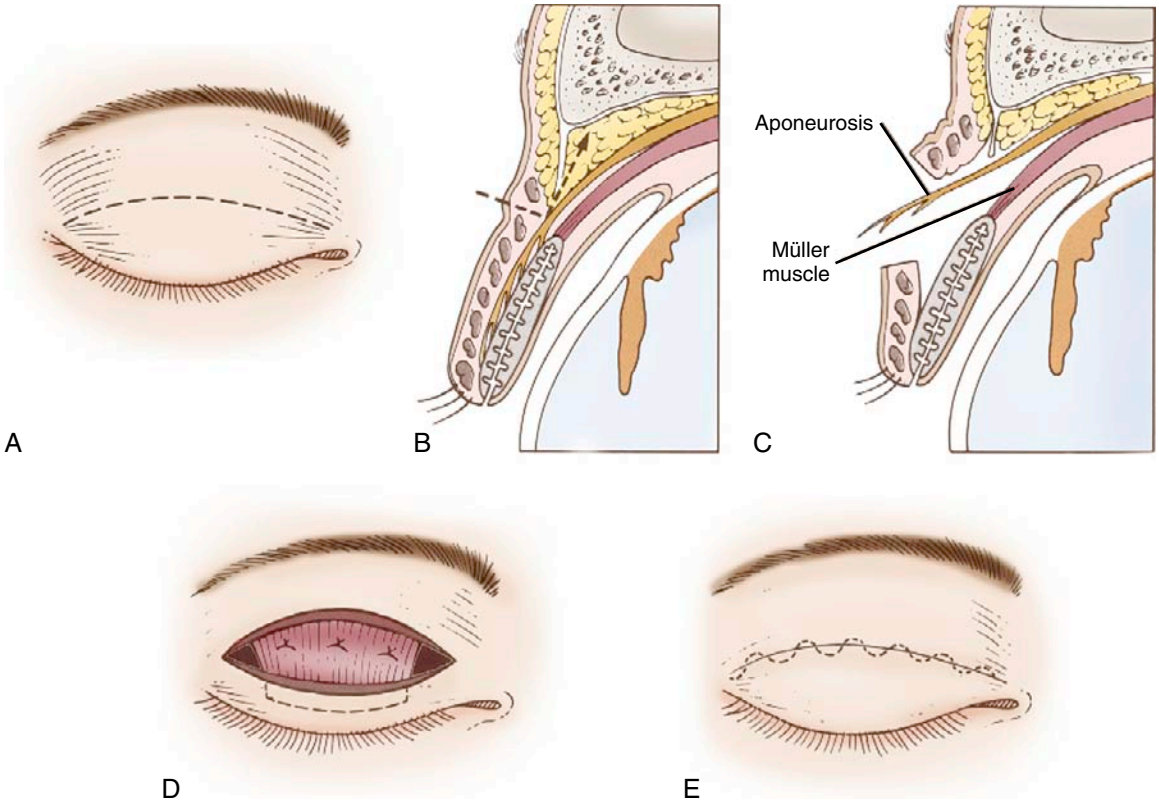


FIGURE 17-25 Levator aponeurosis repair for ptosis. **A**, Eyelid crease is marked. **B**, Skin incision is made, and the orbicularis and orbital septum are divided while dissection proceeds toward the orbital rim. **C**, The anterior surface of the tarsus is exposed, and the aponeurosis is separated from the Müller muscle. **D**, The aponeurosis is reattached to the tarsus with partial-thickness permanent sutures. Lid contour and position are adjusted. **E**, The eyelid crease is created by suturing the pretarsal orbicularis muscle to the aponeurosis, and the skin is closed.

3. The aponeurosis is incised across the tarsus and dissected off the orbicularis. The levator is reattached to the tarsus with interrupted 6-0 suture.
4. If the patient is awake, he or she is asked to look forward and the sutures are adjusted as needed.
5. The pretarsal orbicularis is sutured to the aponeurosis to reconstruct the lid crease.
6. The surgeon closes the skin incision with a running 6-0 nonabsorbable suture.

FRONTALIS SUSPENSION

1. The upper lid is marked, one incision is made in the lid crease, and two incisions are made above the eyebrow (Figure 17-26, *A* and *B*).
2. The surgeon places a lid plate behind the upper lid, exposes the tarsus, and secures the suspension material (fascia graft or a synthetic implant) to the tarsus with nonabsorbable sutures (Figure 17-26, *C*).
3. Using a Wright needle, the surgeon passes the suspension material away from the globe deeply into the orbital septum and out through one eyebrow incision (Figure 17-26, *D*).
4. The remaining end of the suspension material is passed in the same manner.
5. The surgeon sutures the pretarsal orbicularis to the tarsus to form the lid crease (Figure 17-26, *E*).
6. The lid incision is closed with a running 6-0 nonabsorbable suture (Figure 17-26, *F*).
7. The surgeon passes the long end of the suspension material under the skin between the brow incisions to complete the loop, and sutures the ends of the material together.
8. The brow incisions are closed with interrupted 6-0 nonabsorbable suture.

Excisional Biopsy

Excisional biopsy is removal of lesions for diagnostic examination. Basal cell carcinomas account for 95% of neoplastic lesions of the lid; the treatment of choice is excision with frozen-section analysis or Mohs' technique.

Operative Procedure. Through-and-through excision of skin, muscle, tarsus, and conjunctiva is followed by careful structural closure of anatomic spaces. Depending on the type, extent, and location of the lesion, rotation flaps or free grafts may be necessary.

Plastic Repair for Traumatic Injuries

Lacerations of the lids, including damage to the inferior canaliculus, are repaired surgically. Paramount for success is the careful approximation of the borders of the lid margin and the ends of a torn canaliculus.

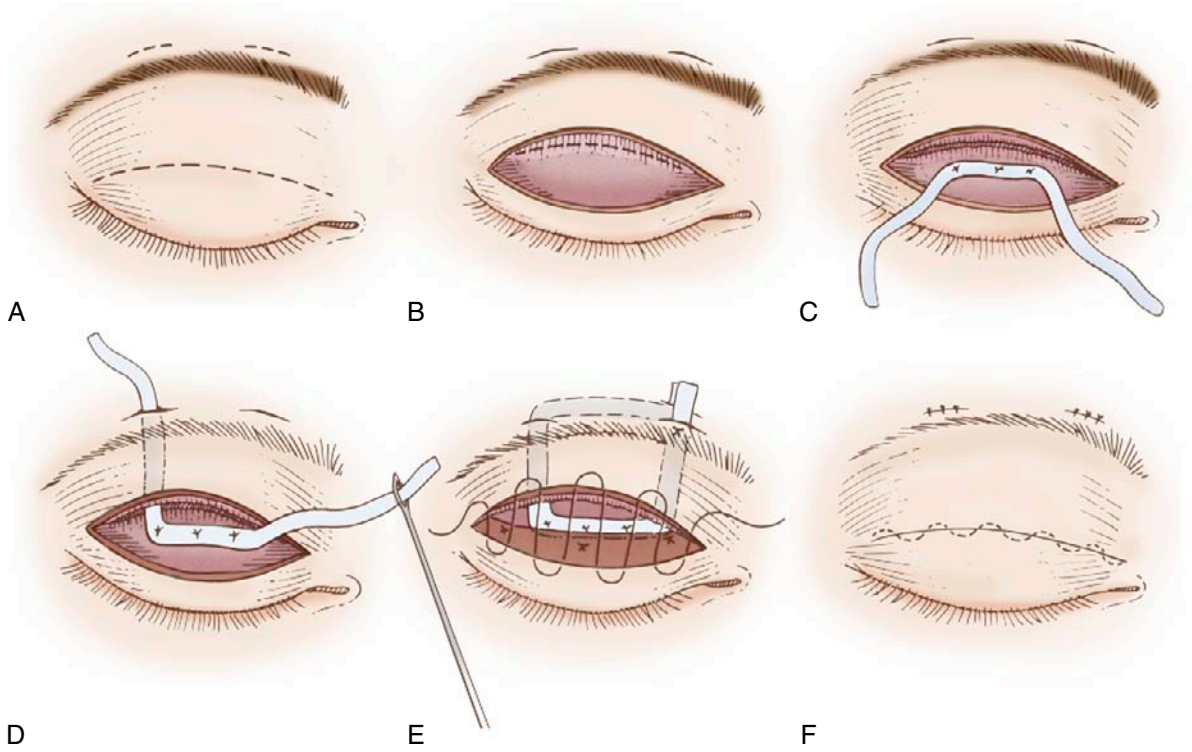


FIGURE 17-26 Frontalis suspension for ptosis. One method used to suspend the eyelid from the brow.

Operative Procedure. Lacerations of the lid margin are closed with a 6-0 silk suture to align the gray line of the lid that lies between the lash follicles and the orifices of the meibomian glands. Once this anatomic line has been approximated, all other sutures are placed, maintaining the approximation. If the canaliculus has been lacerated, the lacrimal drainage system is intubated with a silicone tube and the canaliculus and lid are reconstructed around the tube.

SURGERY OF THE CONJUNCTIVA

The conjunctiva of the eye is a transparent and elastic membrane that lines the inner surface of the eyelids and covers the sclera. Lacerations caused by injury as well as deficits resulting from excision of tumors, cysts, nevi, or pterygia can usually be repaired by simple undermining and suturing.

Pterygium Excision

A pterygium is a fleshy, triangular encroachment of conjunctiva onto the peripheral area of the cornea. Because pterygia tend to recur, surgery is delayed until vision is affected by encroachment on the visual axis.

Operative Procedure. The major steps in the McReynolds technique are illustrated in Figure 17-27. A pterygium can also be excised totally and the limbus treated with an eye cautery or bipolar ESU. The conjunctiva can then be closed, or the sclera can be left bare.

Surgery may be combined with beta-radiation, application of mitomycin, conjunctiva autologous grafts, and lamellar corneal grafts, and more recently with amniotic membrane graft.

Excisional Biopsy

Any suspect lesion of the conjunctiva can be removed by simple elliptic excision and sent for pathologic examination. The conjunctiva may or may not be closed, depending on the surgeon's particular technique.

Strabismus Surgery

Strabismus refers to ocular misalignment. Although often neurogenic rather than muscular in origin, surgery on the extraocular muscles may be indicated to improve this misalignment. Strabismus surgery is described in Chapter 25.

SURGERY OF THE CORNEA

Surgery of the cornea is indicated for a variety of conditions in which cosmetic, therapeutic, restorative, and refractive outcomes are desired.

Repair of Lacerations

Corneal lacerations may be closed with direct appositional suturing with 10-0 suture viewed through an operating microscope or with a tissue adhesive, such as cyanoacrylate monomers. The sterile tissue adhesive is applied to well-dried tissue that has been properly oriented anatomically. It polymerizes and seals the wound on contact with the tissue.

Culture specimens are usually obtained at the time of surgery. Antibiotics are injected subconjunctivally before the dressing is applied.

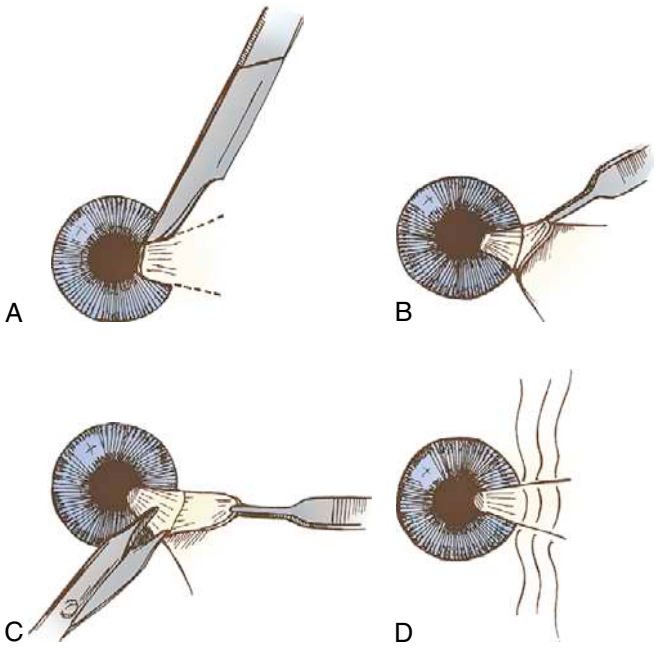


FIGURE 17-27 McReynolds technique for pterygium excision. **A**, Cornea around head of pterygium is incised. **B**, Pterygium flap is dissected upward, leaving clear cornea. **C**, Lower margin of pterygium is dissected, and whole pterygium is freed from sclera. **D**, Sutures are placed for closure of conjunctiva.

Corneal Transplantation (Keratoplasty)

A corneal transplantation (keratoplasty) is performed when the patient's cornea is thickened or opacified by disease and degeneration. The transparency of the cornea may be impaired as a result of scars, infection (bacterial, fungal, or viral), thermal or chemical burns, Fuchs' dystrophy, edema after cataract surgery, or keratoconus (abnormal steepening). Ocular surgery such as phacoemulsification, vitrectomy, or intraocular lens implant can potentially damage the corneal endothelium. Corneal transplantation, in which corneal tissue from one human eye is grafted to another, is done to improve vision when the retina and optic nerve are functioning properly; it was first performed in 1905. Because the cornea is tissue that lacks blood vessels, it can be transplanted with less rejection and at a 90% success rate. Keratoplasty may be performed as a lamellar (partial-thickness) graft or a penetrating (full-thickness) graft. Over 50,000 grafts were made available in 2007. Corneal transplant is one of the most frequently performed human transplant procedures, with more than 700,000 performed since 1961 (Eye Bank Association of America [EBAA], 2009.)

Phototherapeutic keratectomy (PTK) procedures use excimer laser ablation to remove superficial corneal lesions and smooth the corneal surface. PTK can be used on conditions that would require corneal transplant and may delay or replace the occurrence of penetrating keratoplasty in some cases.

Procurement of Corneas. The eye bank may be a central community agency or may be owned and operated by a hospital. Eye banks help coordinate the procurement of eyes from recently deceased persons under the Eye Bank Association of America (EBAA) guidelines. Persons of any age can be eye donors, and poor eyesight or cataracts do not influence eye viability (EBAA, 2009). The donor's family, medical, and social histories are reviewed. It is not necessary to perform antigen matching as with other tissue or organ transplants, but blood serum tests for human immunodeficiency virus (HIV) and hepatitis B virus are performed on the donor. The procurement team removes donor eyes within 6 hours of death in accordance with legal regulations. Tissue, such as a cornea, must be recovered, processed, and transplanted in controlled surgical environments. If the donor eye is unsuitable for the cornea to be transplanted, the eye can be used for research or education.

Many individuals have signed donor cards or eye-donor designation on their drivers' licenses. A special consent form is required and should be signed by the authorized next of kin and by a hospital representative designated by institutional policy. Federal regulations require hospitals to report all deaths and imminent deaths to organ procurement organizations. With the collaboration of hospitals, organ procurement organizations, and eye and tissue banks, the family of every potential donor is informed about the option to donate organs or tissues.

The enucleations may be done in the hospital morgue or emergency department under aseptic conditions. The procured cornea is placed in Optisol GS sterile buffered tissue culture medium within 12 hours of death and transplanted within 3 to 7 days. Optisol GS sterile buffered tissue culture medium contains polypeptides, dextran, and antibiotics (gentamicin and streptomycin) and can preserve a donor cornea for 14 days under refrigeration. It is best if corneal transplantation is performed in 2 or 3 days because the cornea may become boggy from constant exposure to the tissue culture solution.

PROCEDURAL CONSIDERATIONS. Postmortem preparation includes elevating the donor's head with a pillow to minimize edema in the face or near the eye. The eyes are irrigated and lightly taped closed to avoid pressure on the eye. A small ice pack may be applied to the forehead or over the eyes if the donor is not in a refrigerated morgue within 1 hour of death.

For the procurement procedure, the eyes are washed and irrigated in the routine manner of preparation for eye surgery. The sterile field, drapes, and instruments are essentially the same as those for an enucleation on a living patient. For the transplant procedure, the nurse positions and preps the patient in the same fashion as a cataract procedure.

OPERATIVE PROCEDURES

Donor Tissue Procurement

1. Eye specimen jars are labeled for right and left eyes.
2. The speculum is inserted, and after routine enucleation the donated eye is placed with the cornea up and secured in a metal eye cage or on gauze in the sterile specimen jar.
3. The eye sockets are packed with cotton, and the lids are closed.
4. Specimen jars are sealed with tape and labeled with the donor's name or identification number, time of death, time of enucleation, and date. The jars are placed on wet ice in an insulated carrier and transported to the eye bank. The entire cornea with a scleral rim will be placed in Optisol GS before transplant.

Penetrating Keratoplasty

1. After insertion of the eye speculum the surgeon places superior rectus and inferior rectus bridle sutures if a Flieringa ring is not to be used. If a ring is used, the surgeon secures it in place with four 5-0 sutures (Figure 17-28).

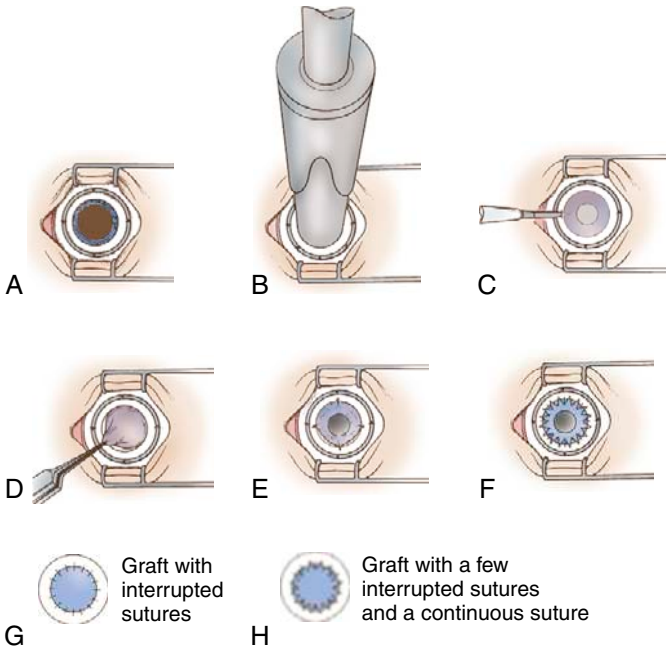


FIGURE 17-28 Corneal transplantation. **A**, Eye of patient who will undergo corneal transplantation. Flieringa fixation ring is sutured in place with 5-0 nonabsorbable sutures. **B**, Corneal trephine is placed on recipient cornea, and partial penetration is made approximately three fourths through stroma. **C**, Anterior chamber is entered through groove, and the remainder of button is excised with right and left corneal microscissors. **D**, Corneal button is removed. **E**, Donor cornea graft is sutured in place with four sutures. **F**, Donor cornea graft is sutured in place with interrupted or continuous 10-0 nonabsorbable suture (**G** and **H**).

2. A corneoscleral button that has been refrigerated and stored in tissue culture medium (Optisol GS) is removed from its container.
3. The surgeon places the donor corneoscleral button on a sterile Teflon block with the epithelial (outside) surface down. Using the corneal trephine as a punch, the surgeon presses out the button. A drop of Optisol GS may be used to cover the donor button until it is implanted.
4. Using a handheld trephine or a disposable suction trephine, the surgeon excises a corneoscleral button from the recipient's cornea. The section of cornea removed from the recipient's eye is usually 0.25 mm in diameter smaller than the graft taken from the donor's eye.
5. Peripheral iridectomies or iridotomies may be performed at this time at the surgeon's discretion, or a cataract extraction with IOL implantation may also be performed if the lens is opaque.
6. The surgeon places the graft into the opening of the recipient's eye and anchors it in place by means of four single-armed sutures placed at the four cardinal meridians, viewed through an operating microscope. Some surgeons preplace sutures in the graft. The surgeon sutures the graft to the host with either continuous or interrupted 10-0 nonabsorbable sutures.
7. Air or sodium hyaluronate (Healon) may be injected into the anterior chamber of the recipient's eye to keep the iris from adhering to the suture line. Mydriatic or miotic solutions are used at the surgeon's discretion.
8. A subconjunctival injection of antibiotic solution or a topical application of antibiotic drops may be used at the completion of the procedure. Antibiotic ointment is applied, followed by an eye pad and a protective shield.

Lamellar Keratoplasty

1. The surgeon inserts the eye speculum and then places the superior rectus and inferior rectus bridle sutures (if needed).
2. The perioperative nurse presents the donor eye from the eye bank to the sterile field; the surgical technologist washes it in balanced salt solution.
3. The surgeon wraps the donor eye in a surgical dressing and makes a groove at the desired depth in the cornea with the trephine. The Castroviejo keratome is set at the desired depth, and the lamellar sheet of cornea is removed and placed into a petri dish.
4. The recipient cornea is grooved with the same trephine to the appropriate depth. Using the operating microscope, the surgeon performs a lamellar resection, that is, removes the anterior part of the cornea at a predetermined depth with a Gill knife, Beaver knife blade #64, or other corneal splitter.
5. The surgeon sutures the donor tissue in place with a continuous 10-0 nonabsorbable suture.
6. A mydriatic agent and subconjunctival or topical antibiotics may be used.
7. The eye is patched.

DEEP LAMELLAR ENDOTHELIAL KERATOPLASTY. Deep lamellar endothelial keratoplasty (DLEK) is an emerging technique. It consists of replacing the endothelium without transplanting the cornea to restore vision. This technique offers the potential for highly predictable corneal power for extended periods without the astigmatism that often occurs with penetrating keratoplasty. The transplanted endothelium is inserted into the host through a small incision, greatly reducing the risk of infection.

Keratorefractive Procedures

Keratorefractive procedures are corneal procedures designed to correct myopia, hyperopia, astigmatism, and aphakia. These procedures require reshaping the cornea with relaxing incisions or cryolathing corneal tissue to change the refractive power of the cornea. They include photorefractive keratectomy (PRK), which uses the excimer laser to treat myopia (nearsightedness), and laser-assisted in-situ keratomileusis (LASIK), which uses the excimer laser for photoablation of the corneal stroma bed to alter the curvature of the cornea and correct myopia or hyperopia (farsightedness).

PRK is a surface ablation technique that involves manual scraping, alcohol, and a brush. Surface ablation avoids the complications of flap formation and provides excellent visual results. A major drawback, however, is delayed visual rehabilitation and pain, though it can be controlled with topical and oral therapy. Epi-LASIK, another form of surface ablation, mechanically separates the epithelial layer from Bowman's membrane with the use of a mechanized keratome but without alcohol. After ablation the epithelial flap is positioned on the cornea followed by a bandage contact lens. Some strategies to promote healing include careful preoperative testing for dry eye and using nontoxic antibiotics (Donnenfeld, 2008).

More than 800,000 Americans underwent LASIK surgery in 2007. Excimer laser technology was introduced in 1975 and exploration of ophthalmic applications began in 1983. Stuart (2008) notes that improvements in performance and reliability, combined with a host of complementary techniques and innovations, have turned excimer refractive surgery into the most popular elective surgical procedure worldwide. Thus it is especially important for the perioperative nurse to keep updated with emerging technologies and techniques as they develop.

LASIK Surgery. With the LASIK procedure, the curvature of the cornea is reshaped using an excimer laser. The purpose is to permit the individual to see well at a distance without glasses. For nearsighted patients the central curvature of the cornea is flattened. To flatten the cornea, the surgeon removes stromal tissue from the center of the cornea (Figure 17-29, *A*). For farsighted patients the central curvature of the cornea is steepened. To steepen the cornea, stromal tissue is removed from the periphery of the cornea, leaving the center untreated (Figure 17-29, *B*).

PROCEDURAL CONSIDERATIONS. An extensive preoperative evaluation (refraction, topography, wavefront analysis, and determination of targets for desired refraction) is necessary to be sure that the patient is a candidate for the LASIK procedure. Before surgery, a topical antibiotic and topical anesthetic are placed in the patient's eye. If the patient has astigmatism, he or she is taken to a slit lamp and a mark is made on the conjunctivae to assist in the correction of the astigmatism. Circular corneal markers (3 mm and 4 mm) may be used. The LASIK complication rate has been dramatically reduced by the development of new-generation microkeratomes and the improvement in the femtosecond laser. The three basic steps in LASIK are: (1) prepare stroma or create flap, (2) perform photoablation to change refraction, and (3) reposition flap (Donnenfeld, 2008).

OPERATIVE PROCEDURE

1. The patient is positioned supine, and the surgeon positions a locking lid speculum. The patient's head position is adjusted to account for the astigmatism.
2. The surgeon marks the cornea to assist in the placement of the "corneal cap" after the procedure. A suction device is placed on the eye to immobilize it.
3. A microkeratome (e.g., Hansatome, ACS, Moria, Amadeus) is used to create a lamellar keratectomy of 0.130 to 0.180 micrometers in thickness. This piece of cornea is reflected out of the way with a flat cornea spatula, and the laser treatment is applied to the base of the lamellar keratectomy.
4. The surgeon replaces the corneal cap on the stromal bed using a Slade irrigating cannula on a 3-ml syringe with saline. The corneal cap is permitted to dry for several minutes. The corneal cap stays in position because of capillary attraction.
5. Antibiotic drops and nonsteroidal antiinflammatory drops are placed in the eye. A goggle is placed over the eye to prevent slippage of the corneal cap for the next 24 hours.

LASEK Surgery. Laser epithelial keratomileusis (LASEK) is similar to PRK, because the procedure is performed on the surface of the cornea. After numbing the eye with topical anesthetic drops, the surgeon loosens the epithelium with a diluted alcohol solution and pushes it aside. A laser is then used to treat the corneal surface, similar to PRK and LASIK procedures. The epithelial flap is then returned to its original position, and a bandage contact lens is placed for the duration of the healing process, which may last several days.

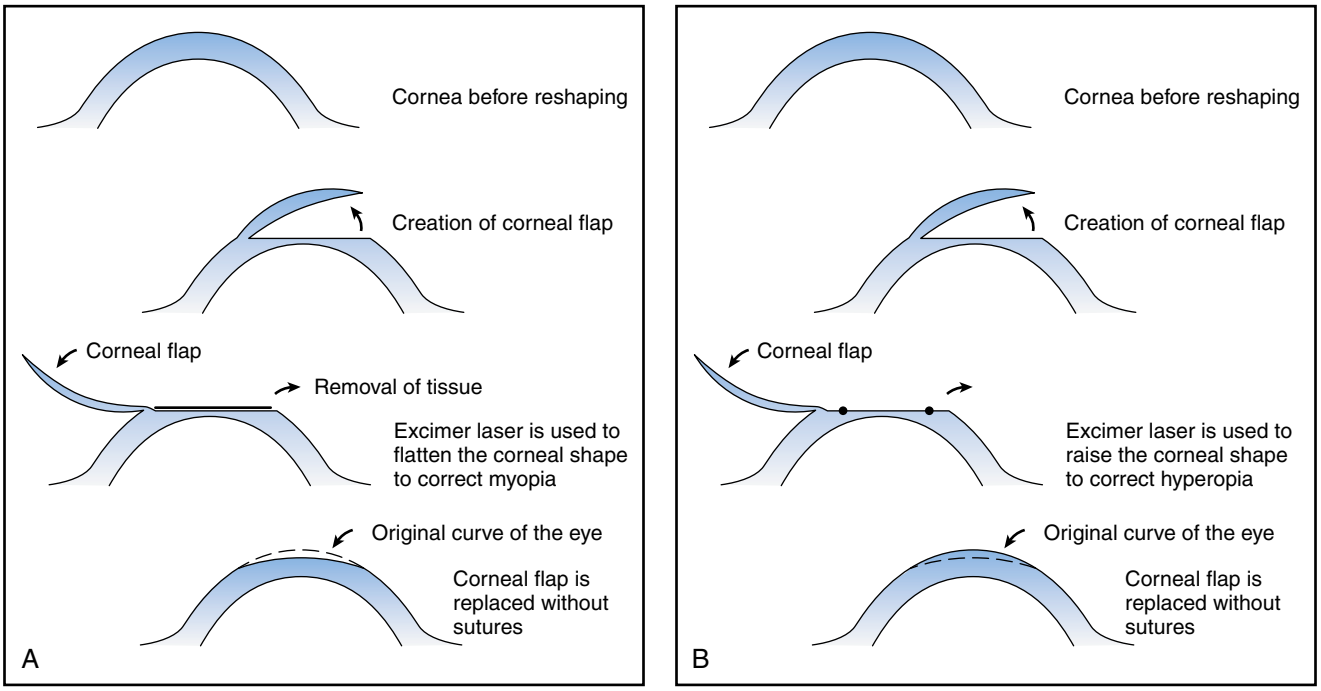


FIGURE 17-29 Laser-assisted in-situ keratomileusis (LASIK) surgery. **A**, Diagram of LASIK correction for nearsightedness. **B**, Diagram of LASIK correction for farsightedness.

SURGERY OF THE LENS

Cataract Extraction

A cataract is defined as any opacification of the lens. Cataracts may be congenital, posttraumatic, or induced by medications (particularly corticosteroids), but are most commonly the result of age-related changes.

Normally, light passing through a clear lens projects a sharp image onto the retina. When the lens becomes cloudy (cataractous) through the aging process, vision becomes blurred. A cataract can be compared to a window that is frosted or yellowed (Burlew-Quartey, 2008). More than half of all Americans over age 80 have a cataract or have undergone surgery for it. The lens is made of mostly water and protein; over time, some of the protein may clump together, leading to clouding of the lens (cataract). The vision gradually gets worse as the lens changes from clear to a yellow/brown color (Figure 17-30); the pupil may appear gray. The tinting eventually makes it difficult to differentiate certain colors like purple or blue, and difficult to read or perform routine activities. Cataract removal is warranted when there is interference with everyday activities such as driving, reading, and watching television (NEI, 2008b). Other symptoms include having poor night vision, noticing glare from headlights or lamps, and perceiving that sunlight is too bright. Halos may be noticed around lights as well. Double vision might also be noticed. These symptoms may indicate other eye problems so an eye exam would be warranted to determine the exact cause. See Figure 17-31 for a depiction of a person's view with normal vision, cataract, glaucoma, and diabetic retinopathy.

Besides age-related cataracts, the following other types of cataracts exist:

- *Congenital*—Children may be born with cataracts or develop them throughout their youth.
- *Traumatic*—After eye injury or electric shock, cataracts may develop even years later.
- *Secondary*—After eye surgery for other conditions, cataracts may develp, or they may be associated with other health problems such as diabetes, steroid use, smoking, and prolonged exposure to sunlight (NEI, 2008b).

A cataract extraction is removal of the opaque lens from the interior of the eye and can be accomplished by several methods.

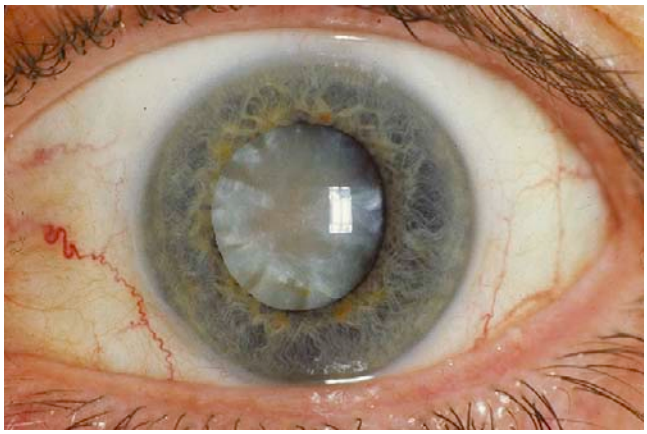


FIGURE 17-30 A hypermature age-related cortico-nuclear cataract with a brunescent (brown) nucleus.

The *intracapsular cataract extraction* (ICCE) method of cataract removal consists of removing the lens within its capsule with a cryoprobe and is rarely performed today except in the event of a dislocated lens. If an ICCE is scheduled, alpha-chymotrypsin (Catarase, Chymar), an enzyme that acts on the zonules of the lens, and a cataract cryoprobe need to be procured.

In the extracapsular method (ECCE), the anterior portion of the capsule is first ruptured in a controlled manner and removed. The surgeon expresses the lens cortex and nucleus from the eye, leaving the posterior capsule behind. Restoration of functional vision is necessary after removal of the crystalline lens (aphakia). Contact lenses can be used to correct aphakia. They offer an excellent option for visual correction and can be used for monocular aphakia.

Over the past years numerous microsurgical techniques have been developed for lens removal through a small self-sealing incision and most recently through a clear corneal incision. ECCE with phacoemulsification is still performed, especially with very mature or hard cataracts, and may be performed in combination with trabeculectomy for patients with glaucoma. Patients receiving long-term glaucoma therapy (which causes pupil constriction) may not dilate well and may need iris retractors during surgery. Adequate pupil dilation is necessary for safe visualization of all affected intraocular structures.

Basically, each technique involves opening the lens capsule and using a phacoemulsification unit with irrigation and aspiration (I/A). Pressures in the anterior and posterior chambers are generally equal. Once the surgeon makes the incision into the anterior chamber, aqueous fluid leaks from it. Pressure in the anterior chamber falls below that in the posterior chamber, and vitreous from the back of the eye tries to push forward and could carry other structures with it. To minimize the risk from these pressure gradients, early in the procedure the surgeon will inject thick viscoelastics, which do not leak.

The high-frequency ultrasonic energy of phacoemulsification fragments the hard lens material (similar to a jackhammer), which can then be aspirated from the eye. Some phacoemulsification units utilize oscillating movements (side-to-side). All perioperative personnel using specialized instruments and equipment must have thorough knowledge of the operation as well as problems that may be encountered and actions to correct them.

Roughly 90% of people who have cataract surgery have better vision afterward. Cataract surgery not only is one of the most common surgeries performed in the United States but also is one of the safest and most effective surgeries (NEI, 2008b). Patients with cataracts in both eyes that need surgery will generally have their procedures performed at separate times, usually 4 to 8 weeks apart. Months or years after cataract surgery, cells may grow back, causing opacification of the posterior capsule and a haze in the vision. The YAG laser may then be indicated for capsulotomy, creating a hole in the center of the capsule to allow light to pass through and restore clear vision (Burlew-Quartey, 2008).

Potential complications, though rare, are discussed as part of informed consent. In a patient with vision in only one eye, the risks/benefits of surgery must be carefully evaluated. The potential problems include infection, bleeding, inflammation, loss of vision, double vision, and high or low eye pressure (NEI, 2008b). The American Society of Cataract and Refractive

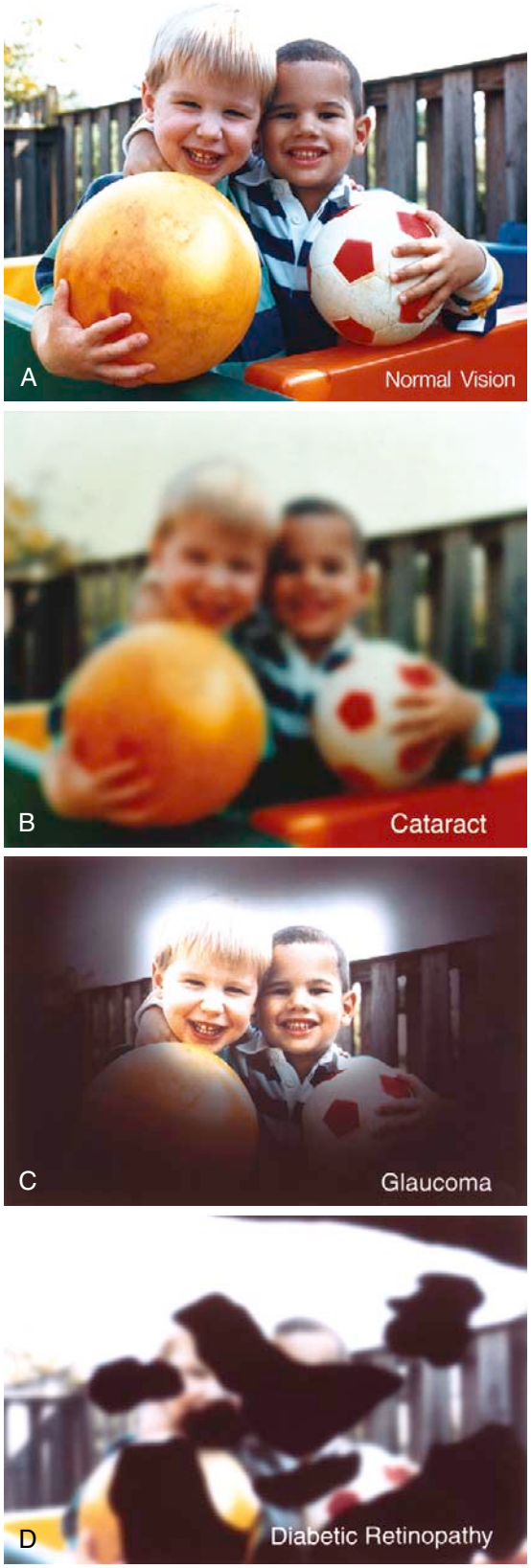


FIGURE 17-31 Comparative views with (**A**) normal vision, (**B**) a scene as it might be viewed by a person with cataract, (**C**) a scene as it might be viewed by a person with glaucoma, and (**D**) a scene as it might be viewed by a person with diabetic retinopathy.

Surgery and the American Academy of Ophthalmology (AAO) have issued a joint clinical *Information Statement and Patient Advisory,* recommending that "patients taking alpha-blockers to treat prostate enlargement or other conditions inform their ophthalmologist about these medications before undergoing eye surgery. Prior to being started on this class of drugs, patients with cataracts should be informed that alpha-blockers, in general, and Flomax (tamsulosin), in particular, may increase the difficulty of cataract surgery" (AAO, 2009). The condition of intraoperative floppy iris syndrome (IFIS), first reported in 2005, is explained: "The iris, the part of the eye that gives it its color, opens and closes in response to varying light levels. Because the iris is located in front of the cataract, the pupil (opening in the iris) must be widely dilated to perform the surgery. A large pupil is obtained, in part, by using dilating drops that stimulate the iris dilator muscle. Alpha-blockers, such as Flomax, block this iris muscle, leading to poor dilation and sometimes causing the pupil to suddenly constrict during surgery." The patient advisory emphasizes the importance of communicating any history of Flomax use as the complication may occur even if the drug has been discontinued. This communication for proper medical judgment for each individual patient is essential for positive outcomes: "The overall risk of serious cataract surgical complications is low, and when the ophthalmologist is informed of the patient's history of alpha-blocker use, the success rate of cataract surgery remains very high."

Although various manufacturer's systems and platforms exist for cataract surgery, basic considerations remain. Parameters are not interchangeable between formats; power and vacuum settings are measured differently in different machines. Even the height of the irrigation bottle may be measured differently. The nurse and team must challenge themselves to new ideas in evaluating new technology and adjusting to varied practice settings. Foot pedals also are different; for example, positions 1, 2, and 3 have different functions in each machine. Overall, through teamwork and adequate training and monitoring for competency, the surgical team can optimize technology for safety and efficiency in cataract surgery regardless of the equipment used.

Intraocular Lens. Extraction of the cataractous lens removes one of the major refractive components of the eye. Three options for replacing this lost refractive power are (1) use of aphakic glasses, (2) use of aphakic contact lenses, and (3) intraocular lens (IOL) implantation. IOLs offer many advantages to patients, including reduced dependence on spectacles, reduced thickness of any spectacle correction needed, and elimination of aberrations produced by aphakic glasses or contact lenses.

Current generation IOLs are made of silicone or acrylic resin. Foldable and injectable designs and new implantation techniques challenge perioperative nursing personnel to keep abreast of changes in techniques for IOL implantations. Posterior chamber lenses (PCLs) can be implanted only when the cataract was removed by extracapsular cataract extraction (ECCE). Placement behind the iris is the most physiologic position for an artificial lens (posterior chamber lens) and is the most common method. Anterior chamber lenses (ACLs), placed in front of the iris, are used in the absence of capsular support, including after vitreous loss or ICCE and for secondary lens implantation (when the cataract was previously removed without lens replacement) (Burlew-Quartey, 2008).

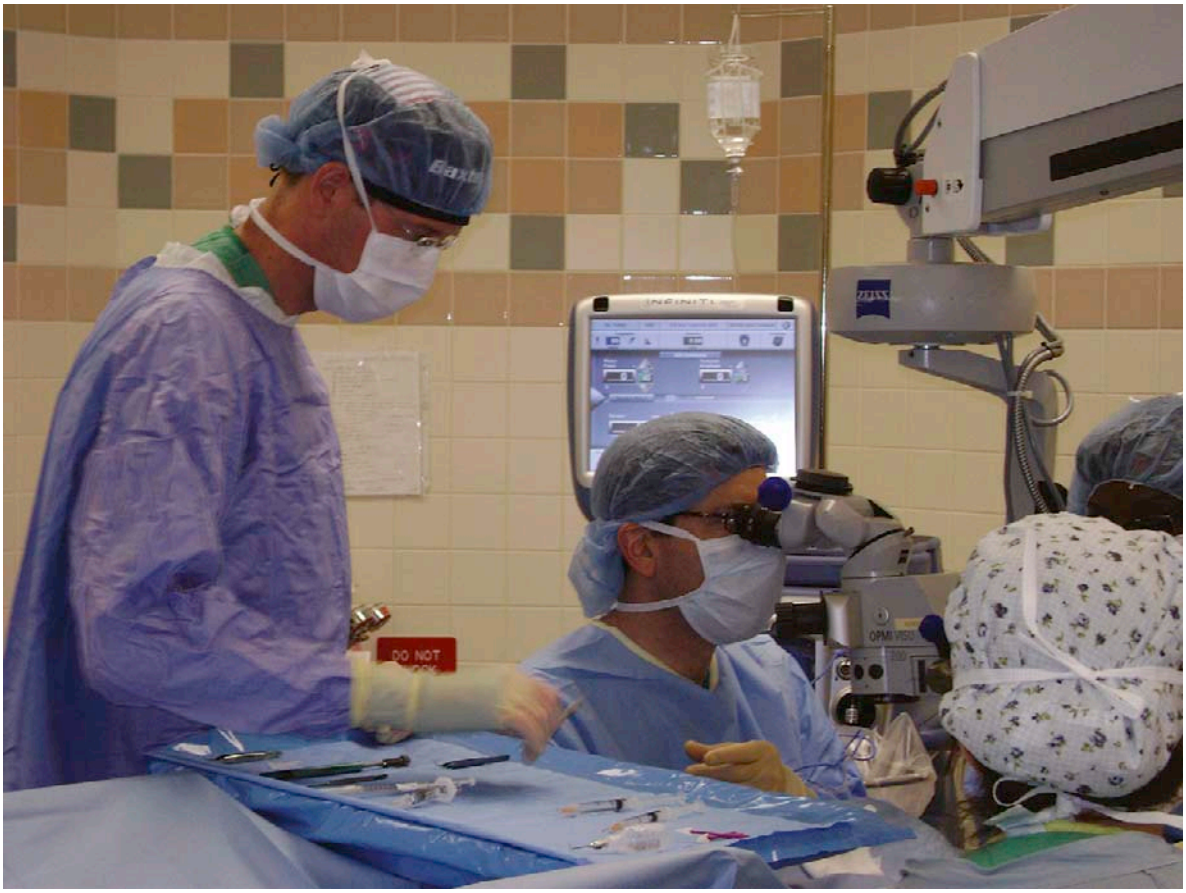


FIGURE 17-32 Cataract surgery in progress. Note irrigation bottle and phacoemulsification unit in background; surgeon sitting at side of patient (temporal approach); scrub person ready to anticipate surgeon's needs; anesthesia provider at patient's side for reassurance and comfort. Circulating nurse, not shown, is coordinating all activities and monitoring for safety.

IOLs are available in various diopter powers. The necessary power customized for each patient is determined by measuring the curvature of the patient's cornea (keratometry) and the axial length (length from cornea to retina). A mathematical formula is then used to calculate the correct lens power. IOLs are also available in bifocal and multifocal types. Some feature ultraviolet protection.

Sutureless cataract techniques have become increasingly popular because of rapid visual rehabilitation. Clear corneal microincisions (3 mm wide or less) with the use of topical anesthesia and insertion of foldable IOLs have produced even better visual results with the opportunity to fully correct refractive errors.

Procedural Considerations. Instrumentation varies with surgeon's preference but usually includes forceps to insert the lens and lens haptics and a hook to aid in rotating and positioning the lens. Perioperative nursing personnel must be familiar with institutional policies pertaining to IOLs and their use. For example, the American Academy of Ophthalmology (AAO, 2008) developed recommendations to minimize the occurrence of preventable errors such as wrong IOL implant (i.e., to ensure the highest level of patient safety in surgery). The tenets encompass the importance of communication with surgery staff. The recommendations emphasize the importance of heightened communication and verifications of preoperative calculations of lens style and power ordered, and documenting it as a written order. Besides verifying the implant during the time-out, it is recommended that the surgeon have some form of written documentation regarding the case and IOL (white board, or copy of operative plan taped to microscope) available to view when scrubbed, gowned, and gloved and seated at the surgical microscope.

Surgical techniques vary based on surgeon training and experience. Some surgeons sit at the head of the bed whereas others use a temporal approach (Figure 17-32). Some use topical drops, and others use anesthetic gel. Regardless, the surgery follows certain basic steps.

TOPICAL CLEAR CORNEAL CATARACT PROCEDURE. Developments with the use of topical anesthetics, new materials for foldable IOLs, and diamond knives for self-sealing or no-stitch wounds led to clear cornea incisions and new techniques for phacoemulsification and lens implantation for cataracts. Clear cornea microincisions create the opportunity for full correction of refractive errors during the surgical procedure.

Topical anesthesia replaces retrobulbar anesthesia for cataract surgery, and because the patient can fixate, this allows for refractive surgical techniques. Patients must be able to hear

and follow directions so that they can cooperate with verbal instructions to fixate on the microscope light. Various medications and protocols are used for administering topical anesthetics before cataract surgery.

Procedural Considerations. The nurse administers a drop of topical tetracaine 0.5% into the operative eye before the patient enters the OR. The patient is instructed to keep this eye closed to prevent the cornea from drying. As the patient is being positioned, the nurse administers another drop of tetracaine. An armrest is positioned on the operative side, and the patient's head and the microscope are adjusted. The patient is instructed to look at the light of the microscope and told where to fixate. If the patient cannot open his or her eye, a facial nerve block should be considered. If the patient cannot fixate on the light at all, a retrobulbar block should be considered.

Operative Procedure

1. The surgeon places an eyelid speculum with an open temporal area.
2. A 1-mm-wide stab incision (paracentesis, tiny incision in cornea opposite the main incision) is made at 5 o'clock in the left eye or at 11 o'clock in the right eye into the anterior chamber.
3. Intercameral anesthesia may be used: 1 ml of unpreserved lidocaine is slowly injected into the anterior chamber through a 30-gauge cannula using a tuberculin syringe.
4. The surgeon injects viscoelastic material into the anterior chamber to deepen the chamber and widen the pupil.
5. The temporal cornea incision is made with a (diamond or single-use) keratome. Some surgeons may use a caliper to mark the incision width, and may use a second knife to make a vertical cut before the horizontal pass with the keratome (Figure 17-33, *A*).
6. A capsulotomy and capsulorrhexis are performed with a capsulorrhexis forceps (Figure 17-33, *B*). This step of tearing the capsule in a controlled manner is critical in creating a round, stable opening into the capsular "bag."
7. Using a 30-gauge cannula and saline, the surgeon performs hydrodissection (and sometimes hydrodelineation) to separate the center/nucleus from the capsule and maneuver the lens within the capsule (Figure 17-33, *C*).
8. The surgeon uses a phacoemulsification tip to sculpt the nucleus with the ultrasound vibration.
9. A second instrument is inserted through the left-handed paracentesis incision to help rotate and divide the cataractous nucleus into quadrants (Figure 17-33, *D*).
10. Cataractous nucleus removal usually proceeds in two phases: nuclear sculpting, wherein the nucleus is cracked or sculpted into smaller fragments, and quadrantic emulsification of those fragments.
11. Following removal of the lens nucleus, the surgeon places an irrigation/aspiration (I/A) tip into the eye and uses it to remove the remaining cortical material (Figure 17-33, *E*). This combination of irrigation and aspiration intends to maintain equilibrium within the eye. Removing the cortex minimizes postoperative inflammation.
12. Some surgeons may polish the posterior capsule or aspirate anterior lens epithelial cells.
13. The surgeon injects viscoelastic material to inflate the anterior chamber and capsular bag.
14. A posterior chamber IOL is folded and placed into the eye with an injector or forceps and then into the capsular bag (Figure 17-33, *F* and *G*). The IOL is positioned with a Sinsky hook or the I/A tip. Some surgeons may need to widen the corneal incision before placing the IOL.
15. The surgeon uses the I/A tip to remove any remaining viscoelastic material. Leaking of the wound may be controlled or prevented by hydrating the wound edges. Occasionally a 10-0 nylon suture is necessary.
16. Topical antibiotics or combination antibiotic-corticosteroid ointment or drops are placed on the eye. The eye is not patched, but a shield is commonly used.

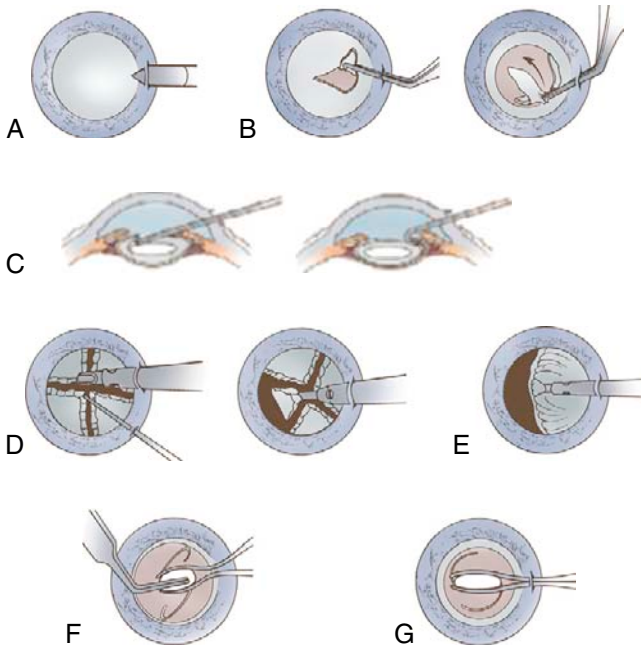


FIGURE 17-33 Clear cornea cataract extraction. **A**, A 2.6-mm incision is made into the cornea. **B**, Capsulorrhexis is performed on anterior capsule of lens. **C**, Nucleus of lens is loosened by hydrodissection. **D**, Nucleus of lens is "cracked" into four quadrants and removed with phacoemulsification. **E**, Irrigation and aspiration (I/A) handpiece is used to strip the remaining cortex from the capsule. **F**, Intraocular lens (IOL) is folded. **G**, IOL is placed into the capsular bag.

EXTRACAPSULAR METHOD WITH PHACOEMULSIFICATION

Operative Procedure

1. After a superior rectus bridle suture is placed, a small limbus-based flap is dissected superiorly.
2. Using sharp dissection with a Beaver knife blade the surgeon cleans the surgical limbus. Hemostasis is obtained with the bipolar ESU.
3. A 3-mm or smaller incision is made into the eye with either a keratome or a sharp microknife.
4. The surgeon opens the lens capsule with capsulorrhexis forceps or a cystotome. The anterior chamber may be kept formed with air or an irrigating solution.
5. The lens nucleus is loosened from the cortex with the cystotome or a blunt cyclodialysis spatula.
6. The surgeon checks the ultrasonic handpiece for appropriate vacuum control and introduces it into the eye. *The vacuum control check is critical and must be performed before the handpiece is introduced into the eye.*

7. When the lens nucleus has been emulsified and removed, the surgeon removes the lens cortex with the I/A handpiece.
8. If a foldable IOL is to be implanted, the surgeon may use a keratome to widen the incision to 3.2 mm before folding and inserting the lens. If a rigid IOL is to be implanted, the wound is extended to 5.1 mm to accommodate the lens diameter. Acetylcholine may be introduced to constrict the pupil.
9. The corneoscleral wound is closed with a 10-0 nonabsorbable suture.
10. The conjunctival flap is closed with a suture or using the bipolar ESU.
11. An eye pad and shield are applied.

Anterior Segment Vitrectomy

The main indications for vitrectomy in the anterior segment are as follows:

- Vitreous loss during cataract extraction
- Opacities in the anterior segment
- Complications associated with vitreous in the anterior chamber
- Miscellaneous causes, such as hyphema, pupillary membranes, and residual soft lens material

Procedural Considerations. The procedure varies according to the surgeon's preference. A pathologic condition in the anterior segment can be approached through a limbal incision, as in lens extraction with vitreous loss, or through an "open sky" approach, after trephine incision for penetrating keratoplasty. Most phacoemulsification equipment has a vitrector that can be quickly attached if needed.

Operative Procedure

ANTERIOR VITRECTOMY FOR VITREOUS LOSS DURING CATARACT EXTRACTION

1. The surgeon introduces the vitreous cutter into the eye through the cataract wound. Infusion may be through the handpiece or a separate cannula and infusion line.
2. The cutter is placed in the middle of the pupil, posterior to the iris, and enough vitreous is removed to ensure that no vitreous remains in the anterior chamber and that the iris has fallen back into its normal position.
3. The pupil is constricted with acetylcholine. The anterior chamber may be re-formed with balanced salt solution (BSS).
4. The procedure is completed as for a lens extraction.

ANTERIOR VITRECTOMY FOR ANTERIOR SEGMENT OPACITIES, HYPHEMA, PUPILLARY MEMBRANES, AND RESIDUAL SOFT LENS MATERIAL

1. Appropriate fixation sutures or a lid speculum is placed.
2. The surgeon makes an incision at the limbus either through clear cornea or under a conjunctival flap. One to three incisions are made, depending on the vitreous cutter chosen and the technique.
3. If a multifunction probe is not used, the surgeon places an infusion cannula into one incision and the vitreous cutter into another incision. A third incision may be used for an accessory instrument. The vitreous, blood, or other material is removed.
4. The incisions are closed, and the eye is patched.

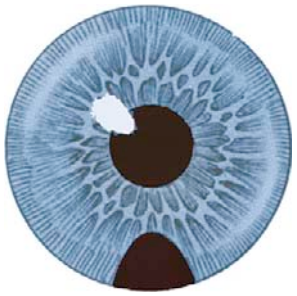


FIGURE 17-34 Peripheral iridectomy.

SURGERY FOR GLAUCOMA

Iridectomy

Peripheral iridectomy is removal of a section of iris tissue (Figure 17-34). Peripheral iridectomy is usually performed as part of a trabeculectomy procedure or may be performed when laser iridotomy is not feasible because of cloudy cornea or uveitis. Peripheral iridectomy is done in the treatment of acute, subacute, or chronic angle-closure glaucoma when extensive peripheral anterior synechiae have not formed. This operation is performed to reestablish communication between the posterior and anterior chambers, thus relieving pupillary block and permitting the iris root to drop away from the trabecular meshwork to reestablish the outflow of aqueous fluid through Schlemm's canal.

Operative Procedure

1. The speculum is introduced. The globe is fixed with a 4-0 traction suture passed under the superior rectus and fastened to the drape with a hemostat.
2. A small beveled incision is made at the superior limbus, or a perpendicular incision is made in the clear cornea.
3. The surgeon grasps the peripheral iris with forceps, pulls it through the incision, and excises it.
4. The iris is repositioned by gently stroking the cornea with a blunt spatula or muscle hook. The iris can also be repositioned by irrigating with BBS.
5. A clear corneal incision is closed with 10-0 nonabsorbable suture, and a limbal incision is closed with absorbable suture. Subconjunctival antibiotics may be administered, and an eye pad is applied.

Trabeculectomy

Trabeculectomy is a filtering procedure accomplished by incising a conjunctival flap and a scleral flap, creating a fistula, performing an iridectomy, and creating the filtering bleb. Trabeculectomy is often combined with cataract removal (phacoemulsification) and insertion of an IOL.

Procedural Considerations. Adjunctive medical therapy to decrease postoperative fibrosis includes application of an antimetabolite-soaked sponge (5-fluorouracil [5-FU] or mitomycin C) placed under the conjunctival flap. Because 5-FU and mitomycin C are antimetabolites, nursing precautions for handling hazardous waste must be carried out. The perioperative nurse must wear gloves while drawing up the antimetabolite from the vial to transfer to the operative field. All items used with the medication should be disposed as hazardous waste. Instruments that contact antimetabolites should be washed separately.

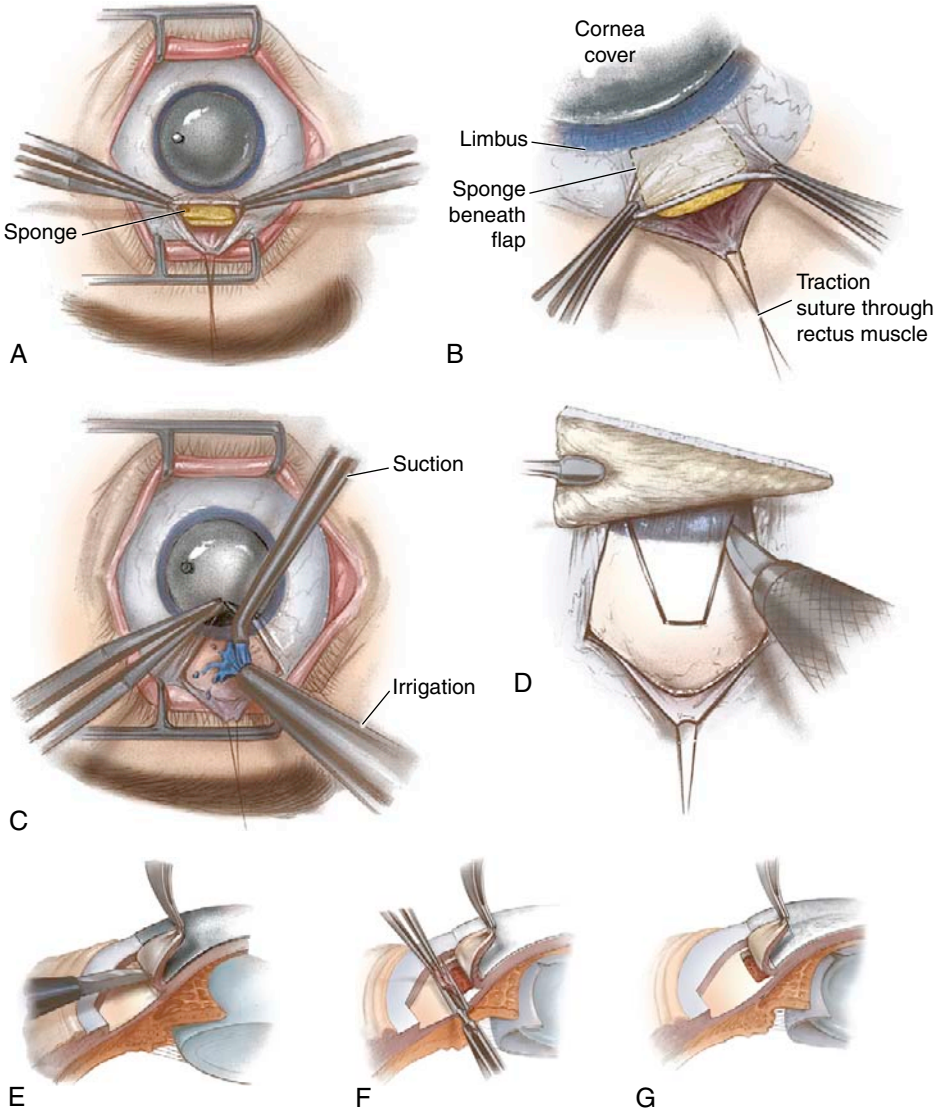


FIGURE 17-35 Trabeculectomy. **A**, Sponge soaked in antimetabolite is placed on sclera and (**B**) held in place for 3 to 5 minutes. **C**, Area is thoroughly irrigated. **D**, Scleral flap is formed. **E**, Incision is made into anterior chamber. **F** and **G**, Fistula is created by removing a flap of limbal tissue.

Operative Procedure

1. Incisions are made into the conjunctiva and Tenon's capsule, dissection is done, and a conjunctival Tenon's capsule flap is created. Hemostasis is obtained with bipolar coagulation (Figure 17-35).
2. If antimetabolite is to be used, the surgeon applies it to the sclera before making any incision into the sclera. A small piece of sponge is saturated in the antimetabolite (5-FU or mitomycin C) and placed between the conjunctival Tenon's capsule flap and the sclera. The sponge is left in place for 3 to 5 minutes, and then the site is irrigated vigorously with copious amounts of BSS.
3. The surgeon creates a square or triangular partial-thickness scleral flap.
4. The scleral flap is retracted, and the surgeon makes an incision into and through the limbus into the anterior chamber with the tip of the blade. The limbal incision is extended to a rectangular flap of deep limbal tissue, which is then excised to create the fistula.
5. An iridectomy is performed. The eye cautery is applied to bleeding sites and to the ciliary processes.
6. The surgeon replaces the scleral flap and closes it with interrupted 10-0 nonabsorbable sutures. The conjunctival Tenon's capsule flap is closed with a running suture, and the conjunctiva is closed.
7. BSS is injected through a cannula into the anterior chamber to deepen the anterior chamber and elevate the conjunctival bleb.
8. An eye pad and shield are applied.

Glaucoma Drainage Devices

Several types of drainage devices (Figure 17-36) have been implanted into the posterior subconjunctival space with varying success when filtering procedures have been unsuccessful. These include the Molteno implant, Krupin valve, Ahmed

FIGURE 17-36 Glaucoma drainage devices (GDDs). **A**, Components of GDD. **B**, Photo of Molteno3 implant. **C**, GDD in place. Tip of drainage tube in anterior chamber. Donor scleral patch or pericardium covering tube from plate to edge of cornea.

EVIDENCE FOR PRACTICE

Systematic Review of Aqueous Shunts in Glaucoma Surgery

When surgeons are unable to control primary or secondary glaucoma with medication, laser treatments, or standard surgical techniques (e.g., trabeculectomy), they may have to utilize an aqueous shunt. A variety of commercially produced shunts are available for use. Shunts lower intraocular pressure (IOP) by providing a passageway for aqueous fluid to drain from the eye and be absorbed via the capillaries into the general circulation.

Numerous studies and clinical trials have been conducted to determine which type of shunt is most effective and if shunts are more effective than other forms of therapy aimed at reducing IOP. A Cochrane Database Review examined 15 trials with a total of 1153 participants with mixed diagnoses. Other researchers reported findings to the American Academy of Ophthalmology after examining 17 previously published randomized trials, 1 prospective nonrandomized comparative trial, 1 retrospective case-control study, 2 comprehensive literature reviews, and published English language, noncomparative case series, and case reports. Both groups concluded that at this time there is no demonstrable evidence of superiority of one type or brand of shunt over another but stated that aqueous shunts do offer benefits comparable to trabeculectomy; they agree that further long-term, comparative studies are necessary to determine efficacy and note that the physician's judgment should be the key factor when making treatment decisions for patients with IOP.

Modified from Mickler DS et al: Aqueous shunts in glaucoma, *Cochrane Database Syst Rev* 19(2):CD004919, 2006; Mickler DS et al: Aqueous shunts in glaucoma: a report by the American Academy of Ophthalmology, *Ophthalmology* 115(6):1089-1098, 2008.

device, Baerveldt device, and Schocket implant. Complications have been reduced through modifications in design and technique (Evidence for Practice).

Procedural Considerations. The glaucoma drainage device may be soaked in an antibiotic solution, and the pericardium or donor patch graft will also need to be hydrated or soaked. The drainage device and graft are documented as implants per facility procedure.

Operative Procedure

1. The surgeon incises the conjunctiva and exposes the sclera.
2. Two rectus muscles are isolated using silk ties as traction sutures.
3. The surgeon takes measurements for placement of the plate of the device. The plate is then sutured to the sclera.
4. After the patency of the device is checked, the surgeon inserts an occluding suture into the drainage tube.
5. With a needle, a tunnel is created into the anterior chamber for the tube and paracentesis tract.
6. The tube is trimmed and inserted into the anterior chamber. The surgeon sutures the tube to the sclera with 9-0 nonabsorbable suture.
7. The tube is covered with patch graft of donor sclera or pericardium.
8. The occluding suture is passed through Tenon's capsule and the conjunctiva into the inferior cul-de-sac, secured with absorbable suture, and trimmed.
9. The surgeon removes the traction sutures from around the rectus muscles, and closes the conjunctiva with a continuous 7-0 absorbable suture.
10. Antiinfective agents are injected subconjunctivally. The eye is dressed with an eye pad and shield.

VITREORETINAL SURGERY

Vitreous fluid fills about two thirds of the eye, helps keep the round shape of the eyeball, and is originally attached to the retina. The vitreous slowly liquefies, atrophies, and shrinks as we age. The vitreous then can become stringy, and shadows can be cast onto the retina, causing "floaters" ("cobwebs" or specks that float in the field of vision). They may look like spots, threadlike strands, or squiggly lines. Floaters are more noticeable when looking at bright objects, such as a white piece of paper. Floaters are more common in patients who have diabetes, have undergone cataract surgery, or are nearsighted. Over time, the floaters usually settle below the line of sight but do not completely disappear. Floaters in and of themselves generally do not require treatment. However, if a patient experiences a sudden increase in the number of floaters, retinal examination is warranted to rule out a retinal tear, break, or hole (NEI, 2008c).

The retina, the light-sensitive layer of tissue lining the eye, sends visual signals via the optic nerve to the brain. Attached to the retina are millions of fine fibers intertwined with the vitreous. The shrinking vitreous in an aging eye causes the fine fibers to pull on the retinal surface. When the fibers break, the vitreous separates and shrinks from the retina, causing traction on the retina. Normally, the vitreous detaches from the retina (a posterior vitreous detachment). However, sometimes the vitreous can create traction on the retina and pull a piece of the retina with it, creating a retinal tear. Fluid can then leak under the retina into the subretinal space, leading to a retinal detachment; symptomatic breaks (manifested as new floating objects or flashing lights) are likely to progress to a retinal detachment.

Posterior vitreous detachments (PVDs) are usually not sight-threatening and, like floaters, typically do not require treatment. Patients at risk for the development of PVD are those who are nearsighted and more than 50 years of age. The condition is very common after age 80. Again, it may not be noticeable, or will simply be annoying because of an increase in floaters. A small but sudden increase in new floaters is a symptom of vitreous detachment. Flashes of light in side vision may also occur (NEI, 2008d).

Occasionally, some of the vitreous fibers pull so hard on the retina that it causes a retinal detachment (RD)—that is, the sensory retina (neural layer) is separated from the underlying retinal pigment epithelium layer. RD is considered an emergency and should be treated immediately. Anyone who has a sudden increase in floaters or an increase of lightning flashes in peripheral vision (a result of separation of the retina) should see a retinal specialist as soon as possible for an eye exam. The dilated eye exam is the only way to diagnose the exact cause of the vision problem; potentially, permanent loss of vision can occur without timely treatment (NEI, 2008e).

An additional symptom of retinal detachment is the appearance of a "curtain" in the field of vision, from above, below, or the side. Retinal detachment may occur because of the presence of intraocular neoplasms originating in the retina or choroid (exudative type) or, more commonly, as a result of retinal tears or holes associated with injury, degeneration, or vitreous contraction. One in 10,000 people develops a retinal detachment each year; 1 in 3 patients who have undergone cataract surgery develop it. Males are more likely to develop retinal detachment than females (Gutierrez and Peterson, 2007). The most common cause is diabetic retinopathy. Retinal detachment is more common in people older than 40 years. Caucasians are affected more than African Americans. Other risk factors include history of nearsightedness or retinal detachment in the other eye, family history of RD, presence of lattice degeneration (thinning of the retina in nearsighted people), and occurrence of an eye injury.

Other retinal diseases can be grouped into categories. Treatment of specific conditions partly depends on the category, such as surgical repair for structural disorders or laser repair for vascular conditions. Retinal disease categories and examples include the following:

- *Traumatic/structural:* retinal detachment, intraocular foreign body
- *Neoplastic:* choroidal melanoma, retinoblastoma
- *Immune/infectious:* endophthalmitis (infection inside the eye including pus)
- *Vascular:* diabetic retinopathy, retinal vein occlusions
- *Toxic:* systemic tamoxifen retinal toxicity

Prevention is a key emphasis to avoid the need for treatments. Studies show that optimal management of systemic disease can potentially and dramatically prevent vision loss. For example, one study demonstrated strict glucose level control over 5 to 10 years reduces the onset of diabetic retinopathy by 75% and reduces progression of retinopathy by 50%; another study showed a 35% reduction in the need for retinal laser treatment through strict control of high blood pressure (Gariano, 2008).

Microvascular disease is related to the eye's vulnerability as a result of its dense network of capillary vessels. Diabetes leads to retinal changes (diabetic retinopathy). The presence of diabetes for more than 15 years significantly increases the likelihood of developing some form of retinopathy, typically bilaterally. However, the severity may be different between eyes. Retinopathy is classified in either of the following ways:

- *Background, or nonproliferative:* In this form of retinopathy disease is confined to the retinal surface. Retinal capillary walls develop microaneurysms (bulges) that can lead to leakage and the development of exudates under the retina. Hemorrhages occur within the retina and are reabsorbed. Capillary membrane changes result in blocked capillaries and, thereby, retinal ischemia. Eventually deterioration progresses to the next stage.
- *Proliferative:* Neovascularization, or the formation of new retinal blood vessels, can develop within the retina in an attempt to relieve ischemic anoxia secondary to microvascular damage caused by diabetes. These new vessels are fragile and can rupture spontaneously, causing bleeding, and they are very permeable, causing leakage. Hemorrhage into the retina and/or vitreous can consequently ensue, leading to severe visual loss (Phillips, 2007).

The presence of retinopathy predisposes the patient to retinal detachment. In retinal detachment, pigment or blood cells are freed in the vitreous, causing the previously mentioned symptoms of flashes and floaters. Fluid from the vitreous cavity can seep through the retinal tears into the subretinal space and progressively detach the retina. The part of the retina that has separated from its nutritional source becomes damaged and relatively nonfunctional. On occasion, inflammatory/scar tissue can develop on the retinal surface, leading to an epiretinal membrane that can distort vision. As the inflammatory/scar tissue, which is firmly attached to the retina, contracts, the retina can wrinkle or "pucker." When the wrinkle is over the area of the macula, the central vision becomes blurred and distorted. Diabetic retinopathy can also lead to the macular pucker.

In the same manner, as the shrinking vitreous pulls the retina, it can cause microscopic damage. The retina heals itself by scarring, and the macular pucker can result. If the shrinking vitreous pulls too hard, the retina can tear at any location. When the macula is affected, it is more serious because of the effect on central vision, and is called a macular hole. Both macular pucker and macular hole have the same symptoms—distorted, blurred vision (NEI, 2008f). Additionally, a macular hole may present with distortion of straight lines, and difficulty reading. Vision ranges from 20/25 to 20/400 (the latter for untreated macular hole). Fifty percent of very early macular holes close on their own. Vision recovery potential is better for patients who had a macular hole for 6 months (American Society of Ophthalmic Registered Nurses [ASORN], 2007).

Various types of retinal detachment exist:

- *Rhegmatogenous:* This is the most common type. Fluid exudate from a tear or break in the retina leaks under the retina, separating it from the retinal pigment epithelium (RPE).
- *Tractional:* This form of retinal detachment is often secondary to diabetic retinopathy, especially if untreated. The retina also separates from the RPE, but this time it is attributable to the contraction of scar tissue on the retina's surface.
- *Exudative or serous:* In inflammatory retinal disease or trauma, fluid exudate leaks under the retina. In this type, however, there are no breaks or tears in the retina.

Location of the pathology on the retina affects visual symptoms. Macular pucker, for example (also called epiretinal membrane, preretinal membrane, retina wrinkle, or internal limiting membrane disease), generally affects the macula, located in the center of the retina. The macula normally provides sharp, central vision needed for reading, driving, and fine detail work, and when puckered can cause blurred, distorted central vision.

Various modalities for surgical treatment include laser treatments, scleral buckling, vitrectomy, and retinopexy. In addition to any of these therapies, freeze treatment (cryopexy) may be performed in the surgeon's office for small holes and tears to help "weld" and reattach the retina (NEI, 2008d).

LASER TREATMENT IN DIABETIC RETINOPATHY

Laser energy is used to apply burns to peripheral retinal tissue to help neovascularization regress. The pathophysiologic mechanism for regression of neovascularization is not completely understood, but is thought to occur as a result of the reduced retinal oxygen requirement as a result of the scarred retinal tissue. This method of eliminating abnormal vascularization is called panretinal photocoagulation (PRP). Again, in principle, early diagnosis and control of blood glucose levels are paramount, as laser treatment does indeed partially destroy the retina in order to help arrest neovascularization. Thus surgeons use the laser before excess damage occurs, electrocoagulating minute hypoxic areas to prevent the new vessels from forming (Phillips, 2007) (Figure 17-37). Laser treatments may initially begin in an office setting or later within the OR in conjunction with surgeries. The laser may be applied through the slit lamp, with the indirect ophthalmoscope, or directly during vitrectomy surgery using an intraocular endolaser probe.

VITRECTOMY

Vitrectomy is narrowly defined as removal of all or part of the vitreous gel (body). In the broader clinical sense of the term, vitrectomy surgery can also include the excision and removal of fibrotic membranes, removal of epiretinal membranes, and electrocoagulation of bleeding vessels. In its normal state, the vitreous gel of the eye is transparent. In certain disease states, bleeding from damaged or newly formed vessels may cause the vitreous to become opaque, which may severely decrease vision. In addition to the patient's inability to see, the surgeon is unable to visualize the retina and therefore treat the underlying pathologic condition before permanent damage can occur. In these cases, vitrectomy surgery is indicated to restore the patient's vision and to allow the surgeon to institute treatment if indicated.

Formation of membranes may block the visual axis and may cause decreased vision. Contraction of these membranes may produce traction-type or rhegmatogenous retinal detachment. In these cases, vitrectomy surgery is indicated to relieve the underlying pathologic processes leading to decreased vision.

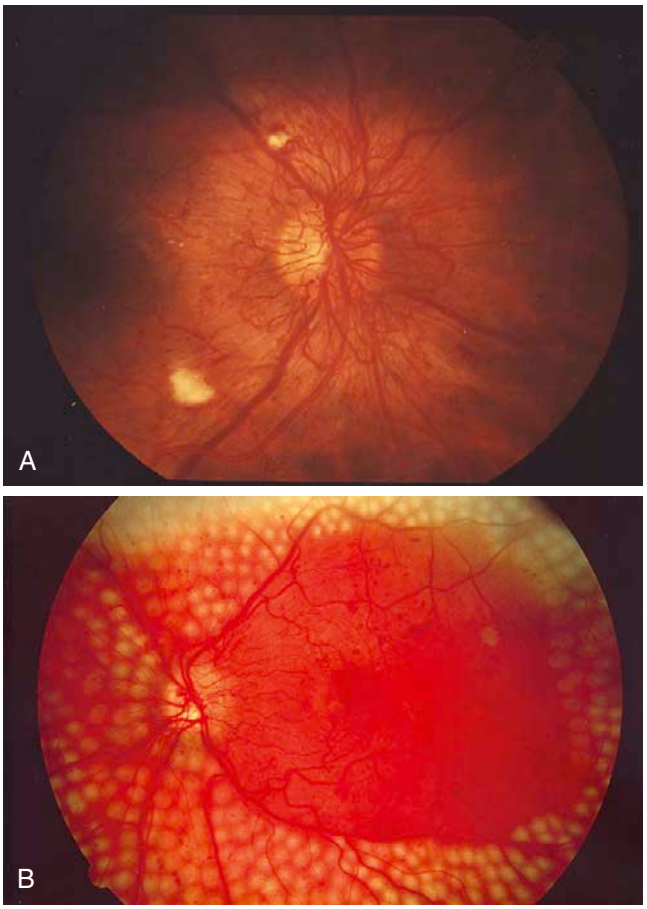


FIGURE 17-37 **A**, Proliferative retinopathy, an advanced form of diabetic retinopathy, occurs when abnormal new blood vessels and scar tissue form on the surface of the retina. **B**, Fundus photo showing scatter laser surgery for diabetic retinopathy.

Posterior Segment Vitrectomy

A pathologic condition in the posterior segment is usually approached through the pars plana, which is tissue that is anterior to the anterior attachment of the retina, typically located 3 to 4 mm from the limbus (corneoscleral junction). Since the pars plana has no retinal tissue, entry at this site poses little risk for retinal detachment (Phillips, 2007). The main indications for posterior segment vitrectomy through the pars plana are as follows:

- Long-standing vitreous opacities
- Advanced diabetic eye disease
- Severe intraocular trauma
- Retained foreign bodies
- Proliferative vitreoretinopathy
- Retinal detachment from giant tears
- Endophthalmitis
- Diagnostic vitreous biopsy

Essentially, vitrectomy vacuums any pooled blood to enhance clarity. Complications of vitrectomy include retinal detachment, retinal tears, cataract, and infection. Of course, the risk of no treatment can be total loss of vision.

Procedural Considerations. Vitrectomy of the posterior segment is a microsurgical procedure requiring a viewing system (operating microscope with an X-Y coupling, zoom lens, and fine focus), contact lens system or noncontact wide-angle viewing system (e.g., Biom), an illumination system, a cutting-suction-infusion system, and accessory instruments.

The surgeon can hold the contact lens in place by hand or can suture it for stabilization. Another option to a sew-on lens is the use of a noncontact panoramic wide-angle viewing system. This system allows a wide, noncontact view of the macula and is mounted to the microscope and swings out of the way for extraocular phases of the vitrectomy. Other advantages are that it provides a good view under air, eliminates the time needed to sew on a lens, and does not require an assistant to hold the lens. The eye may be rotated freely to view the extreme periphery. The image is inverted by a manual knob, foot pedal, or hand control.

The infusion system consists of a 500-ml bottle of buffered BSS, such as BSS Plus or Endosol Extra, a standard IV administration set, and an infusion needle or sleeve. The level of intraocular pressure can be varied by elevating or lowering the infusion bottle in relation to the patient's eye and by adjusting the digital readout of the nitrogen gas–forced infusion.

The suction and cutting systems vary in sophistication and technology. All cutters engage tissue into a port and then cut it by the shearing action between the edges of a moving and a nonmoving part. Guillotine cutters have a linear, back-and-forth action, whereas reciprocating or oscillating cutters rotate in a clockwise-counterclockwise fashion. Suction is operated with a pump controlled by a foot switch to maintain the level of aspiration. The cutter may be part of a single-use multifunction handpiece.

An endolaser or indirect laser delivery system is usually available for photocoagulation. Illumination for vitrectomy is *external,* using the operating microscope for anterior segment vitrectomy; and *internal,* using a fiberoptic light pipe (endoilluminator) for posterior segment vitrectomy. A special light pipe (cannonball) that illuminates a wider area is needed if a wide-angle viewing system is used on the microscope. See Figure 17-38 for the Mayo stand setup of vitrectomy machine attachments.

Replacement of the vitreous with air is facilitated with a special air-exchange unit that may be incorporated into the multifunction vitrectomy machine. Other substances for intraocular tamponade are liquid perfluorocarbons, silicone oil, perfluoropropane gas (C_3F_8), and sulfur hexafluoride gas (SF_6).

Accessory instruments originally had a 20-gauge diameter so that they can be interchanged throughout the procedure. Several accessory instruments may be used for pars plana vitrectomy, depending on the extent of the procedure. Microhooks, picks, and subretinal forceps and scissors (Figure 17-39) are used for dissection, peeling, and removal of membranes. These instruments can be manually operated with a thumb control or run with compressed air from the automated vitrectomy console. Even smaller 23-gauge and 25-gauge trocars allow for finer instrumentation without the need for suturing the trocar sites. This microincisional sutureless surgery has become increasingly prevalent with retinal surgeons. Foreign-body microforceps and various magnetic devices are used to retrieve foreign objects of glass, metal, or other substances.

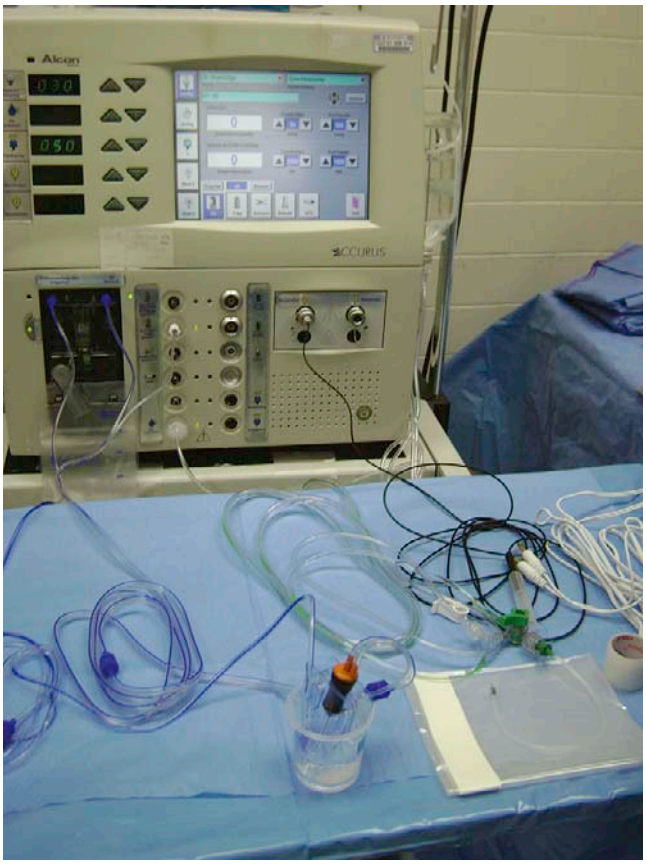


FIGURE 17-38 Mayo stand setup for posterior vitrectomy. *Left to right:* Extrusion tubing for aspiration with soft-tip cannula; vitrectomy cutter handpiece tested in BSS; infusion cannula; intraocular light pipe; bipolar electrosurgery cord. Note bottle hangs at level of patient's eye.

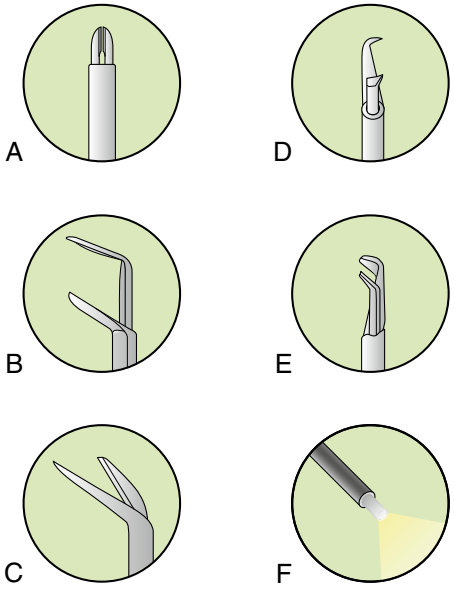


FIGURE 17-39 Tips of micro instruments used in vitrectomy procedures. **A** and **B**, Peeling forceps. **C**, Horizontal scissors. **D**, Vertical scissors. **E**, Membrane peeler and cutter (MPC). **F**, Lighted pick.

An intraocular cryoprobe for cryocoagulation directly on the retina surface can be attached to the cryotherapy device. Flute needles or disposable soft-tipped cannulae are handheld or attached to an extrusion or aspiration line for evacuating pools of blood or for fluid-gas exchange. The soft silicone tips can come into close proximity to the retina without scratching or damaging the tissue.

To prepare for a vitrectomy procedure, the perioperative nurse must know the location of the ocular problem, the surgeon's plan to address the problem, the instrumentation to be used, and the anticipated extent and length of the procedure. Instrument and equipment functioning should be thoroughly checked before the patient is transferred into the OR. When preparing for pars plana vitrectomy in the posterior segment, the perioperative nurse must be aware that a combined scleral buckling procedure may be necessary. Clear communication with surgeons paves the way for effective preparations.

In the case of giant retinal tears, C_3F_8, SF_6, liquid per fluorocarbons, and silicone oil can be used to provide retinal tamponade. Intraocular expansible gases (C_3F_8, SF_6) can be used to provide retinal tamponade, but usually require the patient to be positioned facedown for several weeks in order to help reattach the retina. The expansible gas will slowly be absorbed by the body (usually over a period of 2 to 3 months) as aqueous humor produced by the ciliary body slowly displaces it (Research Highlight). Silicone oil can be used for complicated cases and when positioning would be difficult for patients. The disadvantage of silicone oil is that the patient will require another surgery to remove the silicone oil in the future as the index of refraction of silicone oil is significantly different than that of vitreous, giving patients the impression that they are "looking through a crystal ball."

RESEARCH HIGHLIGHT

Patient Perspective of Extended Facedown Positioning Revealed through Journaling

Facedown positioning is required after certain ophthalmic procedures, such as macular hole surgery, to optimize retinal reattachment. Adherence is often difficult because of physical and psychologic challenges. The experience according to a patient's perspective is rarely documented in research literature.

In a separate study on functional outcomes of macular hole surgery, a self-motivated patient presented to researchers the diary that she had written during her 77-day recovery period. When the researchers requested a qualitative analysis of her journal, she consented.

Seven categories of content emerged: emotional state, quality of sleep, nutritional considerations, visual functioning, physical status, social support, and entertainment needs. Overall, this study gives patients and their caretakers (including nurses) a better understanding of what facedown positioning means to an individual during the extended recovery period. This patient's successful coping can provide hope for other potential patients. Guidelines can be developed and refined for overcoming both physical and psychologic barriers.

Modified from Wittich W, Southall K: Coping with extended facedown positioning after macular hole surgery: a qualitative diary analysis, *Nurs Res* 57(6):436-443, 2008.

Liquid perfluorocarbons such as perfluorooctane (PFO) or Perfluoron, being heavier than BSS, will allow the retina to be pushed posteriorly and so are used as a tamponade to help repair a giant retinal tear. The liquid is then removed from the posterior segment. Silicone oil is a highly viscous oil with a high surface tension that mechanically limits fibrovascular proliferation. The oil may be left in place, but it is recommended that it be removed within 1 year if the retina is reattached and stable. Silicone oil may cause increased intraocular pressure and secondary glaucoma. The National Eye Institute supported a nationwide clinical trial comparing treatment of proliferative vitreoretinopathy with silicone oil or long-acting intraocular gas. The results indicate that either treatment is effective and surgeons thus have options in treating such cases (NEI, 2008d).

Vitrectomy procedures vary in length from less than 1 hour to more than 3 hours. When a long procedure is anticipated, care must be taken to protect the patient's skin and reduce pressure areas. A foam mattress pad, heel and elbow protectors, and elasticized stockings may be used. A wrist support may be placed around the patient's head to support the surgeon's wrist during manipulation of the intraocular instruments.

Because of the amount of fluid used in the operative field during this procedure the perioperative nurse carefully assists with draping to allow for removal of infusion fluid from the field and ensures the electric foot pedals are protected from fluid damage.

Operative Procedure

PARS PLANA VITRECTOMY

1. The eye is prepped and draped using standard sterile conditions for ophthalmic surgery. The surgeon places a lid speculum and incises the conjunctiva (Figure 17-40).
2. The surgeon sutures the infusion line in place with a purse-string suture (for 20-gauge surgeries) and checks it for proper placement.
3. Generally, three incisions are made through the pars plana: one for infusion, one for endoillumination, and one for a vitreous cutter or other instrumentation (e.g., pick, forceps, scissors, laser probe, extrusion needle). In the right eye, these incisions are placed at clock hours 8, 10, and 2; for the left eye, this corresponds to 2, 4, and 10. An illuminating chandelier can also be placed (typically at the 6 o'clock position) for bimanual surgery.
4. The operating microscope is aligned. A wide-angle viewing system is swung into position, or a fundus lens is fixed on the anterior surface of the cornea.
5. The perioperative nurse confirms that the proper infusion rate, cutting rate, and aspiration rate are set on the machine console. If a dense cataract or retained lens material blocks the view of the retina, a lensectomy may be performed with a Fragmatome or other ultrasonic handpiece at this time.
6. The surgeon removes the vitreous under direct visualization. Once the medium has been removed and the retinal condition visualized, the necessary injections or treatments (endolaser photocoagulation, repair of macular pucker, insertion of silicone oil, gas-fluid exchange) (Figure 17-41) are completed. A scleral buckling procedure may also be performed.
7. The trocars are removed from the pars plana incisions. Cultures from the vitreous washings are taken if necessary.
8. Subconjunctival injections of steroids or antibiotics are given. An eye pad and shield may be applied for protection of the eye, although some surgeons opt not to use them.

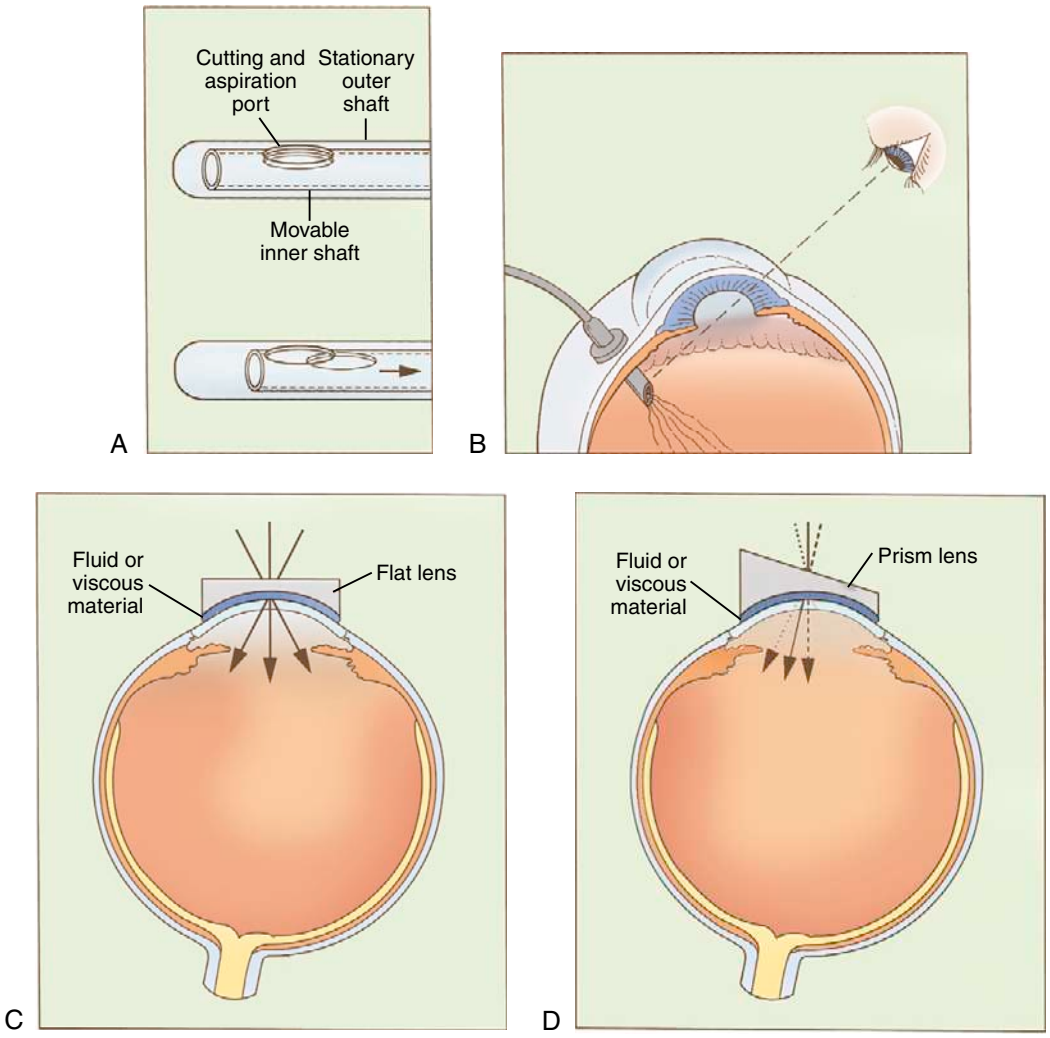


FIGURE 17-40 Essential components for vitrectomy. **A**, Vitrector probe with its cutting/aspirating port close to the tip of the intraocular portion of the handpiece. **B**, Infusion cannula, placed in pars plana, is viewed for correct position. **C**, Flat contact lens, resting on cushion of fluid or viscoelastic material on the cornea, is used for viewing posterior half of the vitreous cavity and retina. **D**, Prism contact lens used for viewing anterior structures in the vitreous cavity.

Scleral Buckling

Procedural Considerations. In the treatment of retinal detachment, the aim is to return the retina to its normal anatomic position. For this specific procedure, repair is done from outside the globe. The purpose of the scleral buckling procedure for retinal detachment is to cause an intrusion or push into the eye at the site of the pathologic source. Treatment by diathermy or cryotherapy causes an inflammatory reaction that leads to a permanent adhesion between the detached retina and underlying structures. The surgery also involves sealing off the area in which the tear or hole is located and may include drainage of the subretinal fluid.

The procedure may be performed using general anesthesia or MAC with local blocks. The scleral buckling may be done using episcleral (working outside of the sclera) technique or by scleral dissection (making a partial-thickness incision into the sclera and creating flaps to expose the underlying tissue). Both techniques may use drainage of subretinal fluid, encircling bands, diathermy, light coagulation, or cryotherapy. Cryosurgery or light coagulation may be used alone or in combination with a buckling procedure.

Operative Procedure

1. A detailed drawing of the retina may be made before surgery and is displayed in the operating suite according to surgeon preference. On the basis of this drawing, the surgeon opens the conjunctiva to a previously determined extent, for example, 90 degrees for a simple horseshoe tear or 360 degrees for an aphakic detachment (Figure 17-42).
2. The inferior, superior, lateral, and medial rectus muscles are isolated using 0 silk ties as traction sutures.
3. Using the indirect ophthalmoscope, the surgeon locates the detachment and tear and marks the site with nonpenetrating diathermy by indentation or with a methylene blue marking pen.
4. Under direct visualization, the surgeon applies the retinal cryoprobe to the external surface of the globe in the area of the pathologic condition and treats the area. An ice ball is seen to form in the proper areas until the entire lesion has been treated.

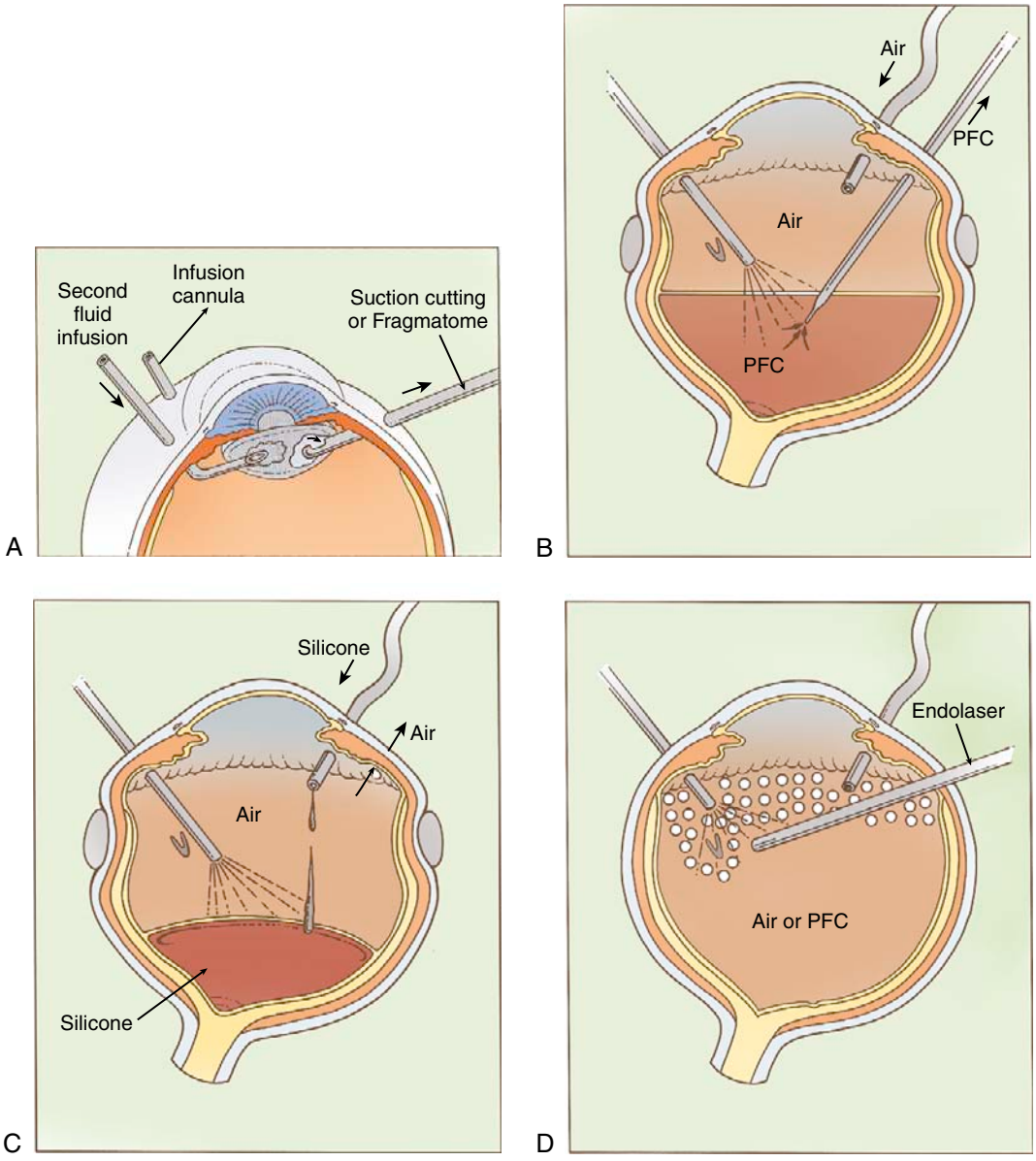


FIGURE 17-41 Procedures done with vitrectomy. **A**, Pars plana lensectomy performed with a second infusion line. **B**, Air/perfluorocarbon (PFC) exchange. The PFC has been placed in the vitreous cavity for removal of subretinal fluid and anatomic reattachment of the retina. Air under positive pressure is then placed through the infusion cannula as the PFC is simultaneously extruded through the tapered needle. **C**, Silicone/air exchange. Silicone is inserted through the infusion cannula as a temporary intraocular tamponade. Silicone is heavier than air and fills the globe from the bottom up, and the air escapes through the sclerotomy site. In silicone/fluid exchange, the silicone floats on the fluid and the fluid is removed with an extrusion needle. **D**, Endolaser photocoagulation is performed after the retina is returned to its normal position.

5. The buckling component of the procedure secures silicone bands, sponges, plates, or tires to the sclera. The surgeon places nonabsorbable sutures (4-0 or 5-0) into the sclera surrounding the lesion and ties them over the silicone sponge, causing the outer shell of the eye to be pushed toward the elevated retina.
6. If an encircling band is to be used, the surgeon places mattress sutures into the sclera in four quadrants. A silicone band is passed 360 degrees around the eye under the sutures and the rectus muscles. The sutures are tied, and a self-holding Watzke sleeve is applied to the band to maintain a predetermined circumference. This causes a 360-degree constriction of the outer coats into the eye.
7. If drainage of subretinal fluid is desired, the surgeon chooses an area under direct visualization in which a significant fluid level exists under the retina, and places a diathermy mark on the sclera. The sclera is split to the choroid, and a small amount of diathermy is applied to the choroid bed. A 27-gauge ½-inch needle is then used to puncture the choroid into the subretinal space to permit drainage of fluid.

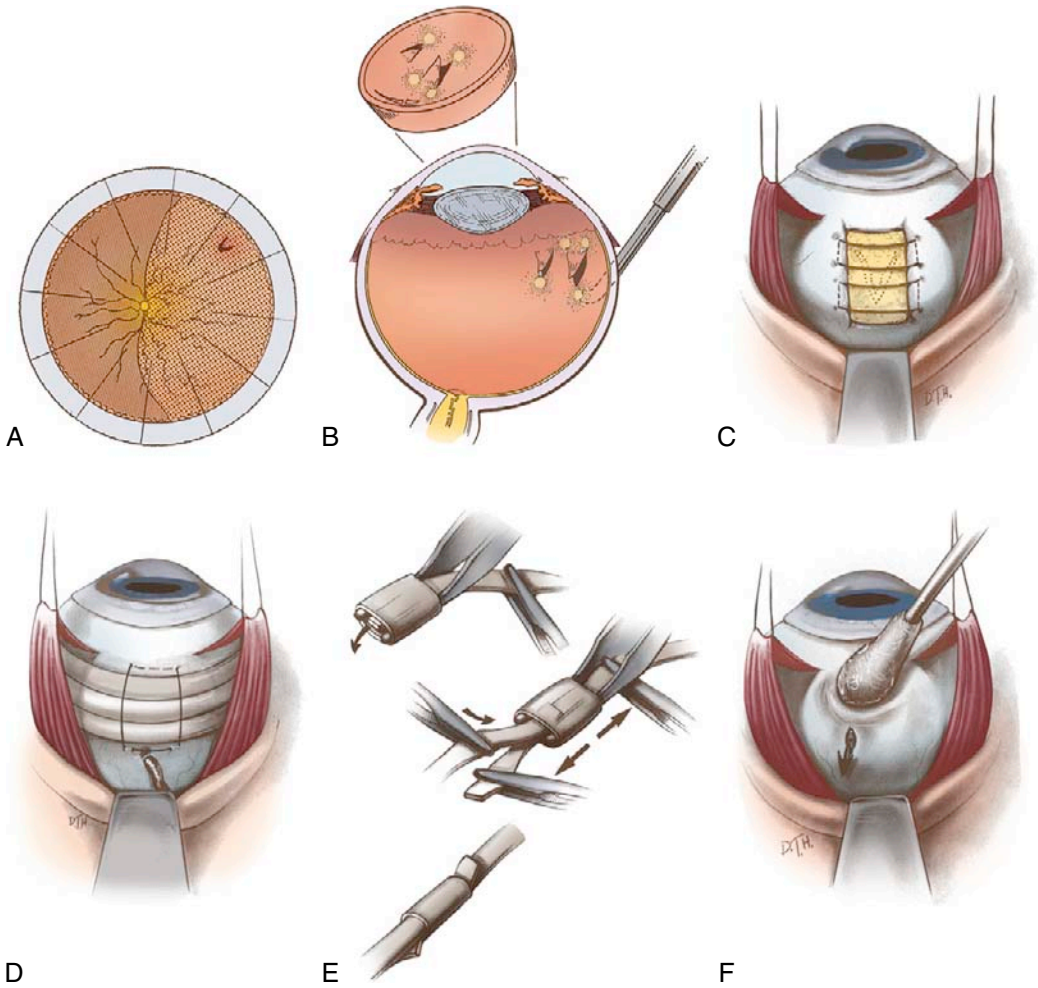


FIGURE 17-42 Scleral buckling operation for treatment of retinal detachment. **A**, Diagram of retina showing detachment of retina of temporal half of left eye, with retinal tear at equator of globe at 1:30 o'clock position. **B**, Examination of fundus by means of ophthalmoscope and handheld lens and depression of sclera with diathermy electrode. Surgeon visualizes field and places electrode beneath retinal tear; burn mark is made on sclera at site of retinal tear with diathermy electrode. **C**, A sponge is sutured in place over treated site of retinal tear. **D**, Band and tire are used to encircle the eye. **E**, Placement of Watzke silicone sleeve is one method to secure edges of encircling band. **F**, Small incision is made through sclera, and choroid is finely incised to allow subretinal fluid to drain.

8. Air or replacement fluids may be introduced into the eye after the drainage of subretinal fluid. This is usually done through the pars plana under direct visualization.
9. The surgeon removes the traction sutures from around the muscles and closes the conjunctiva with 7-0 absorbable suture. A subconjunctival injection of an antibiotic, steroid, or both may be given, and an eye pad is applied.

Retinopexy

In pneumatic retinopexy (Figure 17-43) an intraocular injection of a bubble of air or therapeutic gases provides pressure against retinal breaks, allowing the detached retinal breaks to approximate the pigment epithelium. Retinopexy may be used in combination with scleral buckling and posterior vitrectomy; it may be performed as part of an ambulatory procedure for treatment of certain retinal detachments, using laser photocoagulation with injection of the gas bubble followed by specific postoperative positioning. The gases are drawn through a Millipore 0.22-micrometer filter and may be mixed with filtered air so that the concentration may be varied. The gas bubble is a ratio mixture of gas and air. The higher the concentration of gas to air, the longer the bubble remains in the eye before being "absorbed." Patient positioning after retinopexy is often facedown for several days to weeks but may include tilting the head to one side or the other as well. The head position is determined by the location of the retinal tear/hole. For example, if the retinal tear/hole is located superior temporal in the right eye, the patient would be instructed to tilt the head down and to the left, so the bubble will float upward and to the right where the tear/hole is located. The larger the tear/hole, the longer the bubble needs to be in contact with the area to be reattached.

Sulfur hexafluoride gas (SF_6) is colorless, odorless, and nontoxic. It increases 2.5 times in volume within 48 hours after injection by drawing other gases, specifically nitrogen and oxygen, from the surrounding tissues. SF_6 bubbles remain for at least 10 days (Donlon et al, 2005).

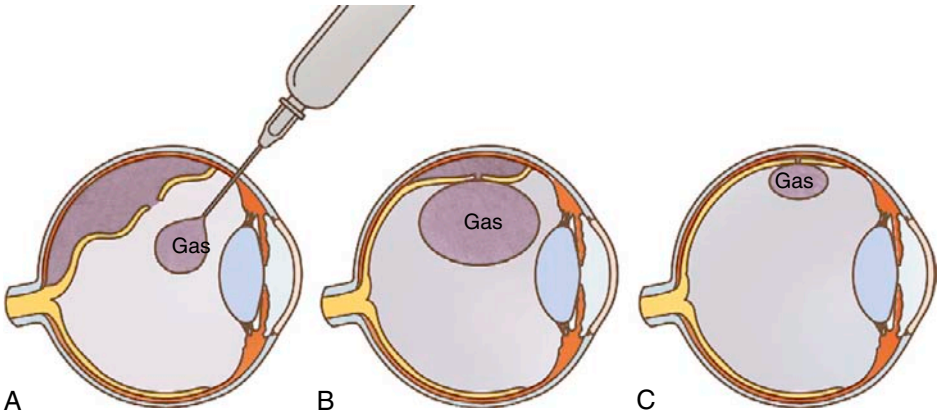


FIGURE 17-43 Pneumatic retinopexy. **A**, Gas bubble is injected through the pars plana. **B** and **C**, The bubble closes and supports the retinal break. After a 7- to 10-day healing period and when the retina is returned to normal position, laser surgery or cryotherapy can be performed to seal the break.

Perfluoropropane gas (C_3F_8) is colorless, odorless, and nontoxic. It quadruples its volume within 48 hours after injection. A 1-mm bubble can remain up to 30 to 50 days.

Because SF_6 and C_3F_8 are expansible gases, certain precautions are required. Patients are given a wristband to wear that states what kind of gas bubble is in their eye and when it was instilled. If they would require surgery, they need to alert the anesthesia provider of the presence of the gas bubble. The intent of instilling a gas bubble is to sustain its size and hold the retina in place. SF_6 and C_3F_8 are inert, very insoluble in water, and poorly diffusible. Since nitrous oxide (N_2O) is 117 times more diffusible than SF_6, it rapidly enters the gas bubble. With continued administration of N_2O the injected gas bubble can increase to three times its original size. Intraocular pressure (IOP) can increase from 14 to 30 mm Hg; 18 minutes after discontinuation of N_2O, IOP will decrease along with the smaller bubble size. Such quick and wide variations in bubble size can negatively affect the surgical outcome. Therefore N_2O should be discontinued at least 20 minutes before an intravitreal gas injection to ensure stable bubble size and IOP. Some anesthesia providers avoid using N_2O for any case where intravitreal gas injection is anticipated. Patients are instructed to avoid air travel until the gas bubble is completely resolved or decreased to a level of 5% of the vitreous volume. Cabin pressurization in air travel will cause severe enlargement of the gas bubble with an increase in intraocular pressure and eye pain. Car or train travel to high elevations should also be avoided unless the change in altitude is done gradually. N_2O should be avoided for 3 to 4 weeks after intravitreal gas injection. The exposure to N_2O could reexpand the bubble, increase IOP, and thereby occlude the retinal artery with loss of vision (Donlon et al, 2005).

Overall, 90% of patients with retinal detachment can now be successfully treated. This is a great advance considering some of the same conditions were inoperable 40 years ago. Visual outcomes, however, are not always predictable, and additional treatment may be necessary. A successful anatomic result of retinal reattachment unfortunately does not always correlate with improvement in visual function. It may take up to several months to evaluate the final visual result. Occasionally, even with the best efforts and multiple attempts at repair, treatment may fail; sight may not be able to be restored. This discussion is part of informed consent. Repairing a detachment before the macula detaches provides the best visual results.

REFERENCES

Alhassan MB et al: Peribulbar versus retrobulbar anaesthesia for cataract surgery, *Cochrane Database Syst Rev 2008* (Issue 3), 2008, Art. No.: CD004083.

American Academy of Ophthalmology (AAO): Patient Safety: Recommendations of American Academy of Ophthalmology Wrong Site Task Force 2008, available at http://one.aao.org/CE/PracticeGuidelines/Patient_Content.aspx?cid=d0db838c-2847-4535-baca-aebab3011217&popup. Accessed May 10, 2009.

American Academy of Ophthalmology (AAO): Clinical statements: Flomax patient advisory, San Francisco, June 2009, available at http://one.aao.org/CE/PracticeGuidelines/ClinicalStatements_Content.aspx?cid=21255f9c-6e66-4684-a3ca-5aa1f4f13ad3. Accessed June 11, 2009.

American Society of Anesthesiologists (ASA): Standards and Practice Committee, Basic Standards for Preanesthesia Care, 2005, available at www.asahq.org/publicationsAndServices/standards/03.pdf. Accessed April 27, 2009.

American Society of Ocularists (ASO): *The American society of Ocularists: 50+ years of excellence in the field of ocular prosthetics: research, education, standards*, Coralville, IA, 2009, ASO.

American Society of Ophthalmic Registered Nurses (ASORN): The aging retina, *Insight* (4):1–11, 2007.

Association of periOperative Registered Nurses (AORN). *Perioperative standards and recommended practices*. Denver, 2009, The Association.

Bollinger KE, Langston RH: What can patients expect from cataract surgery? *Cleve Clin J Med* 75(3):193–200, 2008.

Burlew-Quartey J: Anterior Segment Surgery and the Nurse's Role, Atlanta, November 2008, Presentation at ASORN Conference.

Cullen KA et al: Ambulatory surgery in the United States, 2006, Centers for Disease Control and Prevention, National Center for Health Statistics, Division of Health Care Statistics, Hyattsville, MD, available at www.cdc.gov/nchs/data/nhsr/nhsr011.pdf. Accessed April 19, 2009.

Denholm B: Tucking patient's arms and general positioning, *AORN J* 89(4):755–757, 2009.

Dodge-Palomba S: Providing compassionate care to the pediatric patient undergoing enucleation of the eye, *Insight* 33(1):10–12, 2008.

Donlon JV et al: Anesthesia for eye, ear, nose and throat surgery, In Miller RD, editor: *Miller's anesthesia*, ed 4, Philadelphia, 2005, Churchill-Livingstone.

Donnenfeld E: Refractive Surgery Update—2008, Atlanta, November 2008, Presentation at ASORN Annual Meeting.

Eye Bank Association of America (EBAA): Frequently Asked Questions: Corneal Transplant, available at www.restoresight.org/aboutus/faqs.htm. Accessed May 8, 2009.

Gariano R: Medical and Surgical Treatment of Retinal Diseases, Presentation at ASORN Annual Meeting, Atlanta, November 2008.

Gutierrez KJ, Peterson PG: Alterations in visual and auditory function, In Peterson PG, Gutierrez KJ, editors: *Saunders nursing survival guide: Pathophysiology*, ed 2, St. Louis, 2007, Saunders.

Harris J: Sharps safety in the ophthalmic setting, Franklin Lakes, NJ: BD Medical Ophthalmic Systems, p. 26. 2008.

Jennings J, Foster J: Medication safety: just a label away, *AORN J* 86(3): 618–625, 2007.

Lighthouse International: The Lighthouse for the 21st Century: Helping Millions with Vision Loss, San Francisco, CA, 2007.

Menke AM: *Legal Issues in Ophthalmology: Preventing Surgical Confusion (Review of Wrong-Site Task Force Recommendations)*, Atlanta, November 2008, Presentation at ASORN Annual Meeting.

Mitchell S: Sterilization: practicing the complete sterilization process, *AORN Connections* 7(5):10, 2009.

National Eye Institute (NEI, 2008a): 2005 Survey of Public Knowledge, Attitudes, and Practices (KAP) Related to Eye Health and Disease, available at www.nei.nih.gov/kap/. Accessed on April 19, 2009.

National Eye Institute (NEI, 2008b): NEI Health Information: Facts About Cataracts, available at www.nei.nih.gov/health/cataract/cataract_facts.asp. Accessed March 25, 2009.

National Eye Institute (NEI 2008c): NEI Health Information: Facts About Floaters, available at www.nei.nih.gov/health/floaters/index.asp. Accessed April 22, 2009.

National Eye Institute (NEI 2008d): NEI Health Information: Facts About Retinal Detachment, available at www.nei.nih.gov/health/retinaldetach/index.asp. Accessed April 22, 2009.

National Eye Institute (NEI 2008e): NEI Health Information: Facts About Vitreous Detachment, available at www.nei.nih.gov/health/vitreous/index.asp. Accessed April 22, 2009.

National Eye Institute (NEI 2008f): NEI Health Information: Facts About Macular Pucker, available at www.nei.nih.gov/health/pucker/index.asp. Accessed April 22, 2009.

National Quality Forum (NQF): National Quality Forum Endorses Guidelines to Reduce Disparities in Healthcare and Make Care Patient-Centered and Culturally Appropriate, 2009, available at www.qualityforum.org/news/releases/02%2009%20Cultural%20Competency.pdf Accessed May 11, 2009.

Nichols JR: Taking Care of Your Scleral Cover Shell Ocular Prosthesis, June R.R. Nichols, Ocularist Ltd.; ASO diplomate, Board Certified, Des Plaines, IL, 2009.

Pagana KD, Pagana TJ: *Mosby's diagnostic and laboratory test reference*, ed 9, St Louis, 2009, Mosby.

Phillips N: *Berry & Kohn's operating room technique*, ed 11, St Louis, 2007, Mosby.

Prevent Blindness America (PBA): The Vision Learning Center: Eye Safety: Prevent Eye Injuries at Home, at Work, and at Play! 2005, available at www.preventblindness.org/safety/. Accessed April 19, 2009.

Stuart A: "Birthday for a Beam of Light: Happy 25! A Quarter Century of the Excimer Laser." In Academy News: Eye Net Magazine: Scientific Highlights of Atlanta 2008, available at www.aao.org/publications/eyenet/upload/01AN.pdf. Accessed May 31, 2009.

The Joint Commission: NPSG.03.04.01: Labeling in Procedural Areas, available at www.jointcommission.org/AccreditationPrograms/Office -Based-Surgery/Standards/09_FAQs/NPSG/Medication_safety/NPSG.03.04.01/Labeling+in+procedural+areas.htm. Accessed April 27, 2009.

CHAPTER 18

Otorhinolaryngologic Surgery

TROY J. DeROSE and GREGORY ARTZ

Otorhinolaryngology is the study and science of the human ear (*oto*), nose (*rhino*), and throat (*laryngo*). It is a specialty that continues to evolve as a result of cutting-edge technology; high-powered surgical microscopes; narrower, flexible endoscopes; computer imaging; wound care improvements; and navigation systems that communicate with radiologic imaging. Such advances yield significant gains in improving the health and surgical outcomes of patients with physical ailments of the head and neck. This chapter comprehensively and respectively reviews perioperative care of patients undergoing surgical procedures to the ear, nose, head, and neck.

Surgical Anatomy

EXTERNAL, MIDDLE, AND INNER EAR

The ear is a sensory organ for the identification, localization, and interpretation of sound as well as for the maintenance of equilibrium. Hearing is the sense by which sounds are appreciated. Referred to as the "watchdog of the senses," hearing is the last sense to disappear when one falls asleep and the first to return when one awakens. The physical nature of sound results from the compression and rarefaction of pressure waves and moving molecules, but the sensations humans actually experience are the product of complex mechanical, electrical, and psychologic interactions in the ear and central nervous system. Three anatomic segments—the external ear, middle ear, and inner ear—work together to provide hearing and balance (Figure 18-1).

The *external ear* includes the auricle (or pinna) and external auditory canal, and is composed of cartilage covered with skin. The auricles are fixed in position and lie close to the head; they concentrate incoming sound waves and conduct them into the external auditory canal. Both ears provide stereophonic hearing that gives us very specific sound localization capabilities. Without binaural hearing, determining where sounds emanate can be difficult; this is a common problem for patients with unilateral or asymmetric hearing loss.

The external auditory canal, an S-shaped pathway leading to the middle ear, is approximately 2.5 cm in length in adults and shelters the tympanic membrane. Its skeleton of bone and cartilage is covered with very thin, sensitive skin. The canal lining is protected and lubricated with cerumen, a waxy substance secreted by sebaceous glands in the distal third of the canal. Cerumen helps to trap foreign material, and has a mildly acidic pH that reduces bacterial levels in the outer ear.

Located at the end of the external auditory canal is the *tympanic membrane* (eardrum) (Figure 18-2). It is a thin structure with three distinct layers: an outer squamous epithelial layer in continuity with the skin of the external ear canal, a fibrous middle layer for strength and support, and a medial mucous membrane layer that is continuous with the lining of the middle ear.

The *middle ear* is filled with air, which flows from the nasopharynx through the eustachian tube. It is divided into three areas: the epitympanum (upper), mesotympanum (middle), and hypotympanum (lower). Posteriorly, the epitympanic portion of the middle ear communicates with the mastoid air cells of the temporal bone via the mastoid antrum. The mucous membrane of the middle ear is continuous with that of the pharynx and the mastoid cells, making it possible for infection to travel to the middle ear (otitis media) and mastoid cells (mastoiditis). The eustachian tube serves to aerate the air-filled spaces of the temporal bone and to equalize pressure in the middle ear with atmospheric pressure. It is normally closed at rest and actively opens during yawning, sneezing, or swallowing. A chain of three small articulated bones (ossicles) extends across the middle ear cavity and conducts vibrations (airborne sound waves) from the tympanic membrane across the middle ear into the oval window and the fluid-filled inner ear (Figure 18-3).

The *malleus* (hammer) consists of a head, neck, handle, and short process. The handle and short process are attached to the undersurface of the eardrum, and the head articulates with the body of the incus in the upper segment of the middle ear called the epitympanum or "attic." The *incus* (anvil) consists of a body and long and short processes (see Figure 18-2). The distal end of the long process of the incus is called the lenticular process and articulates with the capitulum (head) of the stapes, which is the third, innermost bone. The *stapes* (stirrup) consists of a head, neck, anterior and posterior crura, and a mobile footplate that is secured to the oval window by an annular ligament. The movable joints between these ossicles contribute to a lever system that amplifies the received sound and transmits and converts vibrations from ambient air to the fluid of the inner ear.

The inner ear is protected from loud noise by the *tensor tympani* muscle, which draws the drum inward to increase tension and restricts its ability to vibrate, and the *stapedius* muscle, which contracts and tightens the stapes in the oval window to reduce the intensity of vibrations passing through the ossicles into the inner ear. The middle ear and mastoid are supplied with blood from the branches of the internal and external carotid artery systems.

The *inner ear* is a membranous, curved cavity located in the petrous portion of the temporal bone; it contains hair cell receptors that provide us with both hearing and balance. The inner ear consists of a bony labyrinth filled with a watery fluid (perilymph) that surrounds and bathes a membranous labyrinth

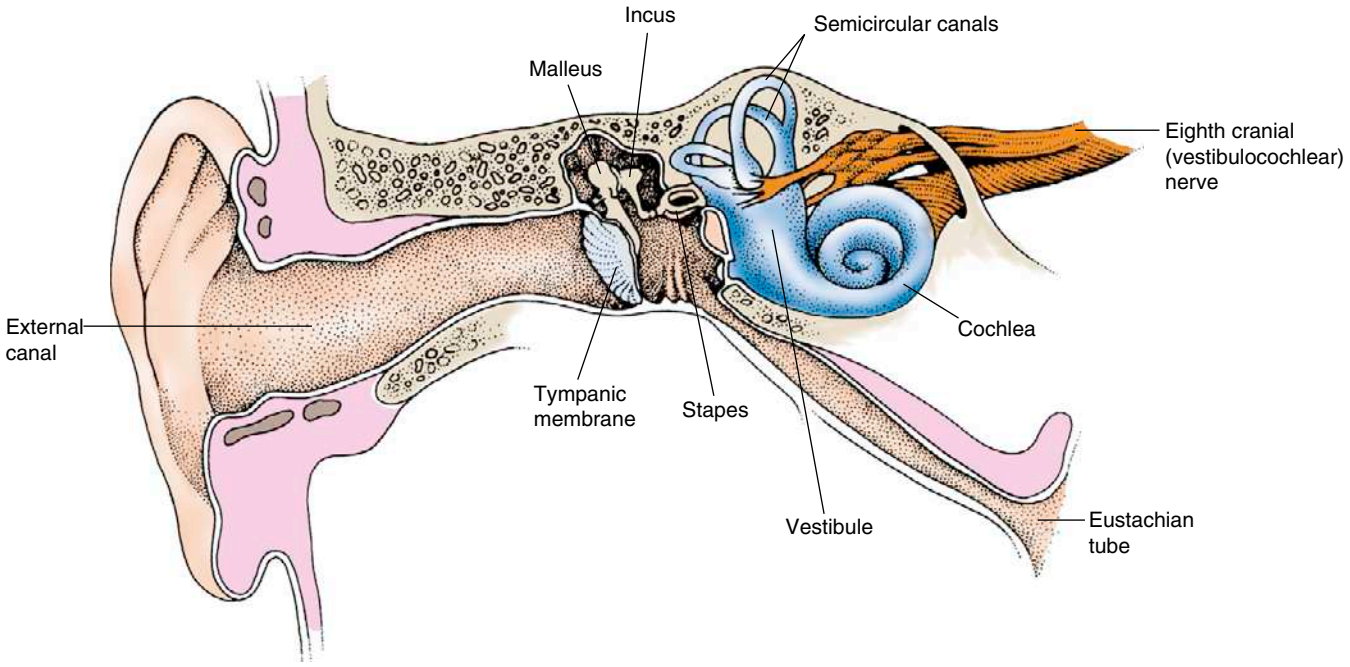


FIGURE 18-1 Anatomic structures of external ear, middle ear, and inner ear.

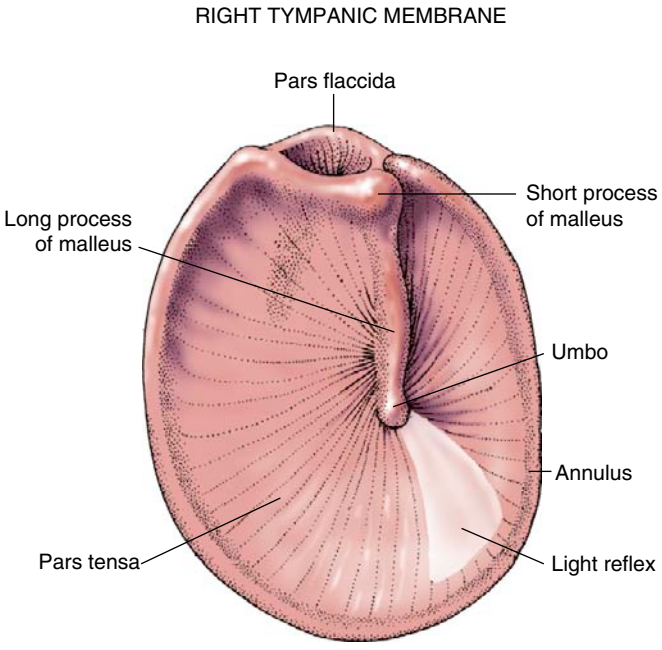


FIGURE 18-2 Structural landmarks of tympanic membrane.

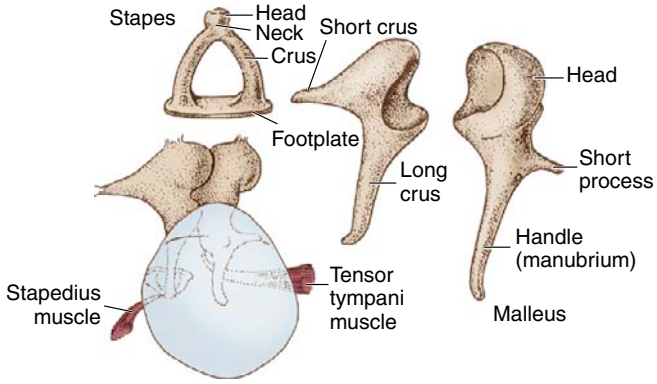


FIGURE 18-3 Articulated ossicles of right middle ear.

filled with another fluid with distinct electrolyte characteristics, called the endolymph. The bony labyrinth includes the cochlea and the vestibular labyrinth.

The *cochlea* resembles a snail shell. It is divided into three compartments: the scala vestibuli, which is associated with the oval window; the scala tympani, which is associated with the round window; and the cochlear duct. The scala vestibuli and scala tympani are filled with perilymph, whereas the cochlear duct contains endolymph. On the basilar membrane of the cochlea lies the organ of Corti—the neural end organ for hearing. Its neuroepithelium projects thousands of hair cells that are set into motion by vibrations passing through the ossicles and oval window to the perilymph. The hair cells convert the mechanical energy of wave movement from vibration in the perilymph into electrochemical impulses. The *vestibular labyrinth* is composed of the utricle, the saccule, and three semicircular canals, referred to as the *lateral, superior,* and *posterior canals.* They are positioned at right angles to one another and are responsible for detecting angular acceleration that can be elicited with any head or body movement. Each canal contains a sense organ (crista) that responds to fluid movement in the endolymph, which triggers impulses in the vestibular branch of the acoustic nerve. Cristae are stimulated by angular accelerations and movements, such as head turning. The maculae of the utricle and saccule of the vestibular labyrinth are gravity-oriented. Linear accelerations are detected by the utricle and saccule; they both have a mat of sensory cells *(otoconia)* imbedded in a gelatinous material covered with calcium deposits. The weight of these otoconia constantly orients us to the direction

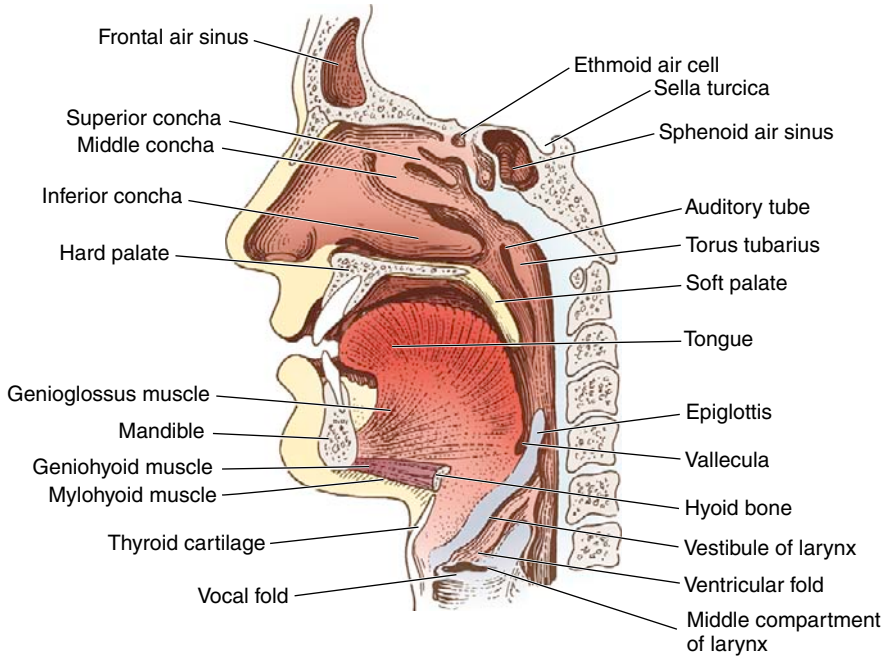


FIGURE 18-4 Sagittal section of face and neck.

of gravity. Their inertia gives information about linear accelerations. The combined signals from the cristae of the semicircular canals and the sensory cells of the utricle and saccule provide a sense of balance and orientation in space. The internal auditory branches of the basilar artery supply the inner ear.

NASAL ANATOMY

The nose is covered with skin and is supported internally by bone and cartilage. The two external nares provide openings for the passage of air through the nasal cavity. These openings contain internal hairs for the filtration of coarse particles that are sometimes carried by air. The nose is divided into the prominent external portion and the internal portion known as the *nasal cavity* (Figure 18-4). The chief purpose of the nose is to prepare air for use in the lungs.

The nasal bones and the frontal process of the maxilla form the upper portion of the external nose, and the lower portion is formed by a group of nasal cartilages and connective tissue covered with skin (Figure 18-5). The nostrils and the tip of the nose are shaped by the major alar cartilages. The nares are separated by the *columella,* which is formed by the lower margin of the septal cartilage, the medial parts of the major alar cartilages, and the anterior nasal spine, all of which are covered with skin. The nasal cavity is divided medially into right and left portions by the *nasal septum.*

The *nasal septum* is composed of three structures: the nasal cartilage, the perpendicular plate of the ethmoid bone, and the vomer bone. The septum is covered by mucoperichondrium on either side that contains blood vessels and mucus-secreting cells. The rich blood supply warms and moistens the air while the sticky mucus traps dust, pollen, and other small particles.

The nasal cavity communicates with the outside by its external openings, called the *nares.* The nares open into the nasopharynx through the choanae. The nasal cavity is also

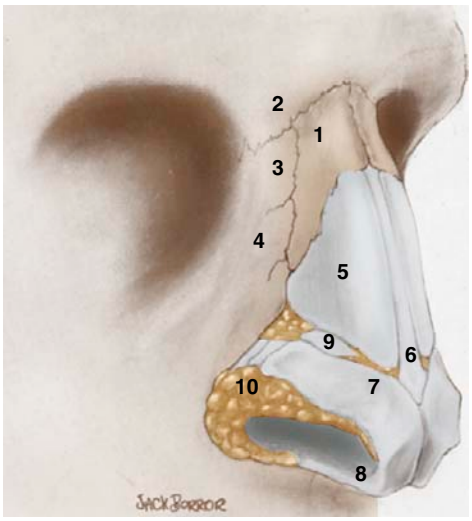


FIGURE 18-5 Nasal bony framework. *1,* Nasal bone; *2,* frontal bone; *3,* lacrimal bone; *4,* maxillary bone; *5,* upper lateral cartilage; *6,* nasal septum; *7,* lower lateral cartilage, lateral crus; *8,* lower lateral cartilage, medial crus; *9,* sesamoid cartilage; *10,* fibrofatty tissue.

associated with each ear, sharing the torus tubarius (opening of the eustachian tube in the nasopharynx) with the paranasal sinuses (frontal, maxillary, ethmoidal, sphenoidal) through their respective orifices (meatus). The nasal cavity also communicates with the conjunctivae through the nasolacrimal duct. The nasal cavity is separated from the lingual cavity by the hard palate and soft palate (see Figure 18-4) and from the cranial cavity by the ethmoids. It is held together by periosteal covering over bone and by perichondrium, which extends over the cartilages. The turbinate bones of the nasal structure are arranged one above the other, separated by grooves that

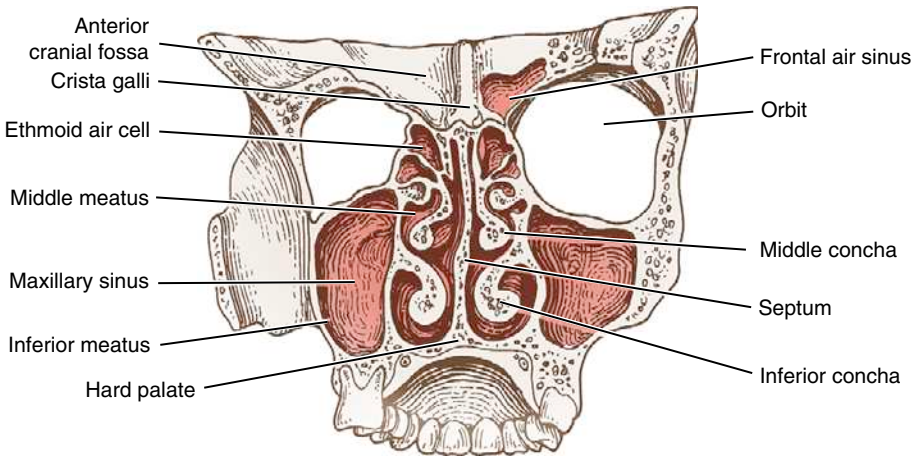


FIGURE 18-6 Vertical section through nose. Plane of section passes slightly obliquely through left first molar tooth and behind second right premolar tooth. Posterior wall of right frontal sinus removed.

are comprised of pseudostratified columnar ciliated respiratory epithelium. The turbinates act as drainage passages of the accessory sinuses and also increase the turbulence of airflow to humidify the air that is nasally inspired. This area is commonly referred to as the *sphenoethmoidal recess* and contains these bony shelves known as the *superior, middle,* and *inferior meatus* or *turbinates* (Figure 18-6).

The nasal sinuses serve as air spaces and communicate with the nasal cavity through the meatus. Anteriorly, on each side of the skull, the frontal sinus, the anterior ethmoidal sinus, and the maxillary sinus (antrum of Highmore) drain into the middle meatus; posteriorly, the ethmoidal and the sphenoidal sinuses drain into the superior meatus and the sphenoethmoidal recess (see Figure 18-6). A passageway for the flow of air is provided by the irregular air spaces between these structures.

THROAT ANATOMY

Oral Cavity

The *oral cavity* is comprised of the mouth and salivary glands. The mouth is formed by the cheeks, the hard palate, the mandible, and the tongue. It extends from the lips to the junction of the hard and soft palates. The portion of the mouth outside the teeth is the buccal cavity, and that on the inner side of the teeth is the lingual cavity. The hard palate forms the upper boundary of the oral cavity. The hard palate is formed by the maxilla and palatine bones. The mandible and floor of the mouth form the lower boundary of the oral cavity (Figure 18-7).

The *salivary glands* consist of three paired glands: the sublingual, the submandibular, and the parotid. They communicate with the mouth and produce saliva, which serves to moisten the mouth and initiate digestion of carbohydrates. The minor salivary glands exist in the submucosa of the cheeks, tongue, palates, and floor of the mouth, pharynx, lips, and paranasal sinuses.

The *sublingual gland* lies on the undersurface of the tongue beneath the mucous membrane on the floor of the mouth and the side of the tongue, on the inner surface of the mandible. The many tiny ducts of each gland separately enter the oral cavity on the sublingual fold.

The *submandibular gland* lies partly above and partly below the posterior half of the base of the mandible and on the mylohyoid and hyoglossus muscles. Its duct (Wharton's duct) runs superficially beneath the mucosa of the floor of the mouth and enters the oral cavity behind the central incisors.

The *parotid gland,* the largest of the salivary glands, lies below the zygomatic arch in front of the mastoid process and behind the ramus of the mandible; it is divided into a superficial portion and a deep portion. The parotid duct (Stensen's duct) pierces the buccal pad of fat and the buccinator muscle, finally opening into the oral cavity opposite the crown of the upper second molar tooth.

Pharynx

The pharynx extends from the posterior portion of the nose to the esophagus and larynx and serves as a channel for both the digestive and respiratory systems (Figure 18-8). It is composed of muscular and fibrous layers with a mucous membrane lining. It is approximately 13 cm long and lies anterior to the cervical vertebrae and posterior to the nasal and oral cavities. The pharynx is associated above with the sphenoid sinus and the basilar part of the occipital bone, and it joins the esophagus below. Seven cavities communicate with the pharynx: the two nasal cavities, the two tympanic cavities, the mouth, the larynx, and the esophagus. The pharynx comprises three groups of constrictor muscles. Each muscle fits within the one below, and each inserts posteriorly in the median line with its mate from the opposite side. The constrictor muscles provide constriction of the pharynx for swallowing. Between the origins of the constrictor muscle groups are so-called *intervals,* through which ligaments, nerves, and arteries pass. The pharynx is divided anatomically into three sections: the nasopharynx, the oropharynx, and the hypopharynx.

Nasopharynx. The nasopharynx lies posterior to the nasal cavity and extends over the soft palate. It communicates with the oropharynx through the pharyngeal isthmus, which is closed by muscular action during swallowing. Infection can spread from the nasopharynx to the middle ear through the eustachian tube.

Oropharynx. The oropharynx lies posterior to the oral cavity and extends from the palate to the level of the hyoid bone. The tonsils are situated on each side of the oropharynx, lodged in a tonsillar fossa that is attached to folds of membrane-containing

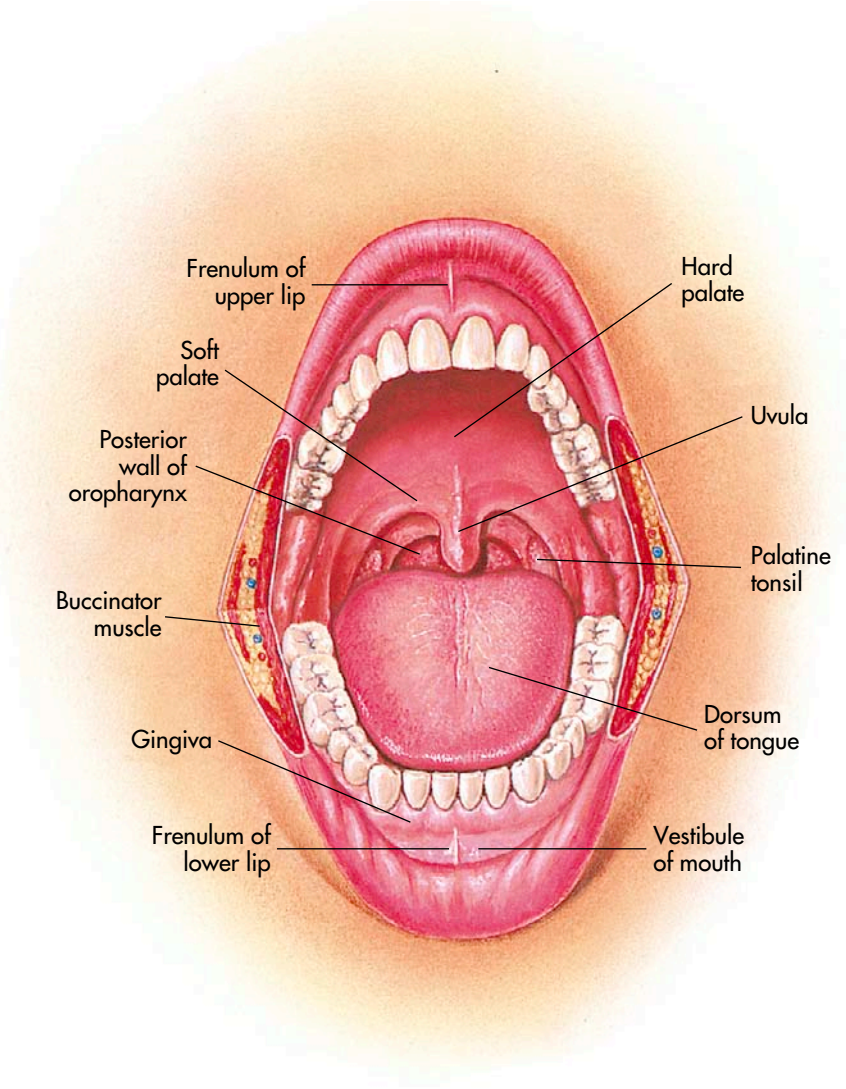


FIGURE 18-7 Anatomic structures of the oral cavity.

muscle. The palatine tonsils (a pair of oval structures) are the only lymphatic organs covered with stratified squamous epithelium. The lateral surface of each tonsil is usually covered with a fibrous capsule. The anterior and posterior tonsillar pillars join to form a triangular fossa, with the posterior lateral aspects of the tongue at its base. The lingual tonsils are lodged in each fossa. The adenoids, or pharyngeal tonsils, are suspended from the roof of the nasopharynx and consist of an accumulation of lymphoid tissue.

Hypopharynx. The hypopharynx extends from the hyoid bone and empties into the esophagus posteriorly and the larynx anteriorly. The piriform sinuses are bound medially by the arytenoepiglottic fold and laterally by the thyroid cartilage and hypothyroid membrane. The fossae are involved in speech.

Larynx and Associated Structures

Larynx. The larynx is a cartilaginous box that lies midline in front of the fourth, fifth, and sixth cervical vertebrae between the trachea and the root of the tongue, at the upper front part of the neck. The location of the larynx between the gastrointestinal (GI) and respiratory systems is strategic in protecting the airway during swallowing and breathing. The larynx has three main functions: as a passageway for respiration, as a valve to prevent aspiration, and as a vibratory source for vocalization.

The larynx can be divided into three portions: *supraglottis* (or upper portion above the true vocal cords), *glottis* (level of the true vocal cords), and *subglottis* (below the true vocal cords). The upper portion of the larynx is continuous with the pharynx above and includes the epiglottis, vallecula, and the laryngeal cartilages. Its lower portion joins the trachea. The skeletal structure provides for patency of the enclosed airway. The complex muscle action and arrangement of tissues within the larynx provide for closure of the lumen, to protect against trauma and entrance of foreign bodies, and for speech.

Laryngeal Cartilages. The skeletal framework of the larynx consists of cartilages and membranes. Of the nine separate cartilages, three are single and six are arranged in pairs. The main cartilages of the larynx include the thyroid, the cricoid, the

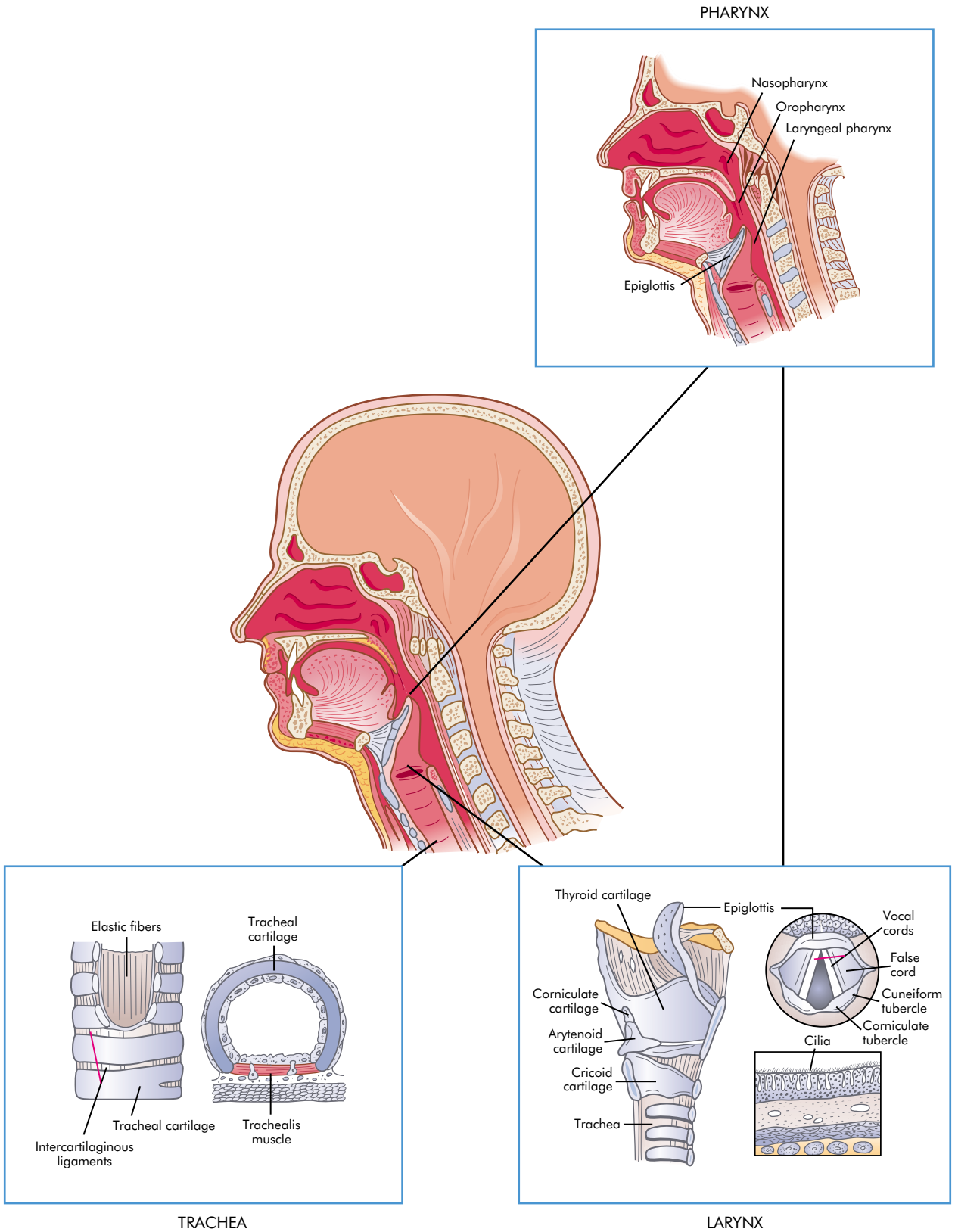


FIGURE 18-8 Structures of the upper airway.

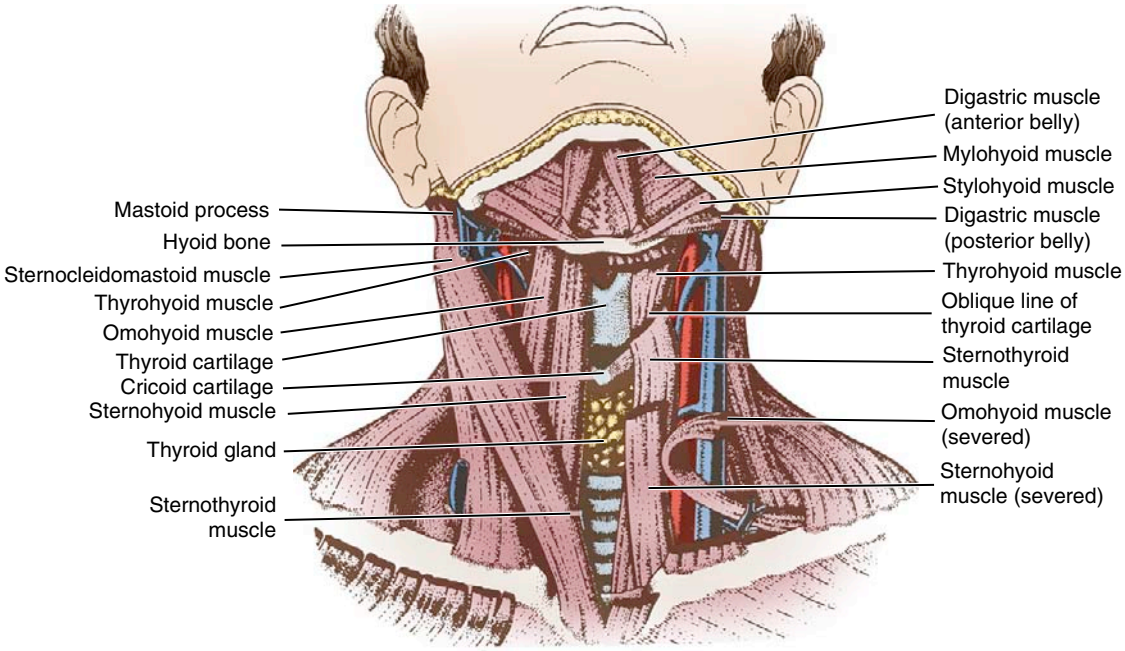


FIGURE 18-9 Extrinsic muscles of larynx.

epiglottis, two arytenoid, two corniculate, and two cuneiform. The thyroid cartilage, or Adam's apple, forms the anterior portion of the voice box. The cricoid cartilage is a complete cartilaginous ring that resembles a signet ring; it rests beneath the thyroid cartilage and supports the airway (see Figure 18-8). The epiglottis is a slightly curled, leaf-shaped, elastic, fibrous membrane that is attached in the midline to the upper border of the thyroid cartilage. The epiglottis helps to protect the larynx during swallowing. Contraction of the cricothyroid muscle pulls the thyroid cartilage and the cricoid cartilage to tighten the vocal cords and close the glottis. The arytenoid cartilages, which rest above the signet-ring portion of the cricoid cartilage, support the posterior portion of the true vocal cords.

Laryngeal Ligaments. The extrinsic ligaments of the larynx are those connecting: (1) the thyroid cartilage and epiglottis with the hyoid bone and (2) the cricoid cartilage with the trachea. The intrinsic ligaments of the larynx are those connecting several cartilages of the organ to each other. They are considered the elastic membrane of the larynx.

The mucous lining of the larynx blends with fibrous tissue to form two folds on each side of the larynx. The upper set is known as the *false vocal cords*. The lower set is called the *true vocal cords* because they are concerned primarily with the speaking voice and protection of the lower respiratory channels against the invasion of food and foreign bodies. The region of the larynx at the true vocal cord level is called the *glottis*, a triangular space between the vocal cords. During swallowing, the rising action of the muscular larynx, the closure of the glottis, and the doorlike action of the epiglottis all serve to guide food and fluid into the esophagus.

Laryngeal Muscles. The laryngeal muscles perform two distinct functions: the extrinsic muscles (Figure 18-9) regulate the degree of tension on the vocal cords, and the intrinsic muscles open and close the glottis. The spoken voice also depends on the sphincter action of the soft palate, tongue, and lips. The muscle action of the larynx permits the glottis to close either voluntarily or involuntarily by reflex action. The closure of the inlet by this mechanism protects the respiratory passages. The closure of the glottis and the action of the vocal cords are precisely coordinated to produce the voice.

Trachea. The trachea is a cartilaginous tube about 15 cm in length and 2 to 2.5 cm in diameter. It begins in the neck and extends from the lower part of the larynx, on a level with the sixth cervical vertebra, to the upper border of the fifth thoracic vertebra. It descends anteriorly to the esophagus, enters the superior mediastinum, and divides into right and left main bronchi. The trachea is composed of a series of C-shaped rings of hyaline cartilage. The posterior surface of the trachea is flattened rather than round because the cartilaginous rings are incomplete. The carina is a ridge on the inside of the bifurcation of the trachea. It is a landmark during bronchoscopy and separates the upper end of the right main branches from the upper end of the left main branches of the bronchi. Branches from the arch of the aorta—the brachiocephalic (innominate) and left common carotid arteries—are in close relation to the trachea. The cervical portion of the trachea is related anteriorly to the sternohyoid and sternothyroid muscles and to the isthmus of the thyroid gland.

Musculature of the Neck

A layer of deep cervical fascia surrounds the neck like a collar and is attached to the trapezius and sternocleidomastoid muscles. The sternocleidomastoid muscle extends from the upper part of the sternum and medial third of the clavicle to the mastoid process. The trapezius muscle extends from the scapula, the lateral third of the clavicle, and the vertebrae to

the occipital prominence. The relationship of these muscles to each other and to the adjacent bone creates triangles used as anatomic landmarks.

The pretracheal fascia of the neck lies deep in the strap muscles (sternothyroid, sternohyoid, thyrohyoid, and omohyoid) and partially encloses the thyroid gland, trachea, and larynx. The pretracheal fascia is pierced by the thyroid vessels. It fuses with the front of the carotid sheath on the deep surface of the sternocleidomastoid muscle. The carotid sheath consists of a network of areolar tissue surrounding the carotid arteries and vagus nerve.

Laterally the carotid sheath is fused with the fascia on the deep surface of the sternocleidomastoid muscle; anteriorly it is fused with the middle cervical fascia along the lateral border of the sternothyroid muscle. Lying between the floor and roof of this triangular formation of muscles are the lymph glands and the accessory nerve. Arteries and nerves traverse and pierce this triangle.

PROXIMAL STRUCTURES

Cranial Nerves

The trigeminal (fifth cranial) nerve supplies sensory innervation to the face, oral cavity, nose, nasal cavity, and maxillary sinuses. It provides motor innervation to the muscles of mastication.

The right and left facial (seventh cranial) nerves are responsible for all the movements of the facial muscles. Both nerves have a very complex and tortuous course from the brainstem to the motor endplates of the facial musculature. The facial nerve enters the internal auditory meatus along with the eighth (vestibulocochlear) cranial nerve and travels through the internal auditory canal, passing through the labyrinthine portion of the temporal bone to the geniculate ganglion, where it turns sharply and passes superior to the oval window. It then turns inferiorly through the mastoid and exits through the stylomastoid foramen. There are three primary branches of the facial nerve in the temporal bone: the greater superficial petrosal nerve controls lacrimation; the stapedial branch controls the stapedius muscle; and the chorda tympani nerve carries the taste sensation to the anterior two thirds of the tongue.

The vestibulocochlear (eighth cranial) nerve connects the inner ear to the brain through its brainstem nuclei and ascending neural pathways. The recurrent laryngeal branch of the vagus (tenth cranial) nerve is the important motor nerve of the intrinsic muscles of the pharynx and larynx.

Lymphatic System

The lymphatic system serves both immunologic and circulatory functions. Interstitial fluid, which may contain bacteria, viruses, or tumor cells, is returned to the blood circulation through the lymphatic channels. As the lymph nodes trap the foreign matter, the nodes may become enlarged, infected, or the focus of metastatic cancer (Figure 18-10).

The nasal cavity, the paranasal sinuses, and the pharynx drain into the retropharyngeal nodes. The mouth, lips, and external nose are drained by the submandibular nodes. The lymphatics of the tip and lateral aspects of the tongue drain to the submental nodes, and the posterior tongue lymphatics drain to the cervical nodes.

FIGURE 18-10 Advanced cancer of the mouth with metastasis to the neck.

The lymphatic drainage of the neck can be divided into superficial and deep nodes (Figure 18-11). Lymph nodes of the neck can be further classified into subzones. Level Ia nodes are submental nodes; level Ib nodes are submandibular nodes. Level IIa nodes are upper jugular nodes anterior to cranial nerve IX. Level IIb nodes are upper jugular nodes posterior to cranial nerve IX. Level III nodes are middle jugular nodes. Level IV nodes are lower jugular nodes. Level Va nodes are posterior triangle nodes of the spinal accessory group, and level Vb nodes are posterior triangle nodes of the transverse cervical artery and supraclavicular group. Level VI nodes are anterior tracheal nodes. Level VII nodes are superior mediastinum nodes.

Perioperative Nursing Considerations

Assessment

Assessment is a systematic and intentional process of collecting and interpreting data concerning a patient's health history and status with diagnoses related to the head and neck. Familiarity with otorhinolaryngologic conditions is essential for effective patient assessment. Information obtained helps to develop nursing diagnoses, which direct nursing plans, interventions, and evaluation. A nursing preoperative assessment is usually obtained either in person during scheduled preoperative evaluation or by telephone before the day of surgery. The perioperative nurse should review this assessment as well as the physician's evaluation to prepare for patient care in the OR. The assessment should include a review of the following:

- *Communication status.* Approximately 17% (36 million) of American adults report some degree of hearing loss severe enough to cause problems with communication and about 2 to 3 of every 1000 children in the United States are born

EVIDENCE FOR PRACTICE

Strategies for Communicating with a Hearing-Impaired Patient

Hearing deficits in patients must be considered when performing assessment, planning and implementing interventions, and providing education. Preexisting and postoperative hearing deficits can present a communication challenge for patients, their families, and perioperative nurses. Recommended strategies for communicating with a hearing-impaired patient include the following:

- Position yourself directly in front of the patient. Most people who have hearing loss rely heavily on seeing the speaker's face (best distance is about 3 feet).
- Ensure that the room is well lighted, making sure the light is shining at the speaker and not in the eyes of the patient.
- Get the patient's attention before beginning to speak.
- Ask the patient what you need to do so that he or she can best understand you.
- If one ear is better than the other, move closer to the less-affected side.
- Speak clearly and slowly using a good elocutionary style (do not exaggerate mouth movements).
- Do not shout. Shouting raises the frequency of sound and makes understanding more difficult.
- Try not to mumble or lower the sound intensity of words at the end of sentences.
- Decrease background noise as much as possible; turn off medical equipment alarms if possible when attempting communication with the patient.
- Do not chew gum and speak at the same time.
- Keep hands and other objects away from your mouth and the speaker's mouth when talking to the patient.
- When family members are present, speak directly to the patient. Do not refer to the patient in the third person.
- Minimize distractions.
- Rephrase rather than repeat—the patient may not have understood a particular word or phrase.
- Have the patient repeat back, in his or her own words, your statements to assess understanding.
- Use appropriate hand motions.
- Be patient and relax. By working together, you can help maximize effective communication.
- Write messages on paper if the patient is able to read.

Modified from Russek JA: Care of patients with ear and hearing problems. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, Philadelphia, 2010, Saunders; Medwetsky L: Hearing loss. In Duthie EJ et al, editors, *Practice of geriatrics,* ed 4, Philadelphia, 2007, Saunders.

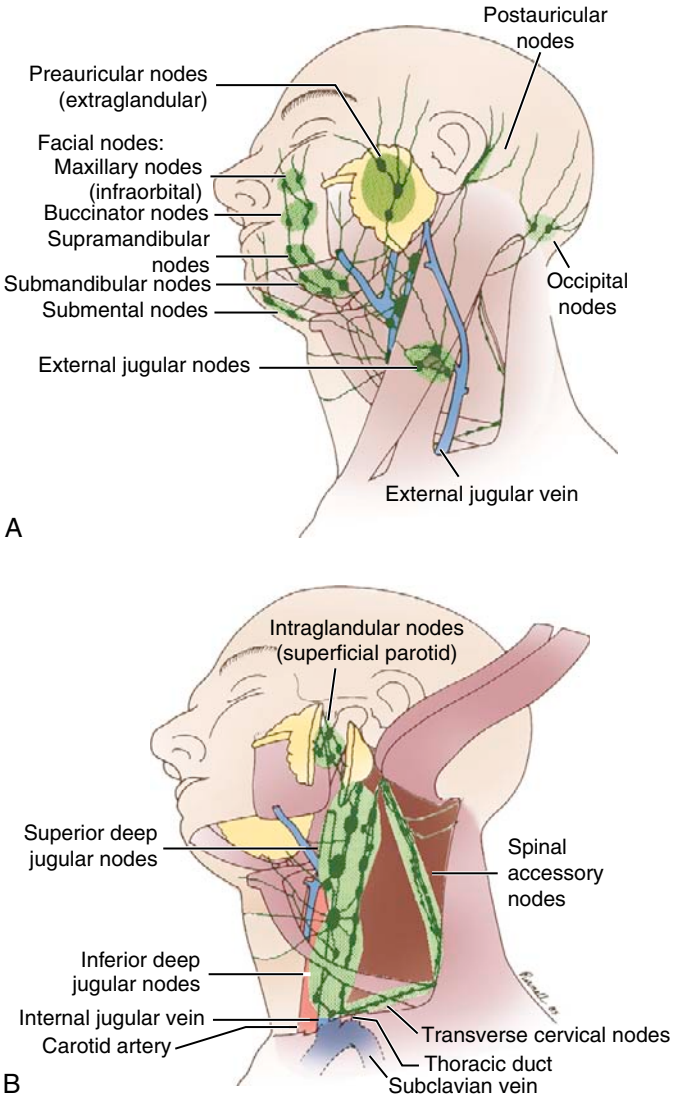


FIGURE 18-11 Lymphatic drainage of neck. **A**, Superficial cervical and facial nodal drainage patterns. **B**, Deep cervical lymphatic drainage patterns. Note that sternocleidomastoid muscle is reflected.

deaf or hard-of-hearing (National Institute on Deafness and Other Communication Disorders [NIDCD], 2009). Hearing loss may be classified as conductive, sensorineural, or mixed (Table 18-1). Nurses must determine the best way to communicate with the patient who is hard-of-hearing (Evidence for Practice). Patients who are unable to speak because of vocal cord dysfunction must be provided an alternate means of communication (e.g., pen and paper, erasable board). Nurses must assess for adaptive responses—lip reading, sign language, written communication—and the effect of the patient's communication status on daily life (e.g., inability to hear traffic, alarms, or telephone; inability of voice to be heard because of hoarseness; voice volume issues; reluctance to communicate).

- *Respiratory status.* Observe and note the quality and character of respirations; observe and note the quality and character of the voice—hoarseness, "hot potato" voice, or hyponasal speech; note inspiratory stridor, expiratory stridor, hemoptysis, or dyspnea.
- *Physical status.* Observe problems in range of motion in all four extremities; note joint replacements, back or neck stiffness or pain, or trismus. Assess facial symmetry, landmarks, color, position, and presence of deformities, lesions, and nodules; note presence or absence of rhinorrhea or otorrhea. Note any cranial nerve involvement (e.g., inability to look downward, nystagmus, facial asymmetry, and facial paresis).
- *Presence of a mass.* Note the length of time the mass has been evident; note if the size of the mass decreased after antibiotic therapy; note a fixed mass versus a mobile mass.
- *Nutritional status.* Note any weight loss, including length of time weight loss occurred. Patients with diagnosed and

TABLE 18-1

Types of Hearing Loss

Classification	Definition	Causes
Conductive	Loss of hearing acuity resulting from failure to conduct sound from external ear to middle ear	Blockage of external canal with cerumen or foreign bodies Edema Trauma Infection Tympanic perforation Otosclerosis, ossicular chain fixation
Sensorineural	Loss of hearing acuity resulting from failure to conduct sound to inner ear (cochlea or acoustic nerve)	Ototoxic medications Exposure to loud noise Trauma Meniere's disease Tumor Presbycusis Infectious disease (measles, mumps, meningitis)
Mixed	Loss of hearing acuity resulting from combination of conductive and sensorineural factors	Develops secondary to either conductive or sensorineural loss (e.g., patient with presbycusis and impacted cerumen)

undiagnosed neoplasms may be nutritionally depleted from dysphagia, tumor, chemotherapy, or radiation therapy.

- *Emotional status and anxiety level.* Observe for restlessness, poor eye contact, facial tension, or increased perspiration.
- *Pain.* Observe location and character of odynophagia, sore throat, facial pain, or otalgia. Note preoperative medications and the time they were administered. Begin education for pain management before discharge (Ambulatory Surgery Considerations).
- *Allergies.* Note allergic reactions to medications, foods, or latex.
- *Medication history.* Note medications taken by the patient for the presenting condition and any other diagnosed medical condition. Medications should include prescription medications, over-the-counter medications, vitamins, herbals, nutraceuticals, ototoxic drugs taken, including salicylates, aminoglycosides, furosemide, streptomycin, quinine, ethacrynic acid, or any history of chemotherapy. Ensure key participants in the patient's care are aware of the medication history (Patient Safety).
- *Past responses to anesthesia.* Local anesthetics are often used either as the sole means of anesthesia for minor procedures or as an adjunct to procedures performed using monitored anesthesia care or general anesthesia. The patient's account of previous dental experiences with local

AMBULATORY SURGERY CONSIDERATIONS

Pain Assessment and Management for Outpatient Otorhinolaryngologic Procedures

Management of pain is an important consideration for otorhinolaryngologic patients undergoing same-day surgery. If pain is not effectively managed, the patient is unduly stressed and complications (e.g., hypertension, tachycardia, nausea, vomiting) may ensue and delay discharge. Unmanaged pain may also lead to readmission or evaluation in the emergency department. Other consequences include immobility, delayed healing, interference with ADLs, and lost productivity. Perioperative nurses must be cognizant of the impact of pain in this population and can use these guidelines to provide effective pain management and education for patients before discharge.

The Joint Commission has established standards for pain management. The underpinning element of these standards is the patient's right to appropriate assessment and management of pain. Among other things, the standards also stipulate education of patients and families regarding pain management, after consideration of their personal, cultural, spiritual, and ethnic beliefs. Expected outcomes in pain management and comfort, which may help patients heal more quickly and have improved outcomes, were researched to develop the following clinical guidelines:

PREOPERATIVE PAIN ASSESSMENT

- Patient states understanding of plan of care and priority of individual needs.
- Patient states understanding of pain intensity scale, comfort scale, and pain-relief/comfort goals.
- Patient states understanding of methods to communicate pain levels to the provider during the operative phase of care (patients receiving local or managed anesthesia care).

POSTANESTHESIA PHASE I

- Patient maintains hemodynamic stability, including respiratory/cardiac status and level of consciousness.
- Patient states achievement of pain-relief/comfort treatment goals.
- Patient shows effective use of at least one nonpharmacologic method.
- Patient verbalizes evidence of receding pain level and increased comfort with pharmacologic and nonpharmacologic interventions.

POSTANESTHESIA PHASE II/III

- Patient states acceptable level of pain relief and comfort with movement or activity at time of transfer or discharge to home.
- Patient verbalizes understanding of discharge instruction plans (specific drug, frequency of administration, potential side effects of medication, potential drug interactions, precautions or limitations when taking drugs, name and telephone number of the physician/resource to contact with emergencies or problems).
- Patient states understanding or shows effective use of nonpharmacologic methods.
- Patient states achievement of pain/comfort treatment goals and level of satisfaction with pain-relief and comfort management in the perianesthesia setting.

Modified from *American Society of PeriAnesthesia Nurses (ASPAN) pain and comfort guidelines,* available at www.aspan.org/Portals/6/docs/ClinicalPractice/Guidelines/ASPAN_ClinicalGuideline_PainComfort.pdf. Accessed August 9, 2009; Leddy KM, Wolosin RJ: Patient satisfaction with pain control during hospitalization, *Jt Comm J Qual Patient Saf* 31(9):507-513, 2005; McGuire LL: Pain: The fifth vital sign. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, Philadelphia, 2010, Saunders.

PATIENT SAFETY

Medication Reconciliation

A National Patient Safety Goal (NPSG) established by The Joint Commission is to "accurately and completely reconcile medications across the continuum of care." Reconciliation of medication information can prevent prescribing errors, such as duplicate prescriptions, incompatible medications, and overprescribing. Whether undergoing an inpatient or outpatient procedure, the patient entering the perioperative setting may be at risk for medication errors because of decreased communication with the patient's primary care physician or other treatment specialists. Otorhinolaryngologic patients may also have communication challenges (auditory or vocal) that increase the risk of error in obtaining an accurate medication history. In ambulatory surgery, perioperative nurses typically review the patient's medication history in the preoperative period and then review medications again in the postoperative/discharge phase. Nurses can positively impact patient safety and reduce the risk for prescribing errors by following medication safety practices, using medication reconciliation processes, and implementing these risk reduction strategies:

- Collect a current home medication list (including dose and frequency along with allergies, drug intolerance information, and immunization history) for each patient on admission.
- Validate the home medication list with the patient whenever possible; a family member, significant other, or surrogate decision-maker may be involved. This involvement should occur at all interfaces of care, and on admission to and discharge from the facility.
- Have the home medication list available for the physician whenever writing orders; place the reconciling form in a consistent highly visible location within the patient chart.
- Assign primary responsibility for collecting the home medication list to someone with sufficient expertise, within a context of shared accountability.
- Assign to someone with sufficient expertise the responsibility for comparing admission orders with the home medication list; identifying discrepancies or interactions; and reconciling variances.
- Reconcile medications within specified time frames (within 24 hours of admission; shorter time frames for high-risk drugs, potentially serious dosage variances, and/or upcoming administration times).
- On discharge from the ambulatory surgery setting, in addition to communicating the updated medication list to the next provider of care during the hand-off report, provide the patient with the complete list of medications that he or she will be taking after discharge as well as instructions on how and how long to continue taking newly prescribed medications. Encourage the patient to carry the list and share it with any providers of care, including primary care and specialist physicians, nurses, pharmacists, and other caregivers.
- Adopt a standardized form to use for collecting the home medication list and for reconciling the variances (includes both electronic and paper-based forms).
- Develop clear policies and procedures for each step in the reconciliation process.
- Provide access to drug information and pharmacist advice at each step in the reconciliation process.
- Provide orientation and ongoing education on procedures for reconciling medications to all healthcare providers.
- Provide feedback and ongoing monitoring.
- When the patient is unable to actively or fully participate in the medication reconciliation process and has requested assistance from another person(s) (e.g., family member, significant other, surrogate decision-maker), involve the authorized person(s) in the medication reconciliation process.

Modified from The Joint Commission: *Sentinel Event Alert,* issue 35, available at www.jointcommission.org/SentinelEvents/SentinelEventAlert/sea_35.htm. Accessed August 9, 2009.

anesthetics can provide a clue as to how the patient will respond to local anesthetic agents. Cardiac status should be noted because many surgeons use epinephrine as an additive to the local anesthetic to achieve vasoconstriction and minimize blood loss. The epinephrine effect may contribute to cardiac dysrhythmias and an increased potential for cardiac arrest.

- *Patient's knowledge and understanding of the surgical procedure.* Note questions and provide answers, or ask surgeon to clarify information for the patient. Review equipment and care (e.g., suctioning, packing, drains) that will be part of the postoperative regimen and possible communication deficits related to the procedure (e.g., inability to speak after laryngeal procedures, decreased hearing after otologic procedures).
- *Patient's support system.* Note family members' names and their location during the surgical procedure, and explain that a nurse will communicate with them during the procedure regarding the patient (as applicable).

In addition to standard office diagnostic procedures performed by the surgeon, several other tests may be performed before the patient arrives in the OR. Study results of most significance to the perioperative team that should be available in the OR may include the following.

Laboratory Data

Red blood cell (RBC) count (may be increased with dehydration or decreased with dietary deficiencies)

- *Male:* 4.7 to 6.1 million/mm^3
- *Female:* 4.2 to 5.4 million/mm^3
- *Child:* 4 to 5.5 million/mm^3

Hemoglobin (values for the elderly may be slightly decreased; may be increased with dehydration, congestive heart failure [CHF], or chronic obstructive pulmonary disease [COPD]; may be decreased with cancer, nutritional deficiency, or severe hemorrhage)

- *Male:* 14 to 18 g/dl
- *Female:* 12 to 16 g/dl
- *Child:* 10 to 15.5 g/dl

Hematocrit (may be increased with trauma or dehydration; may be decreased with hyperthyroidism, cirrhosis, hemorrhage, malnutrition, dietary deficiency, or in the elderly)

- *Male:* 42% to 52%
- *Female:* 37% to 47%
- *Child:* 32% to 44%

White blood cell (WBC) count (may be increased with infection, trauma, stress, tissue necrosis, and inflammatory process; may be decreased with dietary disease, autoimmune disease, and overwhelming infections)

- *Adult:* 5000 to 10,000/mm^3
- *Child ≤2 years old:* 6200 to 17,000/mm^3

Platelet count: 150,000 to 400,000/mm^3 (may be increased with malignant disorders, polycythemia vera, postsplenectomy syndrome, rheumatoid arthritis, iron deficiency anemia; may be decreased with hemorrhage, liver disease, kidney disease, or systemic lupus erythematosus [SLE]) (Pagana and Pagana, 2009)

- Urinalysis (observe glucose level; if positive, check blood glucose level)
- Prothrombin time (PT), partial thromboplastin time (PTT), and activated partial thromboplastin time (APTT)
  - PT: 11 to 12.5 seconds (may be increased with cirrhosis, hepatitis, vitamin K deficiency, salicylate intoxication, or disseminated intravascular coagulation [DIC])
  - PTT: 60 to 70 seconds
  - APTT: 30 to 40 seconds (may be increased with clotting factor deficiencies, biliary obstruction, hepatocellular diseases, vitamin K deficiency, or DIC; may be decreased with early stages of DIC or extensive cancer) (Pagana and Pagana, 2009)
- Blood chemistry analysis
  - Chloride—adult and elderly: 98 to 106 mEq/L (may be increased with dehydration, kidney dysfunction, or anemia; may be decreased with CHF, diuretic therapy, or hypokalemia)
  - Potassium—adult and elderly: 3.5 to 5 mEq/L (may be increased with acute or chronic renal failure; may be decreased with diuretic therapy, diarrhea, vomiting, or insulin, glucose, or calcium administration)
  - Blood urea nitrogen (BUN)—adult: 10 to 20 mg/dl (elderly may be slightly higher; may be increased with renal disease, CHF, or dehydration; may be decreased with liver failure, overhydration, or malnutrition) (Pagana and Pagana, 2009)
- If the thyroid gland is suspect, the following tests may be indicated:
  - Serum calcium levels (to determine parathyroid function)—adult: 9 to 10.5 mg/dl
  - Serum calcitonin (to assess potential for medullary carcinoma)
  - Thyroid scan (to assess presence of "cold" nodule, which is often indicative of carcinoma)
  - Thyroid antibody tests (may show decreased levels in carcinoma): titer less than 1:100
  - Serum thyroxine (T_4): *male,* 4 to 12 mcg/dl; *female,* 5 to 12 mcg/dl
  - Thyroid-stimulating hormone (TSH): 2 to 10 milliunits/ml
  - Triiodothyronine uptake, resin (T_3RU): *20 to 50 years,* 75 to 220 ng/dl; *older than 50 years,* 40 to 180 ng/dl (Pagana and Pagana, 2009).

Computed Tomography. CT scans are radiographic studies that visualize structures by producing serial sections, many times clinically referred to as "cuts," through planes of the head and neck. CT imaging provides visualization of bone, soft tissue, and adjacent intracranial and extracranial pathologic conditions. Intravenous (IV) injection of iodine contrast agents produces visual enhancement of some anatomic structures and pathologic tissues, including highly vascularized tumors. CT is the study of choice to assess intratemporal bone pathologic conditions and to evaluate the paranasal sinuses and adjacent structures. It is also used in the assessment of the oral cavity and neck.

Magnetic Resonance Imaging. Magnetic resonance imaging (MRI) is an imaging modality using powerful magnetic and radiofrequency waves to reproduce cross-sectional images of the human body without exposing the patient to ionizing radiation. On an MRI scan, fat and fluid produce high-intensity signals, which appear as bright areas, whereas bone and air emit weak signals and appear as darkened areas on the scan. MRI is often used with CT imaging in a complementary fashion when evaluating lesions in and around bone for a variety of head and neck conditions including tumors in the oral cavity, external auditory canal, middle ear, and mastoid.

Audiogram. Patients scheduled for otologic surgery may have undergone evaluation of their hearing through audiograms to determine whether they have normal hearing, conductive hearing loss, or sensorineural hearing loss (see Table 18-1). Two types of audiometric testing, pure tone and speech audiometry, are performed on patients with suspected hearing loss.

Nursing Diagnosis

Nursing diagnoses related to the care of patients undergoing otorhinolaryngologic surgery might include the following:

- Anxiety
- Acute Pain
- Risk for Ineffective Breathing Pattern
- Risk for Bleeding
- Disturbed Sensory Perception
- Disturbed Body Image
- Impaired Verbal Communication

Outcome Identification

Outcomes identified for the selected nursing diagnoses could be stated as follows:

- The patient will be able to identify factors that cause anxiety and verbalize an ability to cope.
- The patient will communicate adequate pain control and display absence of physiologic indicators of pain (e.g., tachypnea, tachycardia, pallor, hypertension).
- The patient will demonstrate effective breathing patterns.
- The patient will maintain a hematocrit level of 30 mg/dl or greater or a hemoglobin level of 12 to 14 mg/dl.
- The patient will verbalize understanding of the anticipated postoperative alterations in hearing, smell, or taste as appropriate to the surgical diagnosis.
- The patient will experience a sense of self-worth and self-respect.
- The patient will establish an effective communication method with staff and family.

Planning

The development of a plan of care is based on the preoperative assessment, nursing diagnoses, expected outcomes, and the surgery being performed. Patients undergoing otolaryngologic procedures may have special communication needs that must be considered in planning effective care. The perioperative nurse should determine the best way to communicate with patients who have hearing deficits or impaired

vocalization. Information given to the patient should be reinforced as needed throughout the perioperative experience. The OR environment must be quiet and free of any loud noise. Intraoperative noises, such as those from suction, electrosurgical units (ESUs), and other equipment, should be explained to the locally anesthetized patient before they are generated. This will help avoid startling the patient and adversely affecting the success of the surgery. Patients receiving local anesthetics need to remain still during the procedure, so providing for comfort measures becomes especially important. The room temperature should be regulated at a comfortable setting, and the patient should be adequately covered to maintain normal body temperature.

Preparation of the OR includes checking the availability and functional capacity of suction, the surgeon's headlight and light source, and the ESU. It is essential that the x-ray view box is in working order and appropriately located so that scans may be easily viewed by the surgeon during the procedure. In endoscopic cases, the navigation tower and monitor should be rolled to the head of the table and tested to ensure proper functioning of the light source for the camera wands and suction. If the surgeon plans on video-recording the case, assurance that the video recorder is adequately working is needed before the start of the case.

A Sample Plan of Care for a patient undergoing otorhinolaryngologic surgery follows.

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Anxiety

OUTCOME
The patient will be able to identify factors that cause anxiety and verbalize an ability to cope.

INTERVENTIONS
- Assess patient's level of anxiety (alertness, ability to comprehend, ability to perform activities of daily living [ADLs]).
- Maintain calm and safe environment.
- Assist patient in identifying possible sources of stress.
- Allow patient to ventilate and ask questions. Assess patient for desire for preoperative visit by persons with altered communication methods.
- Following the protocol in place, inform the patient and family what to expect on the day of surgery and the environment of care (preoperative area, OR, postanesthesia care unit).
- Introduce members of the surgical staff. Explain activities performed by the nursing staff in simple language the patient can understand.
- Assure the patient that he or she will be informed before any procedure is done.
- Provide time for the patient and family to express fears and concerns. Provide factual, accurate information.
- Note expressions of distress and anxiety.
- Prevent unnecessary body exposure during transfer and positioning.
- Control external stimuli and noise levels.

NURSING DIAGNOSIS
Acute Pain

OUTCOME
The patient will communicate adequate pain control and display absence of physiologic indicators of pain (e.g., tachypnea, tachycardia, pallor, hypertension).

INTERVENTIONS
- Review with patient normal coping mechanisms that are personally effective; support and encourage these during surgical intervention. As appropriate, consider nonpharmacologic measures, such as guided imagery, music, and relaxation exercises.
- Describe the anticipated sequence of perioperative events.
- Explain that some initial discomfort (e.g., pinprick followed by slight burning and then numbness) may be felt during the administration of local anesthetic.
- Inform the patient before the injection of local anesthetic; provide support and reassurance; evaluate patient response.
- Observe for, document, and report any changes in the patient's vital signs (blood pressure, heart rate and rhythm, respiratory rate, oxygen saturation), skin condition, and mental status.
- Be aware of the maximum recommended dosage of local anesthetics and be alert for signs of allergic reactions or toxic responses.
- Ask the patient whether he or she is experiencing any pain; communicate the presence of pain sensation to the surgeon.
- Administer sedation or analgesics as ordered by the surgeon. Describe the purpose and expected response to the medication administered. Document medications administered.
- Verify with the patient that desired response has been achieved.

NURSING DIAGNOSIS
Risk for Ineffective Breathing Pattern

OUTCOME
The patient will demonstrate effective breathing patterns.

INTERVENTIONS
- Assess respiratory status and breathing pattern. Monitor respiratory rate, rhythm, and depth and oxygen saturation (pulse oximetry). Maintain oxygen saturation at greater than 90%. Report any variances from normal.
- Note any restlessness, apprehension, agitation, lethargy, or repeated swallowing. Use a penlight to examine the throat for bleeding if nasal, oral cavity, or laryngologic procedures were performed. Notify the surgeon if bleeding is present.
- Have emergency medications and airway equipment available.
- Elevate head of the bed (to decrease edema, which can interfere with breathing).
- Increase humidification with a bedside humidifier or a humidified facemask.
- Encourage patient and family to increase frequency of oral hygiene.

NURSING DIAGNOSIS
Risk for Bleeding

OUTCOME
The patient will maintain a hematocrit of 30 mg/dl or greater or a hemoglobin of 12 to 14 mg/dl.

Continued

SAMPLE PLAN OF CARE—cont'd

INTERVENTIONS
- Assist with the insertion of intravenous (IV) lines and fluid replacement therapy. Keep IV lines patent.
- Provide blood or blood products for fluid replacement; assist in replacement therapy and patient monitoring.
- Estimate blood loss on sponges and drapes; communicate to anesthesia provider and surgeon.
- Record the amount of irrigation used.
- Document the contents of the suction canisters.
- Monitor and document hourly urine output (as applicable); communicate results of measurements.
- Observe for signs of shock (e.g., hypotension, abnormal ECG); report signs, and initiate corrective nursing actions.
- Observe for signs of excess blood loss (e.g., rapid, weak pulse; rapid respirations; cool, moist skin; early, slight rise in blood pressure); report signs, and initiate corrective nursing actions.
- Collaborate with the collection and interpretation of intraoperative blood analyses.

NURSING DIAGNOSIS
Disturbed Sensory Perception

OUTCOME
The patient will verbalize understanding of the anticipated postoperative alteration in the senses of smell and taste.

INTERVENTIONS
- Explain to the patient and family that a "mustache" dressing and packing might be in place postoperatively and will interfere with the sense of smell.
- Inform the patient and family that the sense of taste will also be altered, similar to having a head cold.
- Assure the patient and family that these alterations are usually temporary.
- Encourage the patient to maintain proper dietary intake even if the food does not smell or taste as it should.
- Encourage frequent mouth care; rinse with water or half hydrogen peroxide and half normal saline.
- Assess any degree of hearing impairment.
- Agree on a method of communication preoperatively to be used postoperatively.
- Allow patient to wear hearing aid to the OR.
- Identify a method by which patient can communicate basic needs if and when the hearing aid needs to be removed.
- Maintain a quiet surgical environment.
- Speak slowly and deliberately into the dominant ear.
- Reorient patient as needed, and provide frequent explanations and reassurance.
- Provide interpreters (e.g., sign language interpreter, oral interpreter, cued speech interpreter) as needed to facilitate communication.

NURSING DIAGNOSIS
Disturbed Body Image

OUTCOME
The patient will experience a sense of self-worth and self-respect.

INTERVENTIONS
- Acknowledge normalcy of emotional response to actual or perceived change in body structure or function. Experiencing stages of grief over loss of a body part or function is normal, and typically involves a period of denial, the length of which is variable.
- Encourage patient to verbalize feelings and self-perceived changes related to health status and surgical procedure.
- Involve family or significant others in initial communication with patient.
- Encourage patient to ask questions.
- Discuss referrals for support groups.

NURSING DIAGNOSIS
Impaired Verbal Communication

OUTCOME
The patient will establish an effective communication method with staff and family.

INTERVENTIONS
- Plan in advance to obtain necessary assistive devices or interpreters.
- Inform the entire healthcare team of the patient's communication challenges and any interpretive services to be used.
- Agree on a method of communication preoperatively to be used postoperatively. Suggestions include the following:
  - Writing with a pen or pencil and paper, or using an erasable slate
  - Hand signals or signs, body expressions
  - Picture board
- Consult with surgeon regarding requirements for voice rest.
- Place intravenous (IV) lines in nondominant hand.
- Adapt written materials (e.g., consent forms, discharge instructions) as necessary; include visual information such as symbols, pictures, or diagrams to help understanding.

Implementation

The following nursing interventions should be instituted for the patient:

1. Use the institutional verification process immediately before surgery to identify the correct surgical site. This should include verifying the operative side and site with the patient or family and confirmation through review of the medical record, informed consent, diagnostic test reports, and other members of the surgical team during the time-out.
2. Verify that the patient has maintained nothing-by-mouth (NPO) status as directed and that requested laboratory studies are on the medical record.
3. Provide calm, careful, and comforting nursing measures to reduce the patient's anxiety. Allow the patient time to comply with requests, and explain the sequence of perioperative events.
4. Allow patients who wear hearing aids to wear them to the OR. Properly remove them at the time of or after anesthesia induction, or leave them in place if local anesthesia is used. Prescription eyewear should be brought into the holding area because hearing-impaired patients may require them to assist in lip reading when instructions and procedures are explained. If the patient has impaired vocalization, the nurse should ensure that the patient's preferred method of communication (e.g., pen and paper, artificial larynx) is

available. Disposition of any assistive devices brought into the OR must be documented on the record.

5. Protect patients with impaired communication from injury. The perioperative nurse must control the environment because excess stimulation interferes with the patient's ability to hear, vocalize, and comply with instructions and explanations.
6. Carefully review instructions for patients receiving local anesthetics. Remind the patient of the need to remain immobile during the procedure and report any adverse symptoms related to the anesthetic. Symptoms of adverse drug reactions include skin changes, such as rash or itching; restlessness; unexplained anxiety or fearfulness; diaphoresis; and complaints of blurred vision, tinnitus, dizziness, nausea, palpitations or acute changes in heart rate, disturbed respiration, pallor or flushing, and syncope. Emergency drugs, suction apparatus, and resuscitation equipment, including a defibrillator should be readily available.
7. Remain with the patient throughout the induction phase of anesthesia.
8. Perform any hair removal by clipping. Protect the patient's eyes during skin preparation.
9. Promote normothermia through the use of thermal warming blankets, forced-air warming units, and warm IV and irrigating solutions.
10. Use sequential compression devices (SCDs) to decrease the risk of deep venous thrombosis (DVT) and pulmonary embolism (PE) during long surgical procedures.
11. Document the serial number and lot numbers of any implanted materials according to institutional policy.
12. Initiate and document laser safety precautions if the laser is used (see Chapter 7).

Preoperative Room Preparation. Before the patient enters the OR, the nurse and scrub person (who could be a surgical technologist or a nurse) gather the equipment and supplies for the scheduled procedure. A well-organized surgical environment can significantly reduce anesthesia time and enable the perioperative nurse to spend more time attending to the preoperative and intraoperative needs of the patient. Planning includes identifying equipment, instrumentation, furniture, and positioning accessories necessary to perform the surgery. Such equipment may include the operating microscope, video system, monopolar and bipolar ESUs, suction, nerve integrity monitors, specialty instrument sets, prosthetic devices, drill and irrigation accessories, and the laser. A dedicated otorhinolaryngologic specialty storage cart centrally houses assorted prostheses, drill burrs and accessories, and dressing and packing materials, which contributes to efficiency when providing intraoperative care.

Positioning. The supine position with modifications is used during otorhinolaryngologic procedures. The perioperative nurse gathers the supplies necessary to ensure comfort of the patient in a supine position. These usually include a foam headrest or a pillow for under the knees, and warm blankets. The nurse pads the patient's extremities at pressure points and at major nerves. A pillow should be placed under the thighs and the legs should be slightly angled to decrease pressure on the patient's back; this positioning should be carried out before the patient is anesthetized to ensure comfort. Arms are placed on padded armboards with the palms up and fingers extended. Armboards are maintained at less than a 90-degree angle to prevent brachial plexus stretch. If there are surgical reasons to tuck the arms at the side, the elbows are padded to protect the ulnar nerve, the palms face inward, and the wrist is maintained in a neutral position (Denholm, 2009). A drape secures the arms. It should be tucked snuggly under the patient, not under the mattress. This prevents the arm from shifting downward intraoperatively and resting against the OR bed rail. The placement of IV lines in an arm that is to be tucked at the side should be avoided, but in cases where this is not avoidable, patency of those lines must be ensured.

OTOLOGIC SURGICAL POSITIONING. Microscopes are used for most otologic procedures. Based on the design of the microscope and the OR bed used, the patient may be placed on the bed in the reverse position—with the patient's head at the foot of the bed—to facilitate proper placement of the microscope mounted on a floor stand and to allow adequate space for the surgeon and assistant to be positioned on sitting stools near the surgical site.

The patient is placed supine with the operative side as close to the edge of the OR bed as possible, with the head turned and the operative ear upward. This positioning gives the surgeon access in viewing all areas of the middle ear and mastoid. One or more safety/restraining belts are used to secure the patient on the OR bed to ensure safety when turning or rotating the bed. During some procedures, such as mastoidectomy, the patient's head may be secured in position by placing tape across the head and attaching it to the frame of the OR bed. For other procedures, such as myringotomy, the patient's head may be immobilized and supported on a foam headrest. A donut-shaped foam head support helps to immobilize the head and permits easy adjustment of the angle while the operating microscope is being used.

To protect the nonoperative ear, the perioperative nurse should ensure that it is in the center of the donut hole and that the headrest does not cause any pressure on the ear. The dependent arm on the nonoperative side must also be well padded and properly positioned to minimize pressure injury; the patient's body weight could cause injury when the OR bed is rotated laterally to optimize surgical access. Special consideration must be given when the patient's head is positioned for surgery, especially when general anesthetics are used. Extremes in neck extension and head torsion can cause injury to the brachial plexus or cervical spine. Other options to assist in patient positioning are determined by the otologic procedure to be performed and by the surgeon's preference. They may include ophthalmic headrests with a crescent-shaped pad, a padded horseshoe-shaped headrest, or a headrest with skull pins such as the Mayfield, which is used in certain neurologic procedures.

Positioning of the surgeon is equally important to the success of the surgery. The surgeon's chair should be positioned at a height and distance that allow comfortable access to the operative site. The use of hydraulic or electric chairs enables the surgeon to adjust the position to meet these needs.

RHINOLOGIC SURGICAL POSITIONING. A standard headrest may be used to maintain the head in normal position but is not necessary. The entire bed is turned 90 degrees to allow the right-handed surgeon to work from the patient's right side, and the right arm is tucked in at the patient's side. Pad the elbows to protect the ulnar nerve; place the palms

FIGURE 18-12 Nasal procedure with scrub person on right side of surgeon.

facing inward and the wrist in a neutral position. Depending on the procedure, the left arm may be maintained by the anesthesia provider and usually has the IV line placed in it for easier access. The anesthesia provider will be at the patient's head. Raising the head of the bed greater than 45 degrees uses gravity to help minimize intraoperative bleeding. The scrub person may stand at the patient's head or near the patient's waist next to the surgeon's right arm (Figure 18-12). The Mayo stand can be positioned at the head and to the side of the bed; however, it is most commonly positioned over the patient's chest, depending on where the scrub person is standing. If indicated for the procedure, the perioperative nurse assists with setting up the navigation towers and video monitor equipment at this time.

ORAL CAVITY/LARYNGOLOGIC/NECK SURGICAL POSITIONING. The nurse assists with placing the patient in the supine position. A shoulder roll may be used for hyperextension of the neck. The headrest should allow easy movement of the head from side-to-side yet should maintain support. The patient's arms are often tucked at the sides as described earlier in this section to allow access of the surgical team to the operative site. If a microscope or video equipment is used, the OR bed may be turned to accommodate this equipment.

Anesthesia. Both the use of general anesthesia and the infiltration of a local anesthetic agent (local anesthesia) have advantages during otorhinolaryngologic surgery. General anesthesia provides airway control and allows the patient to remain still throughout the procedure, thereby making surgery technically easier to perform, but requires particular attention to extremes in head positioning, possible air emboli, the control of bleeding, and, for otologic procedures, the effects of nitrous oxide in the middle ear (Box 18-1). All anesthetics create an oxygen-rich atmosphere and the perioperative team must consider the patient's safety in this environment (Risk Reduction Strategies).

Local anesthesia is used alone or as an adjunct to many procedures. Safe administration of medication is essential for achieving optimal outcomes (Surgical Pharmacology). Lidocaine is frequently combined with epinephrine. A concentration of 1:200,000 provides maximum vasoconstriction, but some surgeons prefer a concentration of 1:100,000. Cocaine 4% topical solution is the second medication that is used commonly for rhinologic procedures. It is a good vasoconstrictor with the added benefit of anesthetic properties. Some surgeons use a nasal decongestant instead of cocaine for nasal vasoconstriction. These decongestants do not produce some of the cardiac effects seen with cocaine. Because nasal and sinus surgeries are performed in such a confined space, vasoconstriction becomes crucial for appropriate visualization of the surgical field. Hypertension can increase bleeding despite the use of vasoconstrictive agents and may need to be managed medically by the anesthesia provider intraoperatively if the visual field becomes compromised and surgery is impaired.

For rhinologic procedures, before the patient arrives in the OR the nurse prepares a separate prep table, which includes a labeled container of the vasoconstrictor solution, x-ray–detectable cottonoid sponges (usually ½ inch × 3 inches with attached strings), bayonet forceps, and a small nasal speculum. The surgeon soaks the cottonoid sponges with the vasoconstrictor solution and usually packs the nose with the

BOX 18-1

Nitrous Oxide and the Middle Ear

The middle ear and paranasal sinuses are normal body air cavities and consist of open, nonventilated spaces. The middle ear cavity is vented periodically when the eustachian tube opens. During general anesthesia, inhaled nitrous oxide diffuses into the middle ear space through the capillaries of the middle ear mucosa. This results in increased middle ear pressure. Rapid increases in middle ear pressure proportional to inhaled levels of nitrous oxide and abnormal eustachian tube function may cause nausea, vomiting, and rupture of the tympanic membrane in susceptible patients. This includes patients having previous ear surgery, otitis media, sinusitis, upper respiratory tract infections, enlarged adenoids, or other disorders of the nasopharynx.

When nitrous oxide is discontinued, the gas is rapidly reabsorbed and strong negative pressure in the middle ear may occur. This negative pressure may result in nausea, vomiting, serous otitis, hemotympanum, disarticulation of the stapes, and impaired hearing. Some practitioners believe the use of nitrous oxide as an anesthetic inhalation agent is hazardous to hearing in patients who have undergone previous reconstructive middle ear surgery.

Modified from Donlon JV et al: Anesthesia for eye, ear, nose, and throat surgery. In Miller RD, editor: *Miller's anesthesia,* ed 6, Philadelphia, 2005, Churchill Livingstone.

RISK REDUCTION STRATEGIES

Managing the Risk of Fire in Oxygen-Rich Environments

Some estimates suggest that between 50 and 200 OR fires occur in the United States every year, with as many as 20% of reported fires resulting in serious injury or death (Caplan, 2008). Three elements must be present for fire to occur: heat, fuel, and oxygen. All elements are present in the OR.

Patients undergoing otorhinolaryngologic procedures are at greater risk for fire injury because of the proximity of the surgical field to high concentrations of oxygen. Devices used in this specialty (e.g., lasers, fiberoptic light cables, ESU, high-speed surgical drills and burrs) further contribute to risk by providing heat and fuel.

The tenets of fire safety are discussed in length in Chapter 2. Specific recommendations that perioperative nurses caring for otorhinolaryngologic patients must consider include:

- Awareness of risk factors. Oxygen vents into the atmosphere from facemasks, nasal cannulae, and uncuffed endotracheal tubes, accumulating under surgical drapes. This creates an oxygen-enriched atmosphere within the proximity of the surgical site for otorhinolaryngologic procedures.
- Discussion of risk. The perioperative nurse and scrub person should collaborate before procedures to plan for risk and ensure that sterile saline is available on the surgical field, the holster is used for the active ESU electrode, and the volumes of music, conversation, and ambient room noise are reasonable so that the audio from the ESU or laser can be heard. A careful review of the facility protocol for handling fire in the OR, including verification of the location of fire pull alarms, extinguishers, and evacuation routes, is essential and should not be minimized.
- Implementation of specific safety protocols for the use of the laser and the ESU in the airway:
  - Use only air for open delivery on the face for spontaneous breathing sedated patients who can maintain safe blood oxygen saturation without supplemental oxygen.
  - A laser-resistant endotracheal tube should be used, specific to the laser used for the procedure (e.g., CO_2, Nd:YAG). The cuff of the laser tube should be filled with saline and colored with an indicator dye such as methylene blue. Before activating the laser the surgeon should inform the anesthesia provider so that the oxygen concentration delivered to the patient can be safely reduced. Additionally, the surgeon should wait a few minutes before activating the laser to allow the oxygen concentration to diminish.
  - Cuffed endotracheal tubes should be used whenever possible for airway procedures. Before activating the ESU inside the airway, the surgeon should give the anesthesia provider adequate notice that the ignition source is about to be activated. The anesthesia provider should reduce the oxygen concentration to the minimum required to prevent hypoxia and the surgeon should wait a few minutes before using the ESU to allow the oxygen concentration to diminish.
  - Scavenging with the wound suction may be used to reduce the oxygen concentration in the operative field.
  - Sponges and cottonoids (and cottonoid strings) should be moistened when used in oxygen-rich environments to reduce the ignition potential from sources such as the laser or ESU.
  - If an uncuffed endotracheal tube must be used, moistened sponges should be used around the field to minimize leakage and reduce potential heat buildup.
- An immediate halt to the procedure when early warning signs of a fire are noticed. For fire in the airway or breathing circuit, the endotracheal tube should be removed and all flammable and burning materials should be removed from the airway. Delivery of all airway gases should stop, and saline should be poured into the patient's airway to extinguish any residual embers and cool the tissues.

Modified from Association of periOperative Registered Nurses: Guidelines for fire prevention in the operating room. In *Perioperative standards and recommended practices,* Denver, 2009, The Association; Caplan RA: Practice advisory for the prevention and management of operating room fires: a report by the American Society of Anesthesiologists task force on operating room fires, *Anesthesiology* 108:786-801, 2008; Everson CR: Fire prevention in the perioperative setting: perioperative fires can occur everywhere, *Periop Nurs Clin* 3:333-343, 2008; Richter GT, Willging JP: Suction cautery and electrosurgical risks in otolaryngology, *Int J Pediatr Otorhinolaryngol* 72:1013-1021, 2008; (no author): Fire prevention: avoid oxygen to face: *OR Manager,* 261 (1) 18, 2010.

SURGICAL PHARMACOLOGY

Medications Commonly Used in Otorhinolaryngologic Surgery

Category	Dose/Route/Mechanism	Purpose/Action	Adverse Reactions	Nursing Implications
LOCAL ANESTHETICS				
Lidocaine, 0.5% or 1%	Local injection	Blocks pain and temperature fibers, used as medium to dilute epinephrine	Cardiovascular, hypotension, confusion, dizziness, headache, somnolence, tremor, injection site pain, cardiac arrest, cardiac dysrhythmia, seizure	Contraindicated in hypersensitivity to amide locals. Use with caution in CHF, bradycardia, hypovolemia, liver disease, renal impairment.
Tetracaine (Pontocaine)	Topical; 0.25%-0.5% by nebulization or direct application	Blocks pain, suppresses gag reflex	Pain, redness, irritation on initial contact	Solution must be refrigerated. Frequently given by way of an atomizer. Remind patient not to eat, drink, or chew gum for at least 1 hour after procedure or until cleared by physician; return of gag reflex should be determined before discharge from PACU.
Benzocaine/ tetracaine/butamben (Cetacaine)	Topical; available in gel, liquid, and spray	Blocks pain, suppresses gag reflex	Dry mouth, dizziness	Spray is given by way of metered applicator; 1- to 2-sec spray is approximately 200 mg/sec. Should not be used over prolonged periods. Remind patient not to eat, drink, or chew gum for at least 1 hour after procedure or until cleared by physician; return of gag reflex should be determined before discharge from PACU.
Benzocaine	Topical; available in 20% gel and 20% spray	Blocks pain, suppresses gag reflex	Dry mouth, dizziness	Spray delivers 180-200 mg/sec when container is full, 60-80 mg/sec when inverted. Remind patient not to eat, drink, or chew gum for at least 1 hour after procedure or until cleared by physician; return of gag reflex should be determined before discharge from PACU.
Lidocaine hydrochloride	Available as 4% solution, 2% viscous solution	Local anesthetic	High doses may cause cardiac dysrhythmias, minor burning and stinging of mouth and throat on initial contact	Provide patient with emesis basin to expectorate any secretions. Patient may be instructed to gargle or swish with viscous solution to numb oral cavity in preparation for introducing Abraham cannula with 4% solution.
Cocaine hydrochloride	4% topical swab, packing instilled into cavity or spray, may be applied directly to vocal cords or other laryngeal structures on pledgets to promote vasoconstriction	Local anesthetic (also used as vasoconstrictor)	CNS depression, CNS stimulation, anxiety, tachydysrhythmia, seizures; may interact with cannabis, promethazine (Phenergan), and St. John's wort	Contraindicated in hypersensitivity to cocaine products. Use with caution in acutely ill patients or children, on severely traumatized mucosa, or when sepsis is present in area of intended application.

VASOCONSTRICTORS				
Oxymetazoline hydrochloride (Afrin Nasal Spray, Neo- Synephrine 12 Hr, Nasacon)	0.05% nasal spray	Nasal decongestant used for vasoconstriction	Headache, insomnia, nervousness, nasal congestion, rebound congestion, dry nasal mucosa, nasal stinging/ burning, sneezing, cardiac dysrhythmia, hypertension, tachydysrhythmia	Contraindicated in patients hypersensitive to oxymetazoline or other adrenergic agents, narrow-angle glaucoma. Use with caution in patients with cardiovascular disease, concurrent MAOI or tricyclic depressant therapy, diabetes, hypertension, prostatic enlargement, thyroid disease.
Epinephrine	1:100,000 to 1:200,000	Used for vasoconstriction	Palpitations, tachydysrhythmia, paleness and sweating, nausea and vomiting, asthenia, dizziness, headache, tremor, pain in eye, anxiety, apprehension, nervousness, dyspnea, cardiac dysrhythmia, hypertensive crisis, pulmonary edema	Should not be used in patients with hypersensitivity to epinephrine products, narrow-angle glaucoma (ophthalmic form) within 2 wk of MAOI (inhalational form). Proceed with caution in presence of cerebrovascular insufficiency, diabetes, geriatrics, heart disease, coronary insufficiency, hypertension, thyroid disease, pregnancy.
ANTIBIOTICS				
Mupirocin (Nasal Bactroban)	2% topical	Antibacterial and lubricant for nasal packing, applied topically to skin incisions	Dermatologic, nasal stinging and burning, disorder of taste, headache	Do not use with patients hypersensitive to mupirocin products. Prolonged use may result in overgrowth of nonsusceptible organisms including fungi; not intended for open wounds or mucous membranes.
Bacitracin	Topical ointment, 500 units/g	Antibacterial, antibiotic	Swelling, contact dermatitis, pruritus	See implications for mupirocin.
STEROIDS				
Triamcinolone acetonide (Aristocort, Kenalog)	Topical	Used topically to lubricate packs or expand packing	Hypertension, atrophic condition of skin	Use with caution in patients with hypertension, hypothyroidism, pregnancy. Do not use with hypersensitivity to triamcinolone acetonide; local, viral, fungal, or bacterial infections.
Cortisporin Otic suspension (neomycin and polymyxin B sulfates/hydrocortisone)	Topical	Used after otologic surgery as an antiinflammatory/ antibiotic agent	Itching, pain, stinging, burning, ototoxicity	When administering to patient, do the following: Tilt patient's head in opposite direction of affected ear. Instill prescribed number of drops toward ear canal, not directly on eardrum. (Tip: To promote correct placement of drops in children pull auricle down and posterior; in adults pull auricle up and posterior.)

CHF, Congestive heart failure; *CNS,* central nervous system; *MAOI,* monoamine oxidase inhibitor; *PACU,* postanesthesia care unit.
Modified from Dimmitt P: A review of topical anesthetics and decongestants, *ORL Head Neck Nurs* 23(2):21-24, 2005; Skidmore-Roth L: *Mosby's drug guide for nurses with 2010 update,* ed 8, St Louis, 2010, Mosby; Hodgson BB, Kizior RJ: *Saunders nursing drug handbook 2010,* St Louis, 2010, Saunders; Chow AW: Infections of the oral cavity, neck, and head. In Mandell GL et al, editors: *Principles and practice of infectious diseases,* ed 6, Philadelphia, 2005, Churchill Livingstone.

sponges before prepping and draping, to allow time for the vasoconstrictive properties to take effect. The cottonoids are left in place. Some surgeons will also inject local anesthetic at this time, but others may wait to inject at the time of surgery. Maximum vasoconstriction occurs in approximately 10 to 12 minutes after the administration of epinephrine. If a local anesthetic is to be injected next, the prep table should also include a 10-ml Luer-Lok syringe, appropriate-size needle (usually 25 gauge, 1½ inches), and labeled lidocaine (0.5% to 2%, according to surgeon's preference). Additional syringes, needles, and labeled local anesthetic solution should be available on the sterile field for additional administration intraoperatively. Additional labeled cocaine solution and cottonoids should be available on the sterile field as well. The nurse and scrub person ensure that the cottonoids are counted before and at the end of the procedure. (If a cottonoid is placed extremely posterior along the nasal floor, it can slide past the palate and be may swallowed or aspirated by the patient.)

Topical agents used in laryngeal surgery include epinephrine, phenylephrine hydrochloride, or cocaine. These agents may be applied on a cottonoid or sprayed directly on the vocal cords. Lidocaine 4% (Xylocaine) may be instilled into the trachea to decrease the cough reflex when it becomes an obstacle to a thorough physical assessment.

Local anesthesia combined with sedation or monitored anesthesia care is often employed for surgery in the preme-atal region and for stapedectomy and uncomplicated middle ear procedures of less than 2-hours' duration, some rhinologic procedures, and some excisional neck procedures. Sedation should render the patient calm, comfortable, cooperative, and able to understand and communicate. Patients should not be overmedicated to the point of demonstrating obtunded reflexes or being out of touch with their surroundings. Documentation should follow institutional policy for recording intraoperative medications administered (AORN, 2009a).

Preparation of the Operative Site. If hair removal is absolutely necessary, clipping is preferred because shaving may injure the skin and increase the risk of infection. Postauricular and endaural incisions extending upward from the meatus require hair to be about 1 to 2 cm away from the proposed incision site so that hair will not be in the operative field. Long hair is easily managed and kept out of the way with tape or lubricant. It is good practice to pull the top hair out of the way and only clip under the hair, to help maximize normal hair aesthetics postoperatively. Plastic adhesive drapes can be applied circumferentially around the proposed incision site, or a clear sterile drape laid over the entire surgical area. Parotid surgery may require hair removal from just below the temple to a line even with or slightly behind the pinna of the ear. Head and neck surgeries may require removal of hair on the chest to the nipple area on both sides. Thorough drying of the surgical area after the prep has been applied is critical for proper adhesion of the drapes to the skin so sterility is maintained throughout the operative procedure.

A povidone-iodine solution is generally used (unless the patient is allergic to iodine) to prep the surgical site for otologic and head and neck procedures. Povidone-iodine 10% (i.e., Betadine) is generally considered safe for the middle ear space and has not been found to be ototoxic in animal studies; however, in the presence of a tympanic membrane perforation, swabbing of the ear canal skin is preferred to gross spillage in the ear canal to prevent large volumes of prep solution from entering the middle ear space. All other surgical prep solutions, such as chlorhexidine and alcohol, are considered ototoxic and should be strictly limited to the outer ear and surrounding skin. Head and neck procedures may involve extensive skin preparation and usually include the entire area from the chin to the nipples; it may also include a donor skin graft site if a defect or large flap coverage is anticipated. Some surgeons prefer the patient's face to be included in the prep, depending on the type of surgery anticipated and the site of the lesion. If a flap may be raised to reconstruct a defect, saline should be available to remove the discoloration from the skin to allow the surgeon to check for flap viability.

Prepping of the nose and face may or may not be done for rhinologic and laryngeal/oral cavity procedures, depending on the surgical procedure and institutional policy. These areas are considered "dirty" and not possible to prep as effectively as other surgical sites, such as an abdomen. The surgical field is maintained in sterile fashion, and these procedures usually have a "clean contaminated" wound classification (see Chapter 3).

Facial Nerve Monitoring. Audible facial nerve monitors are used intraoperatively during procedures in which the facial nerve is at risk. The purpose of this monitoring technique is to assist in the early identification of the nerve, to increase the possibility of its preservation by minimizing trauma, and to assess its integrity after dissection (Mahlan et al, 2005). Electrodes are placed into the facial muscles before the patient is draped. Consultation and communication with the anesthesia provider are essential because the use of muscle relaxants and long-term paralyzing agents must be avoided. In the setting of a tympanic membrane perforation, lidocaine should not be allowed to spill into the middle ear space when injecting the ear canal, as temporary facial paralysis can ensue from topical anesthesia of a dehiscent facial nerve in the tympanic segment. Facial nerve monitoring is commonly used during acoustic neuroma and mastoid surgery (Figure 18-13).

Draping. Barrier draping minimizes the risk of postoperative infection. Draping technique is based on the surgeon's preference and the procedure to be performed.

OTOLOGIC DRAPING. Draping may be minimal for procedures such as myringotomy. For major otologic procedures,

FIGURE 18-13 Nerve integrity monitor system for intraoperative facial nerve monitoring.

plastic adhesive drapes are applied around the ear to keep the patient's hair out of the surgical field. Sterile, plastic, aperture drapes may be placed over the surgical site with the ear exposed through the opening. The surgeon may elect to expose a portion of the face on the affected side to observe facial movement.

Three or four towels are draped over the aperture drape around the ear and may be secured with nonpenetrating towel clips. A fenestrated drape is unfolded over the patient, with the opening centered over the operative site. An alternative method is the use of a split sheet with the split end secured at the base of the ear and the open flaps wrapped around the patient's head. Disposable drapes with adhesive backing may be used to secure the sheet to the patient.

During mastoid surgery and for resections of acoustic tumors, fluid-collection pouches may be attached to the drape. These pouches will catch fluid runoff when drilling and irrigation are planned. The operating microscope is draped to extend the sterile field (Figure 18-14).

Special consideration must be given to the selection of draping material used during ear surgery and to the technique for removing powder from surgical gloves. Powder and lint cling to gloves and can be transferred to instruments and introduced into the ear. They act as a foreign body in the wound, causing the formation of granulomas in the middle and inner ear, and may contribute to irreversible hearing loss. Therefore gloves worn by the surgical team should be rinsed to remove powder and lint. Lint-free drapes should be used.

RHINOLOGIC DRAPING. Draping is done for most rhinologic cases. A small sheet with a towel on top of it is placed under the patient's head, and the towel is secured around the hairline with a nonpenetrating towel clip. A split sheet is then placed around the head. It is good practice to place a towel over the endotracheal (ET) tube if one is in place; this helps prevent the adhesive portion of the split sheet from sticking to the ET tube and inadvertently pulling on the tube once the procedure is completed and drapes are removed. Except during certain endoscopic procedures, the patient's eyes should be covered with moist gauze or towels if the patient is awake or taped closed if the patient has received a general anesthetic, protecting the eyes from nasal drainage or injury from instruments.

ORAL CAVITY/LARYNGOLOGIC/NECK PROCEDURE DRAPING. Draping of the patient for a laryngeal procedure for a benign lesion (intraoral approach) is minimal, with the primary focus being protection of the patient's eyes and face. This may be accomplished by (1) placing ointment in the patient's eyes, (2) taping the eyelids closed with a nonabrasive, nonirritating tape, (3) applying moist padding over the tape (if use of a laser is anticipated), and (4) placing self-adhering eye pads over the moistened pads. A head drape may be placed over the patient's face to expose only the lips and chin.

Draping for neck procedures often varies according to surgeon preference and is similar to the draping procedures described for rhinologic surgery. Additional drapes may be needed if skin grafts or flaps will be used for reconstructive procedures.

Surgical Microscope. The surgical microscope is often used to provide illumination and magnification for complex procedures to the ear, laryngeal surgery, or reconstructive free flap procedures following neck surgery. Several kinds of

FIGURE 18-14 Draped microscope for otologic surgery with surgeon in correct sitting position.

surgical microscopes with different attachments are available for otologic and laryngologic surgery. The microscope may be floor- or ceiling-mounted. Optimal light is provided by a xenon or halogen light source. Numerous types of monocular and binocular heads are available for the microscope. These heads may be fixed in a straight or angled plane, or they may be designed to be adjustable in an inclinable plane. For operations through an ear speculum, the microscope provides direct light and permits the surgeon to select a magnification of ×6, ×10, ×16, ×25, or ×40. A common eyepiece magnification for an otologic microscope is ×12.5, and the usual objective (lens) is 250- or 300-mm focal length (f). A 400-mm lens is used for laryngeal surgery. The total magnification is determined by multiplying the magnification of the eyepiece times that of the microscope body times that of the objective. The type of head and objective selected is based on the surgeon's preference. Microscopes equipped with a variable distance feature allow the surgeon to adjust the focal length from 200 mm to 400 mm without changing the lens objective. Video equipment may be attached to the microscope, which allows other team members to follow the procedure and to anticipate the necessary instrumentation. Before lenses are placed into the microscope, they should be checked to ensure that they are free from lint, dust, fingerprints, and soil. The surgeon adjusts the microscope before it is draped for surgery and manipulates it during the procedure. The microscope is draped with a sterile cover for otologic surgery, but is often left undraped for laryngeal procedures. It is necessary to keep the drape material away from the light source fan of the microscope. Doing so will allow cool air to continue to circulate and will avoid overheating of the fan, which could prematurely burn out the lamp and possibly cause a fire. When micromanipulators are secured to transmit laser energy to tissue through the operating microscope, special microscope laser drapes must be used. These drapes have an opening in the plastic at the base of the micromanipulator covering the objective, allowing laser energy to pass through the opening of the drape without risk of burning the drape.

Care should be taken when removing the drapes from the microscope to avoid discarding the eyepieces with the drapes or dropping them on the floor. Eyepieces have been lost or damaged in this manner, necessitating costly repair or replacement.

When the microscope is not in use, it should be kept in a locked, upright position and stored in an area that is away from traffic, free from dust, and properly ventilated. Ideally, a set of eyepieces should be left in the scope to prevent the inside of the scope from becoming dusty. The microscope may also be covered with either a protective cover or a plastic bag.

Equipment and Instrumentation. Equipment that may be used in otorhinolaryngologic surgery includes an ESU (both monopolar and bipolar), a forced-air warming unit or other device to maintain normothermia, and headlights. Lasers assist in vaporization of scar tissue, granulomas, and cholesteatomas without damaging surrounding tissue and may be used for select otolaryngologic procedures. Lasers used in this specialty include the carbon dioxide (CO_2), potassium titanyl phosphate (KTP), erbium:yttrium-aluminum-garnet (Er:YAG), and neodymium:yttrium-aluminum-garnet (Nd:YAG) lasers. Lasers can be secured to the operating microscope and laser energy delivered to the tissue by means of a micromanipulator. Laser energy is delivered directly to tissue by fiberoptic probes, which can be navigated around obstructing structures.

For complex reconstructive procedures in the neck, a Doppler unit (to determine the viability of blood vessels) and an electromyographic nerve monitor (to determine the location and quality of nerves) may be employed.

Specimen cups, labels, and a marking pen should be available on the sterile field because often several specimens are obtained. Institutional procedure for correct patient and specimen identification should be followed (AORN, 2009b).

The basic principles of care, handling, and sterilization of instruments are discussed in Chapter 3. The instrumentation used in otorhinolaryngologic surgery is quite specific and is discussed with each surgical intervention. Head and neck instrumentation combines general surgical instruments and procedure-specific instruments. Many otolaryngologic procedures use delicate microinstruments that should be handled individually and should not be allowed to physically contact each other (Figure 18-15). Fine tympanoplasty and stapedectomy instrumentation should be kept in special storage and sterilization trays. These trays help separate instruments, aid in quick identification, protect the instruments from damage, and facilitate handling during surgery. Instruments used in the path of the operating microscope may have an ebony glare-reducing finish. Handles of assorted knives and dissectors may be flat, hexagonal, or round for better gripping or handling during surgery (see Figure 18-15). The shaft of these instruments may be straight, angled, or bayonet-shaped.

Powered Equipment. A powered sagittal saw is used for complex neck procedures. A power drill and assorted rotating burrs are essential for middle ear surgery and some sinus procedures. Many drills are commercially available that are pneumatically or electrically driven. Pneumatic drills must have high torque (power) and more than 20,000 revolutions per minute (rpm) (speed). Some surgeons believe electrically powered drills offer equal torque but better control of the drill tip.

A selection of burrs including assorted sizes of round cutting burrs and diamond polishing burrs should be available. A diamond burr cuts slowly and grinds the bone away rather then tearing into it; it is commonly used around vital structures. Cutting burrs assist in quickly removing bone from areas not close to vital structures. The grooves or teeth of burrs must be clean of bone dust. Bone-cutting burrs tend to clog more easily than coarse-toothed burrs. A sterile wire brush may be used to keep burrs clean intraoperatively. Bone dust must be prevented from settling in areas such as those in stapedectomy, tympanoplasty, endolymphatic sac, or fenestration surgery. A sterile field continuously flooded with irrigation solution helps to lessen clogging of the burr and washes away bone dust.

Evaluation

Perioperative nursing care should be evaluated at the completion of the procedure before the patient is transported to the postanesthesia care unit (PACU) or ambulatory recovery area. If the patient has received a local anesthetic, the nurse will have had the opportunity to evaluate care on an ongoing basis, communicating with the patient throughout the procedure.

At the conclusion of the procedure, the patient should be assessed for any difficulties in breathing. Patients who have undergone nasal surgery may have packing, which can inhibit

breathing; however, the patient should be able to breathe normally through the mouth. Patients who have undergone oral cavity or laryngeal surgery are at risk of airway edema (Rapid Response Team box). The head of the PACU bed should be elevated before transport to the unit for all otorhinolaryngologic patients. Because of the proximity of the facial nerve to many structures within the anatomic field for otorhinolaryngologic procedures, the nurse must evaluate the patient's facial nerve function. This evaluation requires the patient's cooperation in smiling, closing the eye, and wrinkling the nose on the operative side. If facial palsy is observed and not resolved within 2 hours of the procedure, it may be caused by surgical trauma. Skin integrity at positional pressure sites and the ESU dispersive electrode site should be assessed and documented. The amount of drainage present on any dressings should be noted.

During evaluation, the perioperative nurse determines if the patient met the outcomes in the plan of care. Some outcomes can be reached during the preoperative and intraoperative phases of care; they are evaluated before the patient's discharge from the OR. Others require ongoing monitoring and measurement in the postoperative phase. A complete hand-off report allows the postanesthesia care unit (PACU) or intensive care unit (ICU) nurse to detect significant changes in the patient's condition at an early stage. Special considerations should also be included, such as the necessity for flexion of the neck to avoid disruption of the suture line of the trachea in a patient who has undergone tracheal resection. Repeated swallowing should be noted, because this may indicate posterior nasal or oral cavity bleeding. Part of the hand-off report to the PACU or nursing unit should include the outcomes of care provided:

- The patient identified factors that caused anxiety and verbalized effective coping; frequent explanations were provided, which assisted in coping with an unknown environment.
- The patient communicated adequate pain management using a pain scale and demonstrated effective coping with the physical and psychologic effects of pain. Vital signs remained stable; there were no electrocardiogram (ECG) or central nervous system (CNS) changes.
- The patient demonstrated effective breathing patterns. Respiratory rate and depth were within normal limits, and the respiratory pattern appeared effective with no cyanosis or other signs of hypoxia.
- Intraoperative bleeding was kept at a minimum during the case, keeping the patient safe from a dangerous amount of surgical blood loss.
- The patient verbalized understanding of anticipated postoperative alteration in the senses of hearing or smell and taste.

RAPID RESPONSE TEAM

A 57-year-old male underwent a 6-hour tympanoplasty and mastoidectomy for treatment of a recurrent cholesteatoma, facial nerve dehiscence, and perilymph fistula in his right ear. On arrival to the PACU the patient was alert and responsive and complaining of pain to his left shoulder and arm. The perioperative and PACU nurses assessed the patient and observed the patient's left arm to be swollen and slightly dusky. As part of the rapid response protocol at the facility, the PACU nurse notified the surgeon, who determined the patient had compartment syndrome related to prolonged positioning during the otologic procedure. The patient was treated and recovered without incident.

The concept of rapid response is to improve patient care by providing prompt recognition, early advanced assessment, enhanced communication with physicians, and appropriate intervention to patients with perceived changes in or deterioration of the condition. In response to The Joint Commission's National Patient Safety Goal 16.01.01, many facilities have instituted rapid response teams (RRTs). Patients who undergo otorhinolaryngologic procedures at facilities with RRTs benefit from earlier interventions in the face of possible postoperative complications such as:

- Airway compromise caused by swelling related to rhinolaryngologic/oral cavity procedures
- Hypoxia
- Facial nerve dysfunction after otologic procedures
- Hemorrhage
- Hypotension or hypertension
- Mental status changes

In most facilities, the RRT may be activated by any bedside clinical provider including, but not limited to, the nurse, nursing assistant, physical therapist, respiratory therapist, resident, or attending physician. It would be ideal to have an RRT summoned at least 6 to 8 hours before a sentinel decline in condition occurs. RRT activation alerts the multidisciplinary healthcare professionals comprising the rapid response team to begin early interventions and treatment for patients with a change or deterioration in their condition that requires further investigation.

The rapid response team includes the following members (though it may be adjusted depending on the facility's unique resources and patient care needs):

- Staff nurses
- Responding medicine RRT physician
- Responding surgery RRT physician
- Anesthesia provider
- ICU nurse
- Nurse supervisor/manager
- Respiratory therapist

The procedure for activating the RRT often involves calling a STAT in-house telephone number, prompting the operator to alert the ICU, pharmacy, lab, and radiology. The ICU nurse with the rest of the team arrives at the announced room with a crash cart. The team will determine the necessity for physical assessment, laboratory tests, radiologic tests, ECG, drugs, transfusion of IV fluids, vascular access, cardioversion, intubation, or ventilation, or the need to transfer the patient to the next level of care. At this time the team may also decide to discuss with the family end-of-life decisions if no further intervention is necessary. The attending physician of the patient must be notified within 30 minutes of the RRT.

Specific documentation is recorded pertaining to the different staff members of the team and each member of the team is responsible for his or her own identifiable roles and responsibilities.

Modified from Thomas Jefferson University Hospital, Hospital Policies and Procedures, policy number 113.55, 2009.

FIGURE 18-15 **A**, Microsurgical ear forceps including various sizes of cup forceps and alligator forceps. **B**, Forceps out of tray. **C**, Close-up of types of forceps tips. *Left to right,* Straight cup forceps, right cup forceps, large cup forceps.

- The patient verbalized feelings regarding disturbances in body image, interacted positively with perioperative staff, maintained eye contact, and identified personally effective coping strategies.
- The patient is able to communicate effectively (ongoing) and use alternative method (specify) of communication.

Patient and Family Education and Discharge Planning

Patient and family education is an important component of the age-appropriate and culturally sensitive care provided by perioperative nurses. Visual teaching aids, teaching brochures, and written discharge instructions provide the patient with knowledge of the surgery and what to expect during the postoperative period. Preoperative patient education includes preparing the patient for alterations in body image and function, if applicable to the planned procedure. Altered methods of communication must be discussed before disruption of oral or laryngeal function, or hearing. The presence of edema, drains, or dressings; changes in mobility; side effects of surgery or anesthesia; possible complications of surgery; and the pertinent signs and symptoms of these complications must be discussed. The OR environment and presence of equipment should be described to the patient preoperatively to keep anxiety at a minimum. Specific instructions based on the type of surgery performed must be reviewed with the patient, focusing on important areas, such as management of pain and discomfort, restriction of activity levels, and observation for signs of infection. Printed information should be reviewed with the patient, and the patient should repeat back the key points that are essential to a successful recovery (Canobbio, 2006). By the time of discharge, patients and family members should have a thorough knowledge and understanding of what to expect during the postoperative recuperation period. General instructions for otologic surgery are detailed in the Patient and Family Education box.

Surgical Interventions

OTOLOGIC PROCEDURES

The majority of otologic procedures are performed either through the ear canal or from behind the ear. Incisions through the ear canal include endaural and transcanal approaches. The postauricular approach is made through an incision from behind the ear.

PATIENT AND FAMILY EDUCATION

Patient Education for Otorhinolaryngologic Surgery

The following information is applicable to all otorhinolaryngologic procedures. Instructions unique to specific procedures are also included. Teaching is best accomplished using a variety of methods (e.g., conversation, printed materials, written instructions) and should include evaluation of the patient's understanding of the material, such as by having the patient or caregiver "teach back" the concepts previously discussed.

PREPROCEDURAL TEACHING—ALL PROCEDURES

- Review the physician's explanation of the procedure and its purpose; encourage the patient to ask questions and to discuss any fears or anxieties. Discuss the need for informed consent for surgery and anesthesia.
- Tell the patient that nothing-by-mouth (NPO) status must be maintained as directed by the anesthesia provider.
- Describe the OR environment and sequence of events that occur, explaining what the patient will see, feel, and hear during the perioperative experience.
- Provide information about what to expect if a local anesthetic is used (e.g., some discomfort may occur during the initial administration of a local anesthetic; if epinephrine is used with the local agent, the resulting weak, quivering feeling and increased heart rate are effects of the epinephrine and disappear after a few minutes).
- Remind the patient undergoing a local procedure that there will be pressure at some point but not pain. Encourage the patient to inform the perioperative nurse and surgeon if any discomfort is felt during the procedure. Discuss a mechanism to communicate when unable to speak. A gesture as simple as raising the hand nearest to the nurse monitoring the patient may be appropriate.
- Inform the patient that the skin will be cleansed with bactericidal soap or antiseptic solutions to remove bacteria.

OTOLOGIC/LARYNGOLOGIC PROCEDURES

- Review the use of an erasable board, paper and pencil, flash cards, or other communication board if applicable to the surgery performed.
- Encourage questions and verbalization of fears and anxieties regarding possible loss of voice or hearing.

REVIEW OF POSTPROCEDURAL CARE—ALL PROCEDURES

- Explain that the patient will be in high Fowler's position to lessen edema, improve coughing and deep breathing, and provide comfort. Advise patients to use pillows or a wedge to elevate their head by 30 degrees for the first 24 hours after discharge. Note that some patients utilize a recliner chair at home for comfort.
- Discuss the importance of frequent deep breathing and coughing.
- Explain the presence of any dressings and drainage tubes.
- Review pain management, encouraging the patient to use mild analgesics when possible.
- Remind the patient to limit the Valsalva maneuver (e.g., coughing, straining at stool) to prevent tissue damage/bleeding.
- Inform the patient that some bruising and swelling can be expected after many procedures, but it will gradually subside.
- Note that some numbness may be noted postoperatively but gradually disappears.
- Heavy lifting or strenuous activity should be avoided until directed by the surgeon.

RHINOLOGIC PROCEDURES

- Inform the patient that if a nasal pack is inserted, there may be some difficulty in swallowing. When the patient attempts to swallow, a sucking action occurs in the throat because the packing does not allow air passage through the nose, thereby creating a partial vacuum.
- Review the procedure for changing the mustache dressing (or drip pad) that is in place postoperatively to absorb any drainage. This is usually a folded 2-inch × 2-inch gauze pad placed under the nose and secured by tape. Blood-tinged secretions in the nasopharynx are normal in the first few hours after the procedure.
- Advise the patient that forceful nose blowing must be avoided for a time to prevent movement of the rearranged nasal structures. If necessary to clear nasal passages, the patient should sniff gently.
- Review the importance of humidification. As directed by the surgeon, patients may use a humidifier at home to reduce nasal dryness.
- Note that the sense of smell is diminished for a time after surgery but gradually returns.

OTOLOGIC PROCEDURES

- Avoid rapidly moving the head, bouncing, or bending over for 3 weeks.
- Exercise caution when coughing or blowing the nose; open both the nose and mouth if sneezing is unavoidable.
- Avoid drinking through a straw.

ORAL CAVITY/LARYNGOLOGIC PROCEDURES

- Rinse the mouth as directed by the surgeon; avoid contact with agents that may inflame the mouth, such as mouthwashes that contain alcohol.
- Perform oral hygiene after each meal or as often as needed.
- Use a soft toothbrush, Toothette, or gauze for oral care.
- Use and apply topical analgesics and anesthetics as ordered by the physician.
- Observe voice rest as directed by the surgeon.
- Use humidification to decrease dryness and increase comfort.

Continued

PATIENT AND FAMILY EDUCATION

Patient Education for Otorhinolaryngologic Surgery—cont'd

HOME CARE—ALL PROCEDURES

Give both the patient and the caregiver *verbal* and *written* instructions. Provide them with the name and telephone number of a physician or nurse to call if questions arise. Use visual aids to assist in instruction.

- General information
  - Review any explanation about the procedure and any specific follow-up care.
  - Review the signs and symptoms that should be reported to the surgeon or nurse:
    - Infection of the incision: redness, drainage, pain, warm to touch
    - Fever
    - Dyspnea without exertion
    - Difficulty swallowing
    - Bleeding or discharge of clear fluid from the ear or nose
    - Vertigo—lasting more than 24 to 48 hours after surgery
- Activity
  - Remind the patient to plan frequent rest periods.
  - Assist the patient to begin self-care as soon as possible.
  - Review any restricted activities, such as driving, swimming/diving, air travel.
- Follow-up care
  - Stress the importance of regular follow-up visits. Make sure the patient has the necessary names and telephone numbers to contact the surgeon.

Modified from Canobbio MM: *Mosby's handbook of patient teaching,* ed 3, St Louis, 2006, Mosby; Russek JA: Care of patients with ear and hearing problems. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, Philadelphia, 2010, Saunders; Dietzen KK: Care of patients with oral cavity problems. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, Philadelphia, 2010, Saunders.

Endaural Approach

The endaural incision is made in two steps, using a #15 blade scalpel. The first incision starts at the superior meatal wall about 1 cm in from the outer edge of the meatus and extends down the posterior meatal wall to the edge of the conchal cartilage. The second incision on the superior meatal wall extends upward to a point halfway between the meatus and upper edge of the auricle. This approach offers direct access to the external auditory meatus and tympanic membrane and may be used for meatoplasty, canalplasty, selected tympanic membrane perforations, and stapes surgery.

Transcanal Approach

The transcanal approach is used for those procedures that are limited to the mesotympanum, hypotympanum, and tympanic membrane. The incision entails a superiorly based tympanomeatal flap through the ear canal and involves making a semilunar canal skin incision anywhere from to 2 to 10 mm lateral to the tympanic membrane. For exposure, the skin, fibrous annulus, and tympanic membrane are elevated as a unit. Posterior tympanomeatal flaps may be used in stapedectomy, labyrinthectomy, myringoplasty, tumor biopsy, ossiculoplasty, and removal of glomus tympanicum tumors. Congenital cholesteatomas are best approached by superior tympanomeatal flaps, whereas perforations of the tympanic membrane may be accessed through an inferior tympanomeatal flap (Chole and Suddath, 2005).

Postauricular Approach

The postauricular incision is made 2 to 5 mm behind the ear as the surgeon follows the curve of the posterior auricular fold, providing wide-field exposure and a versatile and adaptable incision. It is commonly used for tympanoplasty procedures and it is also used to expose the mastoid process for a mastoidectomy, endolymphatic sac procedure, labyrinthectomy, or translabyrinthectomy resection of an acoustic neuroma.

Myringotomy

A standard myringotomy is an incision in the pars tensa of the tympanic membrane. Myringotomy is often accompanied by the aspiration of fluid under pressure in the tympanum, and the subsequent placement of small, hollow, pressure equalization tubes (PETs) (also known as *tympanostomy* or *myringotomy tubes*). It is indicated for acute otitis media in the presence of an exudate that has not responded to antibiotic therapy. Acute otitis media (AOM) occurs in 84% to 93% of all children. Otitis media with effusion (OME) occurs in 80% of children under the age of 10 years. The majority of children with AOM have spontaneous resolution. Hearing loss is the main concern when fluid is present in the middle ear (OME) (Thrasher, 2009). If left untreated, hearing loss can affect language development. If the fluid persists more than 8 to 12 weeks and is accompanied by hearing loss, removal of the fluid and placement of ventilating tubes in the eardrum are necessary.

Otitis media, although more common in the pediatric population, is also seen in adults. Tympanic fibrosis is common in adults and is a result of repeated infections that occurred in childhood. Acute otitis media is a collection of infected pus in the middle ear. The patient may have severe pain and bulging of the tympanic membrane (Figure 18-16). Failure to respond to oral antibiotics and analgesics or other complications, such as facial nerve paralysis, may require a myringotomy. By release of the pus or fluid, hearing is restored and the infection can be controlled. The procedure may be performed for chronic

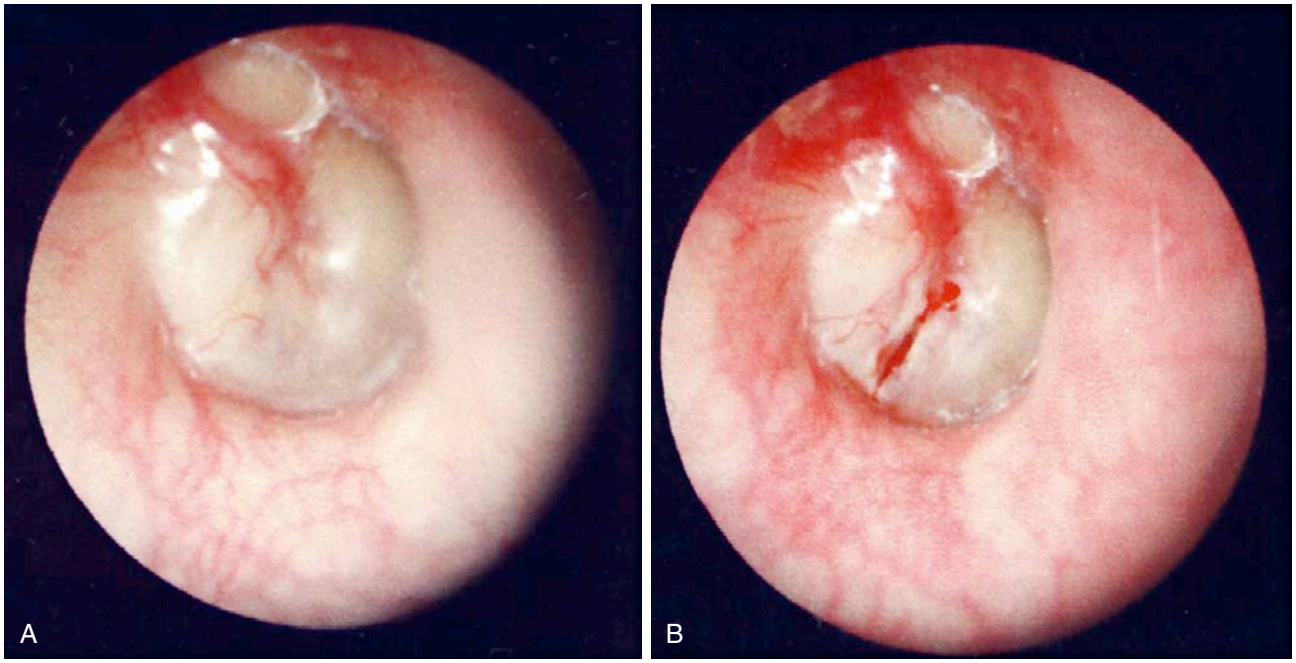


FIGURE 18-16 **A**, In purulent otitis media, pus under pressure pushes eardrum outward, resulting in bulging tympanic membrane. **B**, Radial myringotomy incision.

serous otitis media in which the presence of fluid in the middle ear produces a hearing loss. Frequently, tubes are inserted into the tympanic membrane (Figure 18-17) to allow ventilation of the middle ear. Myringotomy tubes may be used for the treatment of colds and fluid in the ear on a short-term basis (a few months), on an intermediate basis (6 to 18 months), and in long-term treatment (years) for chronic situations. Tubes may also be placed in patients undergoing hyperbaric therapy to prevent ear pain and tympanic rupture while in the hyperbaric chamber. Care must be taken to avoid getting water in the ears while the tubes are in place. Myringotomy is usually performed on an ambulatory surgery basis. A recent alternative to tube placement is CO_2 laser–assisted myringotomy, in which the laser energy is used to create a precise hole in the tympanic membrane. This remains open for 4 to 6 weeks. Laser-assisted myringotomy is done using a topical anesthetic and may be performed in the physician's office.

Procedural Considerations. Myringotomy with tube placement is considered a clean procedure. In adult patients, the procedure may be performed using a topical anesthetic. Pediatric patients generally require general anesthesia. The surgeon may wear gown and gloves or gloves only, depending on the policy related to Standard Precautions at the institution in which the procedure is performed. Myringotomy procedures require a sharp knife for making incisions into the tympanic membrane. Sterile, disposable, single-use blades are supplied with integrated handles or as single blades that may be secured into reusable handles. Myringotomy blades are spear-, lancet-, and sickle-shaped and are a matter of the surgeon's preference. The instrument setup includes a myringotomy knife and disposable blade, assorted sizes of aural specula, ear curettes, suction tip and tubing, a delicate Hartmann forceps, metal aural applicators, a curved needle, a culture tube (if cultures are to be taken), and myringotomy tubes (as applicable). Several types of disposable myringotomy tubes are available for implantation, depending on the length of time the surgeon wishes the tube to remain in place (see Figure 18-17). Once the tube falls out, the tympanic membrane incision usually heals.

Operative Procedure

1. With the head and microscope in position, the surgeon inserts the aural speculum into the ear canal. The external canal is cleaned of excess cerumen using a wire loop curette. With a sharp myringotomy knife, the surgeon makes a small, curved or radial incision in the anterior inferior quadrant of the pars tensa (see Figure 18-16).
2. A culture may be taken to determine the type of organism present. Pus and fluid are suctioned from the middle ear.
3. A tube may be inserted into the incision with alligator forceps or a tube inserter. Care should be taken to consult the manufacturer's directions for handling the tube.
4. Antibiotic drops may be instilled after positioning the tube. Ofloxacin 0.3% otic drops may be instilled to 10 drops per ear.
5. A cotton ball may be placed in the external canal at the end of the procedure.

Tympanoplasty

Tympanoplasty is the surgical repair of the tympanic membrane and the tympanum and the reconstruction of the ossicular chain. It is indicated for conductive hearing losses caused by perforation of the tympanic membrane as a result of trauma or infection; for ossicular discontinuity; for chronic or recurrent otitis media; for progressive hearing loss; and for the inability to safely bathe or participate in water activities as a result

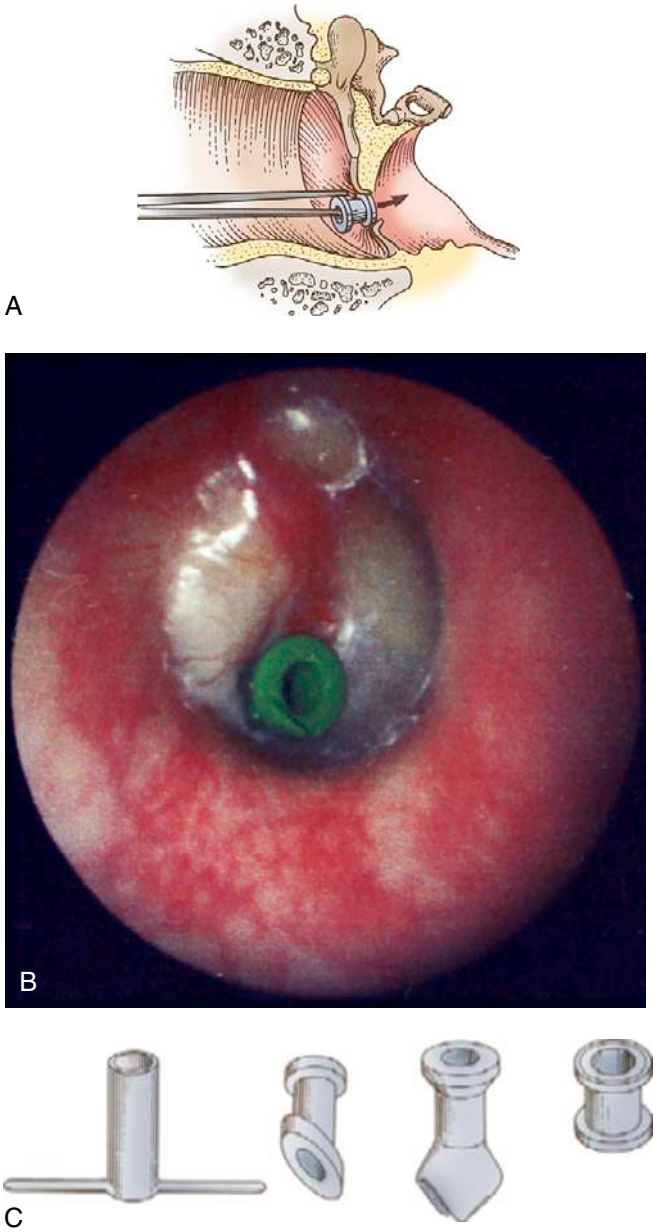


FIGURE 18-17 **A**, Tube (placed on end of alligator forceps) being inserted into tympanic membrane. **B**, Tube in place. **C**, Several types of plastic tubes that may be inserted into tympanic membrane. Purpose of tubes is to aerate middle ear and reduce middle ear infections.

of perforation of the tympanic membrane with or without hearing loss.

Perforation of the tympanic membrane is the most common ear injury necessitating surgical intervention. Perforations may result from (1) direct injury (e.g., cotton applicators, pencil), (2) blow to the ear, and (3) injury from temporal bone fractures. Early diagnosis is the key to proper management.

Conductive hearing loss is caused by an obstruction in the external canal or middle ear, which impedes the passage of sound waves to the inner ear. It may be attributable to disease of the middle ear or tympanic membrane. Occasionally the tympanic membrane does not heal after myringotomy.

Ossicular discontinuity may result from chronic otitis media, trauma, or cholesteatoma—a skin cyst that erodes bone. Various methods and materials are presently used in constructing a closed, air-contained middle ear cavity and restoring a sound-pressure transforming action. Among these materials are high-density polyethylene, silicone, hydroxyapatite, and titanium prostheses.

Procedural Considerations. The ear is prepped and draped as previously described. An endaural or postauricular approach may be used. Both approaches provide similar functional results. The procedure most often is performed after the patient has been administered a general anesthetic.

Operative Procedure

1. The following three approaches may be used when performing a tympanoplasty:
   - **a.** When an *endaural approach* is used, a Lempert speculum is introduced into the external meatus of the ear canal, and the microscope is appropriately positioned. The surgeon injects lidocaine with epinephrine postauricularly and into the external meatus and external auditory canal. The endaural incision is made as detailed previously and then the tympanomeatal incision is made using a sharp, round knife.
   - **b.** When a *postauricular approach* is used, the surgeon injects lidocaine with epinephrine postauricularly. An ear speculum is introduced, and the microscope is appropriately positioned. Additional lidocaine is injected into the external auditory canal. The microscope head is moved from directly over the patient's ear. The surgeon incises the skin behind the fold of the ear with a #15 knife blade. Bleeding vessels are coagulated. An incision is then made into the periosteum down to the bone, and the periosteum is elevated from behind the incision with a Lempert elevator.
   - **c.** During the *transcanal approach,* the surgeon injects the four quadrants of the fibrocartilaginous canal with a 1% or 2% lidocaine solution with 1:100,000 epinephrine. An endaural speculum gently compresses the tissue edema resulting from the injection and assists in the placement of a speculum within the confines of the bony canal. A 30-gauge needle is used to inject the skin of the bony canal. There are various canal incisions that can be made, all of which accomplish the same goal of lifting the posterior ear canal skin and the tympanic membrane in continuity. Once the incisions have been made, the skin is elevated to the tympanic annulus, subcutaneous tissue at the tympanomastoid suture is dissected, and bleeding is controlled before the middle ear is reached.
2. At this point, the surgeon or the assistant harvests a section of temporalis fascia for the graft material used in the repair of the tympanic membrane. Lidocaine with epinephrine may be injected under the fascia to separate it from the temporalis muscle. The surgeon uses a narrow Shambaugh elevator or duckbill elevator to separate the fascia and excises the amount needed using small, sharp scissors or a knife blade. The fascia is trimmed of excess tissue with small, sharp scissors and set aside to dry on a Teflon cutting block that is standard in most otologic instrument trays. Some surgeons prefer to thin the fascia by using a House Gelfoam press before placing the graft on the cutting block.

3. The canal skin may be elevated from the canal with a duckbill elevator, curved needle, gimmick, or similar microinstrument, or it may be removed (lateral/overlay tympanoplasty), depending on the size and location of the tympanic membrane perforation.
4. The surgeon uses a sickle knife, curved needle, 45- or 90-degree pick, or cup forceps to remove all the epithelium from the drum surrounding the perforation edges of the tympanic membrane in preparation for receiving the graft. This is referred to as "freshening the edges" and is a critical step in promoting reepithelialization of the graft.
5. If an edge of the perforation or tympanic membrane cannot be visualized because of the bony canal, the surgeon uses a microcurette or drill to remove the overhang of bone.
6. The middle ear is explored with a pick or similar instrument, and any epithelium present is removed with an alligator, or cup, forceps. The surgeon inspects each ossicle to ensure that it is intact and mobile.
7. If the malleus or incus is diseased or eroded, it may be removed and replaced with a partial ossicular replacement prosthesis (PORP). Ossicles that are removed may be reshaped with the aid of a drill and small burr and replaced. If all ossicles are diseased or eroded, they may be removed and replaced with a total ossicular replacement prosthesis (TORP). This step is accomplished with microinstrumentation, such as Bellucci scissors, cup forceps, malleus nipper, incudostapedial joint knife, sickle knife, picks, and a curved needle.
8. The surgeon prepares the graft for insertion. The edges are trimmed with a #15 knife blade or sharp scissors to fit the shape of the ear canal and the size of the perforation. The surgical site is suctioned with a microsuction device. Hemostasis may be achieved by applying very small, epinephrine-soaked Gelfoam balls with an alligator forceps.
9. Different tissues—such as temporalis fascia or loose connective tissue, tragus perichondrium, and vein grafts—have been used for a tympanoplasty procedure. The most common tissue used is temporalis fascia. Most surgeons prefer to use autograft tissue, although homograft tympanic membranes have also been used. The risk of transmission of infectious disease has reduced homograft use. For easier manipulation, the graft may be dipped in water or saline before its insertion with alligator forceps. A gimmick, sickle knife, pick, curved needle, or similar microinstrument is used to position the graft into place. Small pieces of absorbable gelatin sponge may be packed below the graft in the middle ear space to ensure support and position. The graft and tympanomeatal flap are then laid back into place and Gelfoam packing is used to secure the flap, remnant tympanic membrane, and graft in the proper position. This outer ear canal packing is left in place for 1 to 2 weeks postoperatively and removed in the surgeon's office.
10. The external ear canal is then packed with MeroGel; moistened, absorbable, gelatin sponge pledgets; or antibiotic ointment.
11. The incision is closed with suture of the surgeon's preference.
12. A pressure dressing consisting of fluffed gauze placed around the ear and an elastic gauze wrapped around the affected ear and the head may be applied for the first 24 hours to reduce swelling. Commercially prepared postauricular incision dressings are available.

FIGURE 18-18 Cholesteatoma.

Mastoidectomy

Mastoidectomy is the removal of diseased bone of the mastoid process and mastoid space. Before the introduction of antibiotic therapy, mastoidectomy was commonly performed for infection. Although occasionally still performed for eradication of infection, it is more frequently used in the treatment of cholesteatoma. Cholesteatoma is the result of accumulation of squamous epithelium and its products in the middle ear and mastoid. It occasionally forms a cystlike mass (Figure 18-18). As it expands, it is destructive to the middle ear and mastoid. As a result, the diseased bone (ossicles and mastoid bone) must be removed to prevent recurrence of the cholesteatoma.

There are three types of mastoidectomy. A *simple mastoidectomy* is removal of the diseased bone of the mastoid with preservation of the ossicles, eardrum, and canal wall. This procedure is performed to eradicate chronic infections unresponsive to antibiotics or to remove cholesteatoma. A *modified radical mastoidectomy* is removal of the diseased bone of the mastoid along with some of the ossicles and the canal wall. The eardrum and some of the ossicles remain, leaving a mechanism for the patient to hear. A canal-wall-up mastoidectomy is similar to the modified mastoidectomy without removing the posterior ear canal wall. The benefit of a canal-wall-up mastoidectomy is that the patient's ear canal will appear and function normally. Canal-wall-down mastoid cavities require maintenance with debridement of aculeate debris at least yearly.

A *radical mastoidectomy* is removal of the canal wall along with the ossicles and tympanic membrane. It is rarely performed except for unresectable disease. With either the modified radical or the radical mastoidectomy, a meatoplasty is performed to enlarge the ear canal opening. This facilitates cleaning the mastoid bowl that has been created.

Procedural Considerations. The patient is prepped and draped as for a tympanoplasty. An endaural or postauricular incision may be used (Figure 18-19), but most surgeons believe that the postauricular incision offers better exposure to all areas of the mastoid and middle ear. A drill is used to remove diseased bone and tissue. Facial nerve monitoring is used to alert the surgeon to the proximity of the nerve within the surgical field.

Operative Procedure. Steps 1 through 6 from the tympanoplasty procedure are performed.

7. The surgeon uses a drill with a large cutting burr to drill the mastoid bone under direct vision. As the mastoid cavity

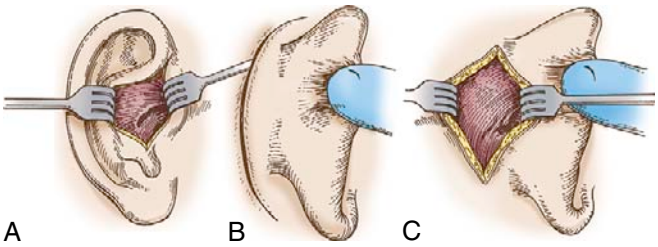


FIGURE 18-19 Mastoidectomy incision. **A**, Endaural. **B**, Postauricular. **C**, Postauricular incision retracted.

is created, the scrub person should be able to anticipate changes needed in burr size. Once the vital structures have been identified, diseased bone is removed by use of diamond burrs of the appropriate size. The surgeon may interrupt drilling to explore areas of the mastoid with a pick, curved needle or annulus elevator or with other microinstruments to identify surrounding structures.

8. On completion of the mastoidectomy, the surgeon focuses on the middle ear. Diseased ossicles are removed, middle ear mucosa is inspected and removed if necessary, and all evidence of cholesteatoma is removed. Depending on the extent of the disease and the reliability that the patient will be available for follow-up care, the surgeon then reconstructs the ossicular chain or prepares the cavity created by a radical mastoidectomy. Some surgeons do not reconstruct at the time of mastoidectomy but reconstruct as a second-stage operation, which serves the added purpose of reexploring the middle ear and mastoid for residual or recurrent cholesteatoma.
9. The mastoid cavity and middle ear may be packed with an absorbable gelatin sponge or MeroGel. The external auditory canal may be packed with MeroGel, an absorbable gelatin sponge, or antibiotic ointment.
10. The incision is closed and dressing applied in similar fashion to that used for postauricular tympanoplasty (as detailed previously).

Stapedotomy

Stapedotomy is removal of the stapes superstructure and creation of a fenestra (opening) in the fixed stapes footplate for treatment of otosclerosis and placement of a prosthesis to restore ossicular continuity and alleviate conductive hearing loss. Otosclerosis is the formation of abnormal bone around the stapes footplate, resulting in immobility of the footplate. Sound waves cannot be transmitted adequately through the oval window and round window to be changed into electrochemical impulses in the cochlea.

There are two types of procedures for replacing the immobile stapes. In *stapedotomy,* the footplate of the stapes is not removed; only the superstructure is removed. A hole is made in the stapes footplate, and the prosthesis is secured laterally to the long process of the incus and positioned medially over the hole created in the footplate. The carbon dioxide (CO_2) laser may also be used for stapedotomy—to create (drill) a hole in the footplate of the stapes for insertion of a prosthesis or to vaporize the stapedial tendon. Ideally, laser energy should be completely absorbed by the footplate and should not heat the perilymph or damage the inner ear (House and Cunningham, 2005). The laser stapedotomy offers improved postoperative hearing results while reducing postoperative dizziness and sensorineural hearing loss. An older procedure that is still used today, however not as frequently as in years past, is the *stapedectomy.* In stapedectomy, the entire stapes (superstructure and footplate) is removed, a graft is placed over the oval window, and a prosthesis is attached laterally to the long process of the incus and positioned medially on the graft over the oval window. Both of these procedures may be performed using monitored anesthesia care (MAC) or local anesthesia for adults, enabling the surgeon to test hearing before the conclusion of the surgery. Certain patient populations, such as children, patients with anxiety, and non–English-speaking patients, may find it difficult to remain immobile during the procedure, and general anesthesia is recommended in these populations to facilitate surgery and patient comfort.

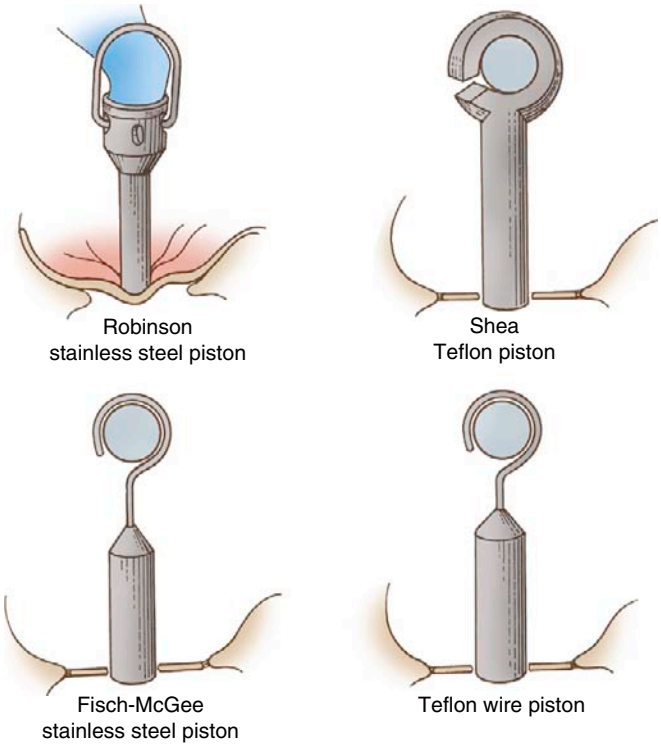


FIGURE 18-20 Stapedectomy prostheses. *Top left,* Prostheses used after the footplate has been removed. *Top right and bottom,* Footplate had been "drilled" to accept a prefabricated piston precisely.

Procedural Considerations. Various materials are used as the prosthesis for the stapes; the most common are stainless steel, titanium, platinum, nitinol, and Teflon. The most common types are either bucket-handle or piston prostheses (Figure 18-20). Both are secured to the incus and extend to the stapes footplate to reconstitute the ossicular chain. The use of stainless-steel materials may present a risk for prosthesis displacement and subsequent sensorineural hearing loss if the patient undergoes MRI studies in the future.

The prosthesis of choice is determined by the surgeon's experience and preference. The scrub person must be aware of each step in the procedure and hand the instruments to the

surgeon expediently. Because the oval window is left uncovered, some perilymph may leak from the inner ear into the middle ear. This leak subjects the patient to the possible complication of a sensorineural hearing loss postoperatively.

Microsuction tips (18- to 26-gauge) are used in this procedure because large suction tips may suction perilymph from the oval window, resulting in permanent hearing loss as well as promoting bleeding in the middle ear. After the incision and reflection of the flap, footplate hooks are used because the tips on picks are too large and long and may cause damage rather than assist in the procedure.

Operative Procedure—Stapedotomy

1. The surgeon or the assistant may harvest a temporalis fascia, fat, perichondrium, or vein graft at the start of the procedure to cover the oval window. Depending on the surgeon's graft preference, the ear, hand, or a portion of the abdomen may be prepped for the graft. Most surgeons use temporalis fascia or postauricular subcutaneous tissue as it is within the surgical field and easily accessible.
2. The ear speculum is introduced, and the microscope is appropriately positioned. The surgeon cleans any cerumen or debris from the ear canal and may gently wash the canal with physiologic irrigating solution.
3. The surgeon injects lidocaine with epinephrine into the ear canal.
4. An ear speculum is inserted, the tympanomeatal flap is created, and the tympanic membrane is reflected forward, exposing the middle ear.
5. If visualization of the ossicles is inadequate because of the overhang of bone, the surgeon may use microcurettes or a drill to remove enough bone to allow proper visualization. Attempts to save the chorda tympani nerve are made because it controls taste from the anterior two thirds of the tongue. If this nerve obstructs the view of the stapes, it may on rare occasion be divided for exposure, and at the conclusion of the procedure the neural ends are reapproximated.
6. The surgeon may measure the distance from the incus to the stapes footplate at this time or after the removal of the stapes. It is accomplished with a depth gauge and done to ensure the proper fit of the prosthesis.
7. The incudostapedial joint is disarticulated to allow fracture and subsequent removal of the stapes, usually accomplished through the use of a joint knife or right-angle hook.
8. Both crura of the stapes are treated with a laser or fractured laterally, usually with a footplate pick or curved needle, and the superstructure is removed with alligator forceps. The surgeon may take this opportunity to ensure hemostasis, using tiny sponges soaked in epinephrine and applying suction with a microsuction tip. The laser helps coagulate middle ear vessels, thus improving hemostasis.
9. An opening is created in the footplate with a laser or a sharp footplate pick. If the footplate is extremely thick, a microdrill may be used. If a stapedectomy is to be carried out, each half of the footplate is removed using a Hough hoe, footplate pick, or footplate hook.
10. The oval window is inspected to ensure that it is long enough, and then a measuring stick is used to approximate the correct size prosthesis required for reconstruction.
11. Holding the prosthesis with alligator forceps, the scrub person passes it to the surgeon. The prosthesis is introduced into the middle ear with the shaft resting against the oval window graft.
12. The wire is positioned over the long process of the incus using picks, Hough hoes, or footplate hooks. Once it is in proper position, the surgeon crimps the wire onto the long process of the incus to ensure its attachment.
13. The surgeon may test the patient's hearing by softly whispering to the patient (if the procedure is performed with the patient administered a local anesthetic) or by touching the malleus with a pick and observing for mobility of the malleus, incus, and stapes prosthesis (if performed with the patient administered a general anesthetic).
14. Tiny pieces of the previously harvested graft tissue are then placed around the base of the prosthesis to ensure its stability. Alligator forceps, picks, a gimmick, and similar instruments may be used for this step.
15. The tympanomeatal flap is returned to its original location. The external ear canal may be packed with an antibiotic gel or ointment or a moistened, compressed gelatin sponge.
16. Cotton is placed in the concha of the ear, and a Band-Aid or small dressing is usually applied to the graft site.

Ossicular Chain Reconstruction

Ossicular reconstruction may be required for long-standing recurrent ear infections. It is commonly performed for the replacement of the incus portion of the ossicular chain. There are many surgical techniques for ossicular reconstruction.

Natural and synthetic prosthetic materials are available for ossicular reconstruction or replacement. The autologous ossicle (incus or head of malleus) taken from the patient's ear is often used, particularly in children who do not have a cholesteatoma. A synthetic PORP (partial ossicular reconstruction prosthesis) or TORP is indicated for reconstitution of the ossicular chain.

Alloplastic materials for partial and total ossicular reconstruction prostheses are available. Hydroxyapatite is used in many prostheses because its mineral content is very similar to that of bone and it is well tolerated by the middle ear, thereby decreasing extrusion rates. Because it is brittle, it is often combined with other materials to allow it to be more easily trimmed for a precise fit in the middle ear. Titanium is another material being used more frequently in middle ear prostheses. Titanium is ideal for ossicular reconstruction because of its properties of being rigid and lightweight. Regardless of the type of prosthesis used, the surgeon must sculpt/trim it to bridge the ossicular gap by simulating the ossicular configuration and preserving the lever mechanism of the middle ear.

Procedural Considerations. *Minor columella* is a term that refers to an ossiculoplasty with a strut from the head of the stapes to the tympanic membrane (or graft) or manubrium. *Major columella* refers to a strut extending from the footplate to the tympanic membrane (or graft) or manubrium. The patient is prepped and draped as for stapedotomy or tympanoplasty.

Operative Procedure. The procedure steps are similar to those for stapedotomy, except that the stapes footplate is not removed or opened.

Endolymphatic Sac Decompression or Shunt

An endolymphatic shunt procedure is the creation of an opening into the endolymphatic sac and the insertion of a shunt to allow drainage of excess endolymph into the cerebrospinal fluid (CSF) or into the mastoid cavity. In Meniere's disease, the endolymphatic sac cannot resorb endolymph, resulting in an overaccumulation. This surplus leads to vertigo, in which patients feel a spinning sensation. Movement usually increases the vertigo, which may be accompanied by severe nausea and vomiting. The vertigo attacks occur unpredictably and may last from several minutes to several hours. Most patients with Meniere's disease complain of tinnitus, pressure or fullness in the affected ear, and a fluctuating hearing loss that begins in the lower frequencies. Diagnostic audiometry reveals the hearing loss to be sensorineural. The vertigo may be so severe that it disrupts the patient's lifestyle. With a medical regimen of tranquilizers, diuretics, vasodilators, and a low-sodium diet, the majority of patients are able to adequately control their symptoms. About 10% to 15% of persons eventually fail medical therapy and may seek surgical intervention (Furman, 2008).

Procedural Considerations. Preoperative assessment should confirm that the patient's electrolyte levels (especially potassium) are adequate; this provides a basis for the support system to be carried out intraoperatively and postoperatively. Because Meniere's disease may develop bilaterally in some patients, conservative therapy is often employed (Schessel et al, 2005). The patient is prepped and draped as for a mastoidectomy.

Operative Procedure. The procedure that follows describes decompression with a shunt. Some surgeons perform endolymphatic sac decompression only, without the shunt. The majority of the bone overlying the sac is removed to allow for more compliance of the sac and the membranous labyrinth.

Steps 1 through 7 of the decompression with shunt are the same as those for mastoidectomy.

8. The surgeon continues drilling with a diamond burr over the posterior fossa dura until the endolymphatic sac is identified.
9. Using a microknife, such as a sickle, Beaver blade, or Ziegler, the surgeon incises the lateral wall of the sac.
10. A shunt (commercially prepared tube, silastic tubing, or silastic sheeting) is inserted with microforceps and manipulated into place using microinstruments, such as a curved needle, fine pick, or gimmick (Figure 18-21).
11. The incision is closed and a pressure dressing applied to the affected ear.

Labyrinthectomy

Labyrinthectomy is a procedure that eliminates the vestibular and auditory function of the labyrinth to relieve severe vertigo. The procedure is usually performed when the disease is unilateral, a shunt/decompression procedure has been ineffective, and the affected ear has severe or total loss of hearing. Because the inner ear is removed, the patient may be very dizzy for several days until the brainstem begins to compensate for the destroyed labyrinth. The operation also leaves the ear with no residual hearing.

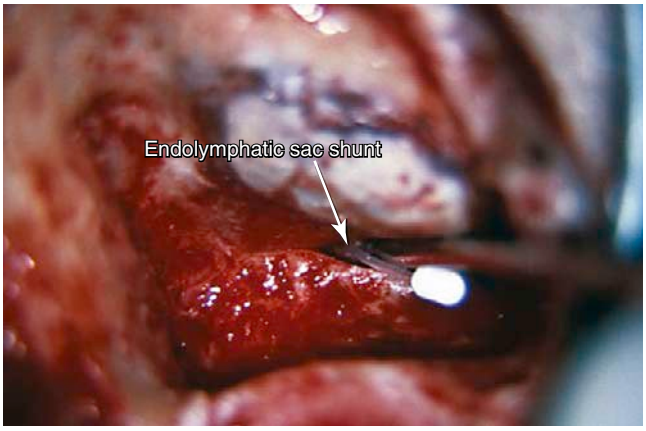


FIGURE 18-21 Endolymph silastic shunt in place.

Procedural Considerations. The procedure is most commonly performed via the transmastoid approach. The patient is prepped and draped as described for the tympanoplasty/mastoidectomy procedure.

Operative Procedure

1. The surgeon creates a postauricular incision and performs a simple mastoidectomy.
2. The vertical segment of the facial nerve is identified, and the incus is disarticulated and removed.
3. The horizontal, posterior, and superior semicircular canals are drilled and removed. The neuroepithelium is completely removed from the ampullae of the three semicircular canals. The vestibule is exposed and the neuroepithelium from the utricle and saccule is removed.
4. The incision is closed in layers. An external pressure dressing of elastic gauze is applied.

Vestibular Neurectomy

Vestibular neurectomy is the division of the vestibular portion of the eighth cranial nerve (acoustic nerve) with preservation of the cochlear portion of the eighth cranial nerve. It may be performed for a unilateral ear disorder, including classic Meniere's disease, recurrent vestibular neuronitis, traumatic labyrinthitis, or vestibular Meniere's disease. It may also be performed when attacks of vertigo severely affect a patient's lifestyle. Vestibular neurectomy is performed when a patient has adequate hearing and accepts elimination of vestibular function on the affected side.

Procedural Considerations. Vestibular neurectomy is most commonly performed through a retrosigmoid craniotomy. Refer to Chapter 20 for procedural considerations related to craniotomy.

Operative Procedure

1. The surgeon creates a 4-cm curvilinear incision 4 cm behind the postauricular sulcus.
2. A craniotomy is drilled posterior/inferior to the junction of the transverse and sigmoid sinuses.
3. The surgeon incises the dura, retracts the cerebellum, and identifies the seventh and eighth cranial nerve complex.

4. The vestibular and cochlear portions of the nerve are correctly identified and the surgeon divides the vestibular portion.
5. The dura is closed with suture and the craniotomy reconstructed with hydroxyapatite cement or titanium mesh plating.

Facial Nerve Decompression

Facial nerve decompression is a procedure designed to identify and relieve an area of compression of the facial nerve. Damage to the facial nerve may occur from trauma, infection, or tumors and may result in a facial nerve palsy, but the most common form of facial paralysis is Bell's palsy. The cause is unknown, although clinical and laboratory evidence indicates a virus of the herpes simplex group may be involved. The patient experiences multiple problems, such as decreased tearing, inability to close the affected eye, and drooping of the affected corner of the mouth with pooling of oral secretions. The facial nerve may be decompressed by a translabyrinthine approach when trauma has destroyed hearing and caused facial nerve paralysis. The narrowest segment of the bony canal compressing the facial nerve is deep in the temporal bone and may also be accessed through the middle cranial fossa approach when hearing is to be preserved. Both approaches may be useful under selected circumstances.

Transmastoid, Translabyrinthine Approach

PROCEDURAL CONSIDERATIONS. The patient is prepped and draped as described for mastoidectomy. Neurologic intensive care is required for the first 24 hours. Preoperatively, ointments protect the eye and the eyelid is taped closed, or an adhesive bubble is placed over the eye to trap moisture. This protection is continued into the postoperative period unless a tarsorrhaphy (suturing the eyelid closed) is performed intraoperatively.

OPERATIVE PROCEDURE. Steps 1 through 7 are the same as those for mastoidectomy.

8. After completing the mastoidectomy, the surgeon continues the dissection using cutting and diamond burrs until the internal auditory canal and the posterior fossa bone are removed.
9. The bone immediately over the facial nerve is removed by the use of nerve excavators and picks.
10. Using a facial nerve knife, neurectomy knife, sickle knife, neurectomy scissors, or micropick, the surgeon incises the facial nerve sheath. The majority of surgeons do not incise the epineurium of the facial nerve, and decompression only is felt to be equally efficacious and less traumatic to the nerve itself.
11. Hemostasis is achieved by the use of moistened, absorbable gelatin sponge; cottonoids; oxidized cellulose; bipolar ESU; or a combination of these.
12. The incision is closed and a pressure dressing of elastic gauze applied.

Middle Cranial Fossa Approach

PROCEDURAL CONSIDERATIONS. The patient's hair is clipped almost to the midline on the affected side. Povidone-iodine solution generally is used for the prep, which includes the portion of the head that has been clipped, the affected side of the face, and the neck. Lidocaine with or without epinephrine usually is injected subcutaneously above the ear to assist in hemostasis. The patient's eye on the affected side is protected as previously described.

OPERATIVE PROCEDURE

1. The surgeon incises the temporalis muscle and elevates it with a Lempert, Shambaugh, or similar type of elevator.
2. Hemostasis is achieved by clamping and tying vessels or by electrocoagulation.
3. The surgeon drills a square of bone from the temporal bone to expose the middle cranial fossa dura. (The bone is saved for replacement at the end of the procedure.)
4. A self-retaining retractor with a blade for retraction of the middle fossa (e.g., Fisch middle fossa retractor, House-Urban retractor) is inserted.
5. The microscope is positioned appropriately, and the surgeon elevates the dura from the floor of the middle fossa with a Freer elevator, a gimmick, or similar instruments.
6. Once hemostasis is achieved and the blade is inserted over the dura to expose the middle fossa, drilling may proceed.
7. When the bone becomes quite thin, the surgeon may remove the remaining bone with excavators to avoid damaging the nerve sheath.
8. The facial nerve sheath can be incised with a facial nerve knife, neurectomy knife, neurectomy scissors, or microknife.
9. The retractor is removed when hemostasis is achieved, and the bone flap is replaced.
10. The temporalis muscle is approximated and sutured, the incision closed, and a pressure dressing applied.

Removal of Acoustic Neuroma (Vestibular Schwannoma)

Acoustic neuromas arise from the Schwann cells of the vestibular portion of the eighth cranial (acoustic) nerve and are therefore more appropriately termed *vestibular schwannomas*. These tumors are benign but may grow to a size that produces symptoms of cerebellar and brainstem origin. Bilateral vestibular schwannomas are a common finding in patients with neurofibromatosis type 2 (NF2) (Gantz and Meyer, 2005).

Most patients experience unilateral tinnitus and hearing loss—the main symptoms of a possible acoustic neuroma. However, depending on the rate and direction of tumor growth, signs and symptoms may include hearing loss, tinnitus, vertigo, headaches, double vision, diplopia, decreased corneal reflex, decreased blink reflex, impaired taste, reduced lacrimation, facial paralysis, diminished gag reflex, vocal cord paralysis, atrophy or fasciculation of the tongue, weakness of the sternocleidomastoid and trapezius muscles, disturbance in balance and gait, hydrocephalus, lethargy, confusion, drowsiness, and coma.

Several surgery centers have developed great expertise in acoustic neuroma surgery, which requires the combined team of a neurologist and a neurosurgeon.

Procedural Considerations. The translabyrinthine approach for the removal of an acoustic tumor reduces mortality and morbidity and offers a good chance of saving the facial nerve if the tumor has not directly invaded it. The patient should be informed about the presence of a Foley catheter, arterial line, temperature probe, clipped hair, and graft-site incision.

The patient's hair is clipped to the midline of the affected side. Some patients prefer to have the entire head clipped to facilitate wearing a wig. This option should be presented preoperatively to enable the patient to make a decision before surgery. The patient is prepped and draped as described for labyrinthectomy. Lidocaine with or without epinephrine may be injected subcutaneously behind the ear. A facial nerve monitor is routinely used in the excision of cerebellopontine angle tumors. A sequential compression device (SCD) is used intraoperatively and for the first 24 to 48 hours postoperatively or until the patient is ambulatory to decrease the risk of deep vein thrombosis (DVT) and pulmonary embolism (PE).

Operative Procedure

1. The surgeon makes a postauricular incision slightly longer and more posterior than the incision for mastoidectomy and elevates the periosteum from the mastoid bone with a Lempert, Shambaugh, or similar type of elevator.
2. Self-retaining retractors are inserted, and the cortical mastoidectomy is begun with a large cutting burr.
3. The microscope is positioned, and the attic is opened to visualize the ossicles. The sigmoid sinus, middle fossa dura, and superior petrosal sinus are left in place with a thin covering of bone. The semicircular canals are exposed. The incus is removed with alligator forceps or cup forceps and suction.
4. The surgeon excises the semicircular canals with the drill. The utricle and saccule are removed, and the aqueduct of the vestibule is drilled out to expose the internal auditory canal 270 degrees circumferentially.
5. Using nerve excavators, Fisch dissectors, or picks, the surgeon removes the remainder of bone from the dura of the internal meatus, posterior fossa, middle fossa, and petrosal angle. The wedge of bone between the facial and superior vestibular nerves (Bill's bar) is removed.
6. The dura is opened with microscissors or a dura knife. The surgeon dissects the tumor with a gimmick, Freer microelevator, microinstrument, and bipolar forceps (with or without suction). Hemostasis is achieved with a moistened, absorbable gelatin sponge; cottonoids; oxidized cellulose; or the bipolar ESU.
7. The tumor is removed by the use of pituitary cup forceps, long alligator forceps, and similar instruments.
8. Graft material (e.g., fat, fascia, or muscle) is obtained to pack the mastoid cavity created from the drilling. The packing is performed meticulously to avoid a cerebrospinal fluid leak.
9. The wound is closed and a thick pressure dressing applied.

Assistive Hearing Devices

A variety of assistive devices are available to patients with hearing loss, including phone amplifiers, closed captioning broadcasts, Telecommunication Device for the Deaf (TDD), and electronic devices, such as hearing aids. Technology has evolved tremendously in the field of otology, enabling surgeons to use surgically implantable devices in the treatment of hearing loss. These devices have greatly benefited the recipients, allowing some to distinguish sounds for the first time. Research continues in this field to develop applications for conditions previously considered untreatable and to refine and improve existing technology.

Cochlear Implantation. Technologic advances have given the deaf patient new hope in the area of cochlear implantation (Research Highlight). The device is implanted in the cochlea, with the receiver resting in the mastoid (Figure 18-22). As the device receives sound through the receiver, it emits electrical impulses through the transmitter into the cochlea and along the acoustic nerve. These impulses are interpreted as sound in the auditory area of the brain, which is in the temporal/parietal area of the cerebral cortex. The patient must be taught to interpret these sounds, which requires extensive training. Adult candidates for cochlear implantation generally possess the following characteristics: (1) severe or profound hearing loss with pure-tone average of 70-dB hearing loss, (2) use of appropriately fitting hearing aids or a trial with amplification, (3) aided scores on open-set sentence tests of less than 50%, (4) no evidence of central auditory lesions or lack of an auditory nerve, and (5) no evidence of contraindications for surgery in general (Wackym et al, 2005). Pediatric candidates (1) are 12 months through 17 years of age, (2) have profound sensorineural hearing loss, (3) experience minimal benefit from hearing aids,

RESEARCH HIGHLIGHT

Evaluating Language Outcomes in Children After Cochlear Implantation

The impact of hearing loss on the pediatric population is significant. Of every 1000 children in the United States, 1 is born with profound hearing loss. Before the availability of cochlear implants, children with hearing loss were treated with hearing aids. While hearing aids do provide sound amplification, children who use them often display delays in written and spoken communication. Language and cognitive development are closely related and language is a known predictor of academic success in children.

Cochlear implants provide an improved auditory experience for children with hearing loss, and the positive impact on speech perception and development is well documented in the literature. This study sought (1) to assess receptive language scores in children after cochlear implantation and compare them with scores from normal hearing children and children with hearing loss that use hearing aids, and (2) to determine how demographic factors, such as age of implantation, impact language outcomes. Researchers hoped to identify factors that impact language skills and gain a better understanding of language development in pediatric patients after cochlear implantation.

A group of 56 pediatric patients aged 6 months to 12 years were evaluated. Participants were educated in the oral communication mode after implantation and were administered language tests at intervals varying from 6 months to 5 years after implantation. Analysis of the data showed that more than 50% of children with cochlear implants had receptive language scores that were within the average range for normal hearing children, and scores that exceeded language skills of children who used conventional hearing aids.

This research serves to validate existing knowledge about the impact of cochlear implantation on pediatric language skills.

Modified from Baldassari CM et al: Receptive language outcomes in children after cochlear implantation, *Otolaryngol Head Neck Surg* 140: 114-119, 2009.

(4) have no evidence of central auditory lesions or lack of an auditory nerve, and (5) have no evidence of contraindications to surgery (Wackym et al, 2005). Appropriate auditory training and psychologic counseling are needed after appropriate selection of candidates.

OPERATIVE PROCEDURE

1. A *modified postauricular incision is used*. The posterior flap, including the temporalis muscle, is elevated, exposing the underlying bone. The site of the internal receiver is identified, and with a special drill a circular depression in the squamous portion of the temporal bone is made to house the receiver.
2. A mastoidectomy is performed with preservation of the bony ear canal and opening of the facial recess.
3. The surgeon secures the internal receiver in the depressed area in the temporal bone, and introduces the intracochlear electrode through the facial recess via a cochleostomy into the cochlea. It is secured in place with a piece of temporalis fascia.
4. The wound is closed. The patient is observed for 2 to 4 weeks until the wound is completely healed. Then the external signal processor is fitted and programmed. This allows transmission of an electrical signal, picked up at an ear-level microphone and processed in a microprocessor worn on the body.

Implantable Hearing Aids. Conventional hearing aids transmit sound using air conduction and bone conduction. Traditional bone-conduction hearing aids are external and secured to the head with a spring device. Their design makes them uncomfortable and obtrusive, causing headaches and skin abrasions. The quality of sound is inferior, and they often require a higher battery consumption. Air-conduction devices use an ear mold that fits into the ear canal. These devices may be contraindicated for patients with physical abnormalities that prevent the insertion of the ear mold into the canal and for those who have chronic eczema, ear drainage, or inflammation in the ear canal. Implantable hearing devices are designed for patients with moderate to severe conductive and sensorineural hearing loss (unilateral or bilateral). Ideally, implantable hearing devices should improve sound quality, provide comfort, improve appearance, and reduce the risk of chronic ear infections. Surgical implantation of hearing devices may be performed on an ambulatory basis using local or general anesthetics. The device is usually implanted in the ear with the best cochlear function.

BONE-ANCHORED HEARING AIDS. Conventional bone-conduction hearing aids transmit sound vibrations transcutaneously to the skull, bypassing a diseased or impaired external or middle ear and going directly to the cochlea. Disadvantages to using traditional bone-conduction hearing aids include discomfort, poor sound quality, poor aesthetics, and shifting of the transducer, which affects speech recognition (Palmer and Ortmann, 2005).

The bone-anchored hearing aid (BAHA, by Cochlear Corp., NSW, Australia) eliminates many of the disadvantages associated with traditional external bone-conduction hearing aids. It is designed for patients 5 years of age and older with moderate to severe conductive hearing loss (unilateral or bilateral) caused by congenital malformations but who maintain good cochlear function (down to 45-dB hearing loss) and for patients with otitis media, cholesteatoma, otosclerosis, microtia, and canal atresia who are unable to benefit from conventional amplification. More recently it has been approved and increasingly used in patients with single-sided deafness, most commonly from sudden profound hearing loss or after surgical excision of an acoustic neuroma. The BAHA system consists of a conventional microphone and amplifier, a specially designed transducer, and a coupling device to attach the device to the skin-penetrating and bone-anchored implant (Figure 18-23). The area behind the ear is prepped and draped, and the implant site is marked. It is important to ensure that the hearing aid does not touch the pinna, which may cause acoustic feedback. A semicircular incision is made around the proposed fixture site.

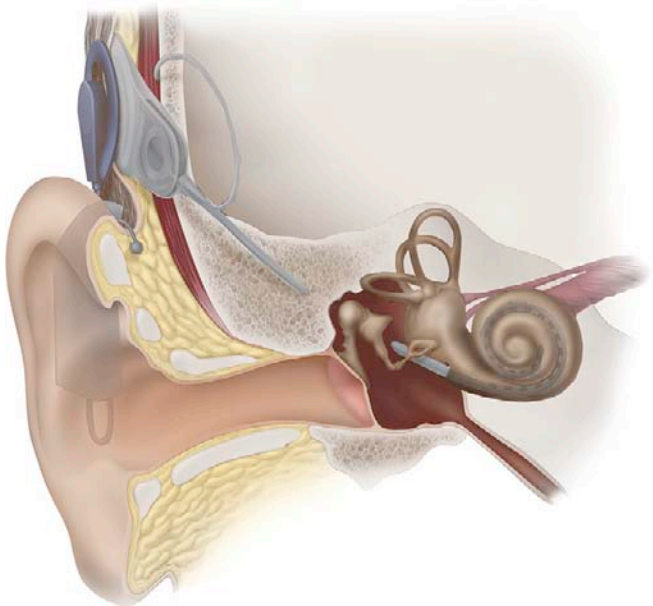


FIGURE 18-22 Cochlear implant system. Sound is transformed into electrical signal in speech processor. Signal is transmitted from external to internal induction coil, which is connected to electrode implanted near cochlear nerve.

FIGURE 18-23 Bone-anchored hearing aid (BAHA) components. *Top to bottom,* External processor, abutment, fixture.

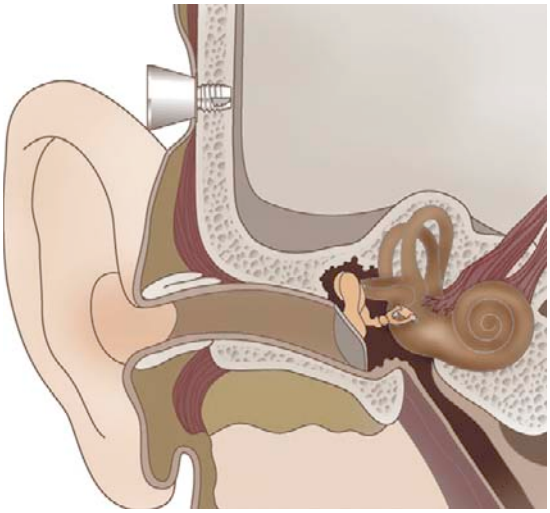


FIGURE 18-24 Cross section showing fixture and abutment.

FIGURE 18-25 Bone-anchored hearing aid (BAHA) abutment.

A titanium fixture is permanently implanted (tapped) into the mastoid bone, and a permanent skin penetration is made with a titanium snap coupler (Figures 18-24 and 18-25). A sound processor is fitted and adjusted to the patient's hearing loss 8 to 12 weeks after the implantation, depending on the age of the patient and ensuring the osseointegration process has taken place (Santina and Lustig, 2005) (Figure 18-26). When the BAHA is placed in young children, the sound processor is fitted in 3 to 6 months to ensure adequate osseointegration.

SEMI-IMPLANTABLE HEARING AIDS. Semi-implantable hearing aids are used in the middle ear and provide sound through direct stimulation of the ossicles; they allow for comfort because the external ear canal remains open. They consist of a microphone speech processor connected to a transmitter with an external coil that transmits electrical energy transcutaneously to an internal device. The internal device consists of an internal receiving coil connected to a receiver, which provides electrical energy to a mechanical driver connected to the ossicular chain. The driver vibrates the ossicles, mimicking the normal vibrations that occur as a result of acoustic sound input (Santina and Lustig, 2005). The internal receiver is implanted in the temporal bone, and the driver is attached to the incus. The external processor is fitted approximately 3 to 6 weeks after the surgery.

Research is ongoing in the development of semi-implantable and fully implantable hearing devices, which are currently considered experimental.

FIGURE 18-26 Patient with implanted bone-anchored hearing aid. The implant is positioned to avoid contact with the pinna, which could cause acoustic feedback if the device is driven at maximum output.

RHINOLOGIC (NASAL) PROCEDURES

Rhinologic surgery is performed to correct structural issues of the nose and to treat sinusitis and other conditions; it is also used an as adjunctive procedure to treat other disorders (e.g., pituitary neoplasms). Procedures that involve both internal and external nasal reconstruction can be done with local anesthetics, usually supplemented with IV sedation and analgesia. If the patient is particularly apprehensive or anxious, a general anesthetic may be more appropriate.

Nasoseptoplasty or Submucous Resection of the Septum (SMR)

A nasoseptoplasty is straightening of either the cartilaginous or the osseous portions of the septum that lie between the flaps of the mucous membrane and the perichondrium. When the nasal septum is deformed, fractured, or injured, normal respiratory and nasal function may be impaired, interfering with airflow and sinus drainage. Deviations of the septum involving cartilage, bony parts (spurs), or both may block the meatus and compress the middle turbinate on that side, thereby resulting in an obstruction of the sinus opening. Septal deviations tend to produce sinus disease and nasal polyps.

The objective of the procedure is to establish an adequate partition between the left and right nasal cavities, thereby

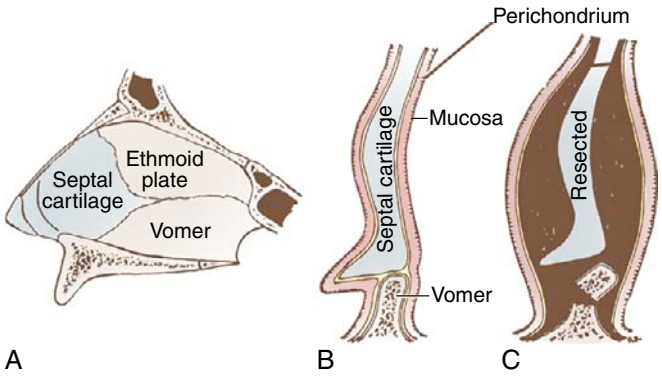


FIGURE 18-27 **A**, Primary components of septum. Incision line is for Killian type of submucous resection. **B**, Septum with deviated cartilage and spur at junction of vomer and septal cartilage. **C**, Resection of obstructive parts after careful elevation of mucoperichondrium and mucoperiosteum.

providing a clear airway through both the internal and external cavities of the nose.

Procedural Considerations. The procedure may be performed using local anesthesia, MAC, or general anesthesia. Regardless of the method chosen, the surgeon will use topical and injected anesthetics to aid in hemostasis. In most cases, the surgeon will opt to wear a headlight to improve visualization of the intranasal structures.

Operative Procedure

1. The surgeon opens the nostril with a nasal speculum and incises through the mucoperichondrium of the septum with a #15 blade. Using a Freer elevator, the tissues are separated and elevated (Figure 18-27).
2. The cartilage is incised with a knife, and the mucous membrane is elevated with a septal elevator.
3. Deviated cartilage and bony, thickened structures are trimmed or removed with a septum punch and a nasal cutting forceps.
4. The surgeon trims the bony septal spurs with a punch forceps or chisel, gouge, and mallet. Suction is used to expose the field. Bleeding is controlled by insertion of additional cottonoids soaked with a topical hemostatic agent or by using the ESU.
5. The perpendicular plate of the ethmoid as well as the vomer may be removed by means of a suitable septum-cutting forceps.
6. The incision is sutured with 4-0 absorbable atraumatic suture on a small, straight needle.
7. Nasal splints made of plastic or Silastic may be inserted to prevent adhesions and maintain the septum. Some surgeons use mattress sutures to provide a patent airway while maintaining support for the septum.
8. A mustache dressing (i.e., a piece of 2-inch × 2-inch gauze folded and placed below the nose and secured with tape across the face or bridge of the nose) is applied. A small ice bag (e.g., a surgical glove filled with ice) may be applied to the nose.

Closed Reduction of Nasal Fracture

The nose is the structure most susceptible to trauma because it is seated midface. The paired nasal bones are thin and project like a tent on the frontal process of the maxilla. If the trauma

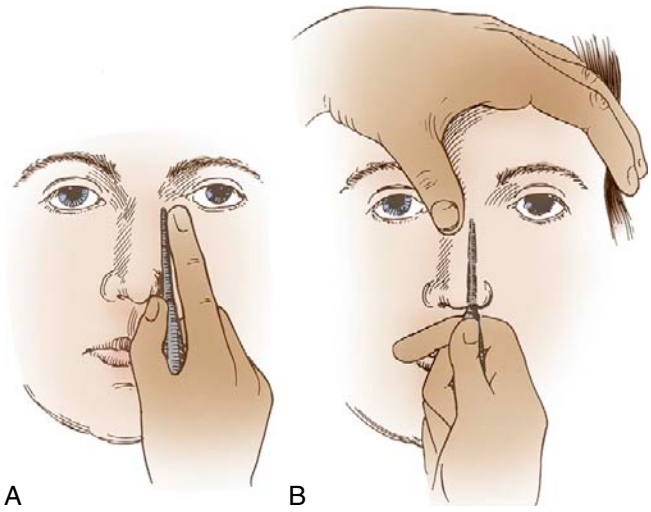


FIGURE 18-28 Reduction of nasal fracture. **A**, Boies elevator is placed along lateral wall of nose to point below nasofrontal angle. Distance to ala is marked with thumb. **B**, Elevator is then placed under depressed nasal bone, lifting it into position; opposite thumb carefully exerts downward pressure on elevated contralateral bone.

is caused by a direct frontal blow, usually both nasal bones are fractured, displaced outward, and depressed into the ethmoid sinus, and the septal cartilages become displaced. Noncontrast CT scans of the sinuses may be performed with protocols compatible with endoscopic navigation systems to have an accurate sense of extension of deviation or possible injury to surrounding sinuses and structures.

Procedural Considerations. Simple nasal fractures often can be managed with topical and local anesthesia. However, as with most nasal procedures, if the patient is significantly anxious, general anesthesia may be necessary. Topical and local anesthetics are used with a general anesthetic to provide vasoconstriction and enhance visualization for the procedure. The patient is prepped and positioned for nasal surgery.

Operative Procedure

1. The nose is packed with nasal cottonoids saturated with 4% cocaine. The local anesthetic is injected as previously described. When epinephrine is used, 10 minutes is the optimum time to wait for the effects of the hemostatic agent. This period of time will vary with other agents.
2. A Boies elevator is inserted into the nostril, and the nasal bones are elevated and molded into place by external manipulation (Figure 18-28).
3. Nasal packing or a Denver splint may be used to stabilize the reduction because sometimes the bony fragments tend to return to a depressed status.

Treatment of Epistaxis

The treatment of patients with epistaxis dates back more than two centuries (History box). Patients with nasal bleeding usually control the problem themselves with direct pressure application. When their efforts fail, they seek help from their physician or an emergency department. When more conservative measures (which involve vasoconstrictive agents and

HISTORY

History of Epistaxis Control

It is well accepted that today's current management of epistaxis is based on sound principles. In the past epistaxis led to many folklore beliefs, such as "its occurrence indicates that you are in love" and "one drop of blood from the nose commonly foretells death or a very severe illness." Preventive measures included a morning drink of whey taken with raisins and wearing a skein of scarlet silk thread with nine knots down the front. Other thoughts about epistaxis and possible remedies advocated through the ages included those suggested by the following individuals:

- Lupton in 1601 advocated the use of the patient's own blood to write the words "consummatum est" on the forehead.
- Moncrief in 1716 fried the patient's own blood and applied it as snuff.
- Hippocrates was one of the earliest physicians to appreciate that pressure on the alae nasi was an effective way of controlling nosebleeds.
- Ali Ibn Rabban Al-Tabiri (AD 850) wrote that the complaint of epistaxis was "due to the swelling of a vein and its rupture, or perhaps a reduction in the force which confines the blood within."
- Giovanni Battista Morgagni observed the extremely turgid blood vessels located about a finger's breadth from the bottom of the nostril.
- Carl Michel (1871), James Lawrence Little (1879), and Wilhelm Kiesselbach identified the plexus of veins situated on the anterior part of the cartilaginous septum as a source of epistaxis.
- Pilz (1868) tied the common carotid artery for the treatment of epistaxis.
- Alfred Seiffert (1928) first introduced ligation of the internal maxillary artery via a transantral approach.
- Henry Goodyear (1937) was the first to tie the anterior ethmoid artery for epistaxis.

Modified from Cordes S, Quinn FB: *Grand rounds on epistaxis,* October 16, 1996, University of Texas Medical Branch, available at www.otohns.net/default.asp?id=14086. Accessed May 8, 2009.

nasal packing) taken in the emergency department fail, surgical intervention becomes necessary.

When epistaxis occurs, it is an important first step to spray oxymetazoline nasal spray in both nares and apply direct pressure to the nose. An initial hold of 15 minutes is recommended. Thereafter, inspection of the anterior nose and posterior oral pharynx should be performed to determine if the site of bleeding is anteriorly based in the nose or posteriorly located deep in the nasal cavity. Evidence of a posterior bleed is usually demonstrated by a trickling flow of blood from the nasopharynx running down along the posterior pharyngeal wall during an oral inspection. Blood may also appear on the tongue and the patient may complain of swallowing blood. Anterior epistaxis characteristically trickles down the front of the face upon the upper lip. If oxymetazoline spray and direct pressure fail to arrest the bleed, packing with nasal tampons or posterior packs should be considered.

The length of the pack should be based upon the suspicion of where the bleed originates. Longer packing (8- or 10-cm packing) is considered when bleeds are more posterior in the nasopharynx. More anterior bleeds can be packed with 4.5-cm packing. Packing should be generously coated with antibiotic ointment and inserted in a horizontal angle following the floor of the nose. The packing is then sprayed with saline or oxymetazoline spray and expands. The patient should receive broad-spectrum antibiotics, such as oral third-generation cephalosporins, and instructed to follow up in 3 to 5 days for removal of packing.

Posterior nasal packing has an exterior balloon along the tube length as well as an anchoring balloon on the end (Figure 18-29). The anchoring balloon is first inflated to keep the tubes in place, and then the pressure balloons are inflated to compress bleeding vessels. If packing is used, it is placed directly against the bleeding site. Posterior nasal packing is placed by inserting a catheter-based tube, usually surrounded with packing, through the nostril. The tube is expanded with saline or oxymetazoline spray and 3 to 5 ml of air is pushed into the port, inflating a distal balloon. The proximal end of the catheter is pulled through the oral cavity with a Kelly clamp (while the distal end remains extending from the nostril).

If this fails to stop the oozing and other hemostatic agents, such as gelatin-based packing, silver nitrate sticks, or oxidized cellulose, fail to halt the bleed, an endoscopic approach to control the epistaxis is warranted. The endoscopy is performed in the OR with the use of general anesthesia or conscious sedation. Occasionally, ligation or embolization of the ethmoid, carotid, or maxillary artery is necessary and should be considered for persistent bleeds.

The setup for endoscopic control of epistaxis is the same as that for all nasal case prepping and draping. Once the navigation mask is applied to the patient and the video monitor is calibrated and functional, attention should be focused on Kiesselbach's plexus in the anterior nasal cavity and on the sphenopalatine artery as these are common sites of persistent bleeds. Suction electrosurgery should be used to electrocoagulate any visual bleeding and to clear the nasal passages of any clot or oozing. Other surgical options include transmaxillary internal maxillary artery ligation, transoral internal maxillary artery ligation, anterior/posterior ethmoid ligation, external carotid ligation, transnasal endoscopic sphenopalatine artery ligation, and submucosal supraperichondrial septoplasty.

Sinus Surgery

Sinusitis can be either recurrent, acute, or chronic. It is caused by bacteria and/or fungi and may be associated with anatomic abnormalities of the nose, such as a deviated septum or poor drainage pathways from the sinuses. Medical management of acute bacterial sinusitis involves a course of appropriate antibiotic therapy for 10 days to 2 weeks. If a patient does not respond to medical treatment for acute bacterial sinusitis or if sinus complaints persist, surgical drainage of the sinuses is indicated. Sinus procedures can be performed intranasally with or without the aid of endoscopes and video or through an open approach determined by which sinus cavity is involved. Generally, surgical treatment involves endoscopy to create a nasal window in acute maxillary sinusitis; a Caldwell-Luc procedure for chronic maxillary sinusitis; ethmoidectomy for ethmoid or sphenoidal sinusitis; and creation of an osteoplastic flap to drain the frontal sinus. Acute fungal sinusitis is treated by serial endoscopic debridements followed by a prolonged course of antifungals.

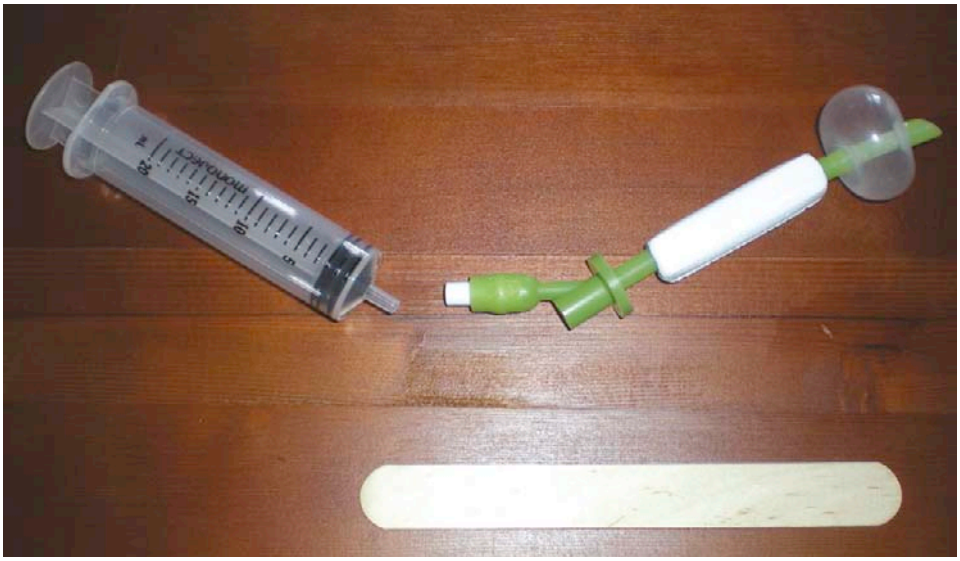


FIGURE 18-29 Posterior nasal packing with syringe for balloon inflation.

Functional Endoscopic Sinus Surgery (FESS). The field of FESS provides a more physiologic type of drainage by reducing trauma to normal tissues. Using direct endoscopic visualization, the surgeons' experience has expanded as technology and instrumentation have improved. Procedures performed endoscopically decrease trauma to normal structures and reduce morbidity. Fewer traumas mean a shortened healing process for the patient (Research Highlight). Many procedures that were once done with an open approach are now performed endoscopically and are considered safer because they are performed under direct visualization by means of an endoscope. Dedicated endoscopic sinus and skull base suites present a popular option for FESS because of the ease of setup and the comfort of multiple monitors, improving exposure (Figure 18-30).

FESS involves the endoscopic resection of inflammatory and anatomic defects of the sinuses. Because of the anatomic relationship to multiple systems, this procedure has many risks, which should be incorporated into the informed consent process. It is considered to be a technically demanding surgery, and techniques vary significantly. Most surgeons now prefer the endoscope to be attached to a video monitor, but some prefer to look directly through the eyepiece. The operative instruments are introduced into the nose alongside the endoscope.

The purpose of FESS is to ensure adequate ventilation and restore mucociliary clearance in the sinuses. If there is contact between the mucosa and the sinus, mucociliary clearance is inhibited and secretions are retained in the sinus. This predisposes the patient to sinus infections and mucocele.

The following sections are discussed with the understanding that they are more commonly performed endoscopically but may be done with an open approach as necessary.

PROCEDURAL CONSIDERATIONS. FESS can be performed after induction of general anesthesia or MAC, depending on the surgeon's and patient's preference. The setup for FESS is the same as the setup for any nasal surgery in terms of prepping, draping, and positioning. The instruments required are the basic nasal set, video equipment including monitor, and light source with the appropriate light cord adapted to the type of endoscope used. The endoscopes used in sinus surgery are much like endoscopes used in other procedures. They are 4 to 5 mm in diameter and have different directions of view: 0, 30, 70, 90, or 120 degrees. Depending on which sinus will be the operative site, the appropriate lens will be requested. Often if

RESEARCH HIGHLIGHT

Endoscopic Sinus Surgery and Symptom Relief

Functional endoscopic sinus surgery (FESS) is an established treatment for a variety of sinus disorders. FESS offers the advantage of targeting and removing small areas of disease in very specific regions, thereby opening the sinuses for better aeration. Multiple studies have demonstrated the efficacy of FESS in reducing symptoms related to sinus disease, but no reports (including a large-scale evaluation of specific symptom response) existed before the meta-analysis conducted by researchers from Georgetown University and St. Louis University School of Medicine.

Researchers evaluated 21 relevant studies involving a total of 2070 patients with chronic rhinosinusitis who were followed for a mean of 13.9 months after surgery. The study dates evaluated ranged from 1980 through 2008. Inclusion criteria included studies with 20 or more adult participants, studies published in the English language, and studies in which the participants had three or more symptoms as defined by the American Academy of Otolaryngology–Head and Neck Surgery Rhinosinusitis Task Force. Individual meta-analyses were conducted for each symptom reported to compare preoperative and postoperative scores of symptom severity.

Results of the study demonstrated that nasal obstruction, facial pain, headache, smell, and postnasal discharge improved by approximately 59%, 61%, 53%, 49%, and 47%, respectively, providing a large body of evidence that symptom improvement is noted generally after FESS.

Modified from Chester AC et al: Symptom-specific outcomes of endoscopic sinus surgery: a systematic review, *Otolaryngol Head Neck Surg* 140:633-639, 2009.

FIGURE 18-30 Endoscopic suites demonstrating navigation systems and monitors.

work is to be done in several sinus cavities, the surgeon may change lenses intraoperatively to obtain the optimal view in each cavity.

In addition to endoscopes, other instruments that may be used in FESS include endoscopic suction tips and suction elevators, biopsy forceps, forceps for retracting and cutting/excising tissue, and scissors. Patients undergo preoperative CT studies to determine the specific areas affected by the sinusitis. These CT scans should be available in the OR and will be referenced by the surgeon during the surgery (Figure 18-31).

The video equipment is located at the head of the bed. The surgeon operates from the right side of the patient, the scrub person stands at the right of the surgeon, and the first assistant usually stands across from the surgeon on the opposite side of the table. More commonly, the surgeon, the first assistant, and the scrub person stand during the procedure. With the use of a navigational system, the surgical procedure can also be viewed on a computer monitor by the rest of the surgical team.

Navigational systems are especially useful in revision sinus surgery, in which the familiar anatomy of the sinuses has been altered by previous surgery and the typical landmarks of the sinuses are now changed. Unfortunately, because of the nature of sinus disease itself in terms of allergic tendencies and mucous membrane irritation that are often chronic conditions, sinus disease can recur. Some patients may decide that their symptoms have recurred to the troublesome point where they elect to undergo surgery more than once. From a safety standpoint and to reduce the risk of a revision surgery, many surgeons will not attempt a revision sinus procedure without having an image-guided system available.

FIGURE 18-31 Computed tomography (CT) scan of maxillary and ethmoid sinuses. Note septal deviation, maxillary sinus ostia, turbinates, and ocular muscles.

Several navigational systems are available, and many of these systems have applications for different types of surgeries, so the initial expense of the machine itself can be defrayed if it is shared with different surgical specialties, such as neurosurgery. Also, technical components to facilitating this type of sinus

surgery must be mastered by the perioperative nursing staff, who must develop competence in system setup, transfer of the CT scan data into the system, and maintenance procedures.

To avoid possible injury, instruments should be passed to the surgeon or first assistant in the closed position and never over the patient's face. They should be passed smoothly and carefully so that the surgeon's or practitioner's eyes do not leave the endoscope or video monitor, limiting distractions. Some surgeons will request a suction-irrigation device that provides visualization of the sinus recesses by allowing simultaneous suction and irrigation of the operative field.

An antifog solution can be used to treat the lens of the endoscope. The solution should not be wiped off the lens; it should be applied to the lens in a thin layer. Another consideration that is crucial to a successful outcome in FESS is to maintain the integrity of the patient's periorbital cavities. The patient's eyes must be visible to the surgeon at all times to avoid injury to the orbit or to immediately recognize injury if it occurs. The surgeon will monitor for movement of the eyeball or appearance of an intraorbital hematoma.

Encroachment of the orbit can be recognized if yellow tissue is seen because orbital fat is yellow. This finding should be communicated immediately to the surgeon. Another good technique is for the scrub person to place all tissue removed by the surgeon into a small labeled container of normal saline or lactated Ringer's solution on the surgical field. If any of the tissue "floats," the surgeon should be notified immediately. The surgeon will push the tissue in question with an instrument and rotate it a few times to release any small air bubbles that may be trapped in it, which could be causing it to float. If this is the case, the tissue will then sink to the bottom of the container; it should then be considered diseased tissue that needs to be removed. However, any tissue that continues to float naturally is presumed to be fat or brain tissue. In this case, it is presumed that the orbit has been encroached, and the situation is treated as a potentially serious complication.

OPERATIVE PROCEDURE

1. The surgeon applies topical anesthetic and administers the local anesthetic.
2. The lens of the endoscope is treated with antifog solution before the endoscope is introduced into the nose.
3. The natural ostium of the maxillary sinus is enlarged with a Lusk probe to provide physiologic drainage through the middle meatus. This creates a maxillary antrostomy and allows a larger drainage pathway into the ostiomeatal complex (Figure 18-32).
4. The diseased tissue is visualized through the endoscope, and straight or angled true-cuts are used to remove it.
5. If an anterior ethmoidectomy is indicated, the surgeon inserts the endoscope into the ostiomeatal complex and performs the ethmoidectomy by taking small bites of the honey-combed bones with straight true-cuts and removing them manually and/or with suction. This reduces the many-celled ethmoid labyrinth into one large cavity to ensure adequate drainage and aeration.
6. A sphenoidotomy is created by biting an opening into one or both of the sphenoidal sinuses with a straight true-cut. It is usually performed only if sphenoid sinus disease is present on CT. Sphenoidotomies are often done with ethmoidectomies because once the ethmoid labyrinth is removed, the surgeon has excellent access through a lateralized middle turbinate exposing the sphenoidal sinuses.

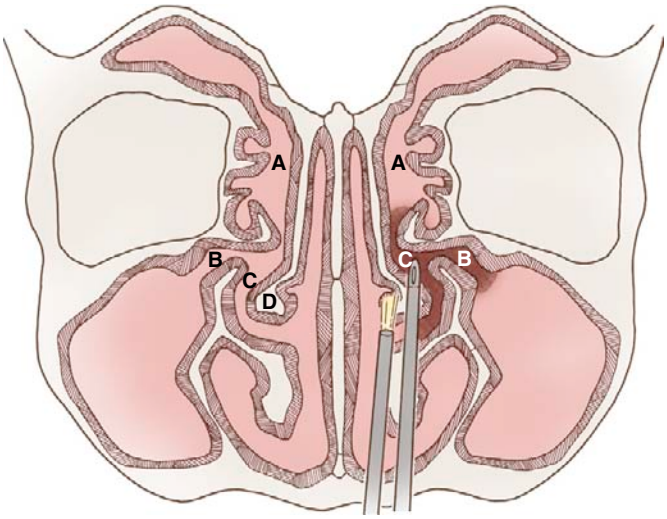


FIGURE 18-32 Surgery is performed using endoscope and forceps by intranasal approach. Diseased tissue is being removed from shaded areas depicting ethmoid sinus area *(A)*, maxillary sinus ostia *(B)*, and middle meatus *(C)*. Middle turbinate is unaffected *(D)*.

7. Because no incisions are made, no sutures are required. Epistaxis should be controlled endoscopically until it becomes a slow ooze.
8. Absorbable gelatin film may or may not be placed into the patient's middle meatus to maintain patency and reduce stenosis. If used, it is rolled into a cylindric splint and set in place with bayonet forceps. An antibiotic ointment may be applied to the splint first, according to the surgeon's preference. The gel splints dissolve gradually, or they may be removed with irrigation.
9. A mustache dressing is applied.

Frontal Sinus Trephination and Obliteration

Frontal sinus trephination is the creation of a hole in the frontal sinus to drain pus or fluid accumulation. It is performed to treat the signs and symptoms of frontal sinusitis, which may include fever and headaches. A catheter may be surgically sewn into place at the incision site of the opening made into the affected frontal sinus; this serves as a drain and medium with which to irrigate the sinus until the disease resolves. If chronic suppuration with repeated acute attacks of frontal sinusitis persists, further surgery via a coronal craniotomy may be performed to remove the diseased lining of the sinus, obliterate the cavity with a fat graft, and reconstruct the nasofrontal duct to provide the necessary drainage. The procedure for a frontal sinus trephination follows.

PROCEDURAL CONSIDERATIONS. The patient's face is prepped according to the surgeon's preference. The head is draped as in nasal procedures. Local anesthetic may be injected in the skin under the eyebrow. Culture tubes should be available as should drainage catheters.

OPERATIVE PROCEDURE

1. The incision is made medially below the eyebrow, along the same contour of the brow (Figure 18-33).
2. The periosteum is elevated from the bone, and a small diamond or cutting burr is used to drill a hole into the sinus.
3. Cultures may be taken of any pus present in the sinus, followed by irrigation.

4. A large Silastic or Teflon tube or appropriate-size catheter may be placed through the incision into the sinus.
5. The incision is closed with suture of the surgeon's preference.
6. A small dressing is usually applied to absorb drainage from the incision and catheter.

Endoscopic Transnasal Repair of Cerebral Spinal Fluid Leak

Cerebral spinal fluid (CSF) leaks are usually created by surgery or trauma. Although rare, spontaneous CSF leaks do occur. Patients usually complain of clear rhinorrhea with a salty taste from the nose, worse when either leaning forward or lying flat. Headache may accompany the rhinorrhea because of low spinal column pressures. Diagnosis is confirmed by sending the nasal fluid to the laboratory to test for β_2-transferrin, a protein specifically found in cerebrospinal fluid. A CT cisternogram assists with diagnosing the leak and often helps locate the site of dehiscence. Prepping and draping of the patient are performed in the same sterile fashion as for an endoscopic transsphenoidal approach to resection of pituitary mass, including prepping one lateral thigh and abdomen for potential graft use. All steps are followed as in a transsphenoidal resection of mass while paying close attention to the location of the carotids on the navigation system. Once the leak is found, a decision on what type of closure to use will be made by the otolaryngologist.

FIGURE 18-33 Incision to expose ethmoidal and frontal sinuses. Resulting scar is almost invisible.

Caldwell-Luc with Radical Antrostomy

The purpose of a radical antrostomy is to establish a large opening into the wall of the inferior meatus, which ensures adequate gravity drainage and aeration. This large opening allows removal of the diseased tissues in the sinuses under direct vision. The Caldwell-Luc approach is also used to access the maxillary artery in cases of extreme epistaxis. The procedure requires an incision into the canine fossa of the upper jaw and exposure of the antrum for removal of bony diseased portions of the antral wall and contents of the sinus (Figure 18-34).

FESS can be used to treat patients with chronic sinusitis, obviating the need for radical procedures, such as Caldwell-Luc. FESS allows the surgeon to target the ostiomeatal complex (OMC) in the anterior ethmoid sinus region, where thickened and diseased tissue often blocks the OMC. Obstruction in this area leads to subsequent infection in the maxillary, frontal, and sphenoidal sinuses. FESS permits removal of only the diseased

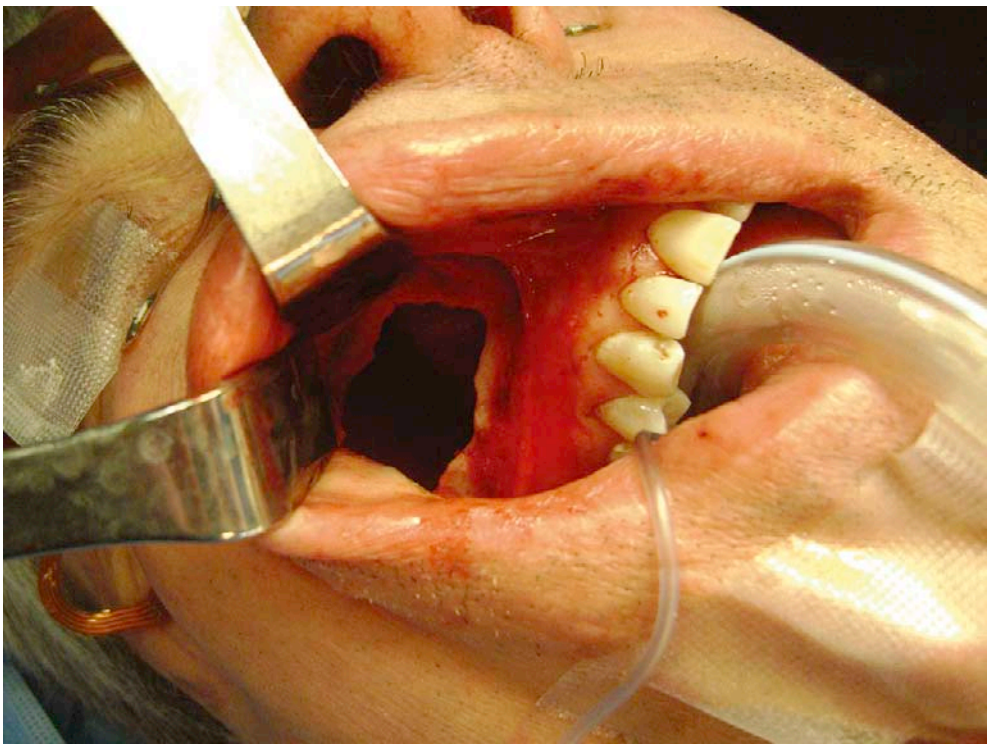


FIGURE 18-34 Caldwell-Luc operation.

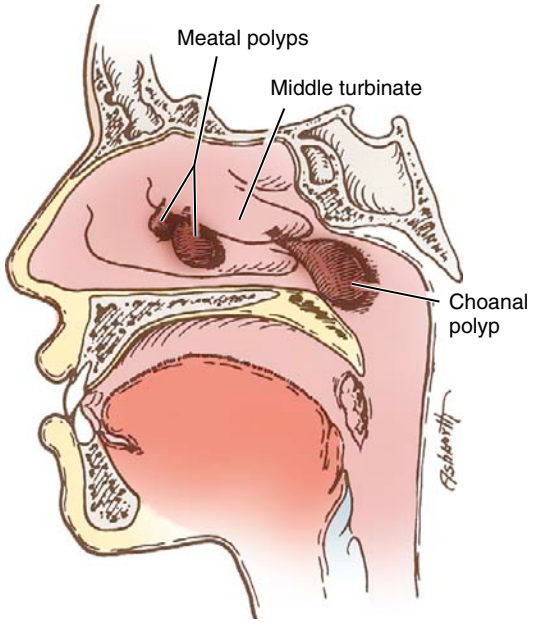


FIGURE 18-35 Nasal polyps. A choanal polyp is usually single and originates in maxillary sinus; however, most polyps are found in middle meatus.

tissue; recovery is more rapid, with minimal and usually temporary effects on the patient's appearance.

Nasal Polypectomy

A nasal polypectomy is the removal of polyps from the nasal cavity (Figure 18-35). Nasal polyps are benign, grapelike clusters of mucous membrane and connective tissue. When the polyps become large, they obstruct the free passage of air, make breathing difficult, and cause a change in speech quality. Performed endoscopically, nasal polypectomies are often done with other sinus procedures that also require removal of diseased tissue. Because of the viscous nature of polyps, microdebriders are particularly helpful in these cases. They can greatly shorten surgical time by their mechanism of morcellating the polyp and removing it by immediate suctioning while controlling bleeding, as opposed to each polyp being manually extracted with an instrument in small pieces. Cases involving inverting papilloma may recur and may require repeat polypectomies as symptoms recur.

Procedural Considerations and Operative Procedure. Nasal polypectomy setup is as for any intranasal procedure, with the addition of endoscopic equipment. Additional instruments may include a nasal polyp snare if a microdebrider is not used. Packing is typically not needed or used.

ORAL CAVITY/LARYNGOLOGIC/ NECK PROCEDURES

Surgery of the Oral Cavity and Pharynx

The oral cavity is susceptible to both benign and malignant lesions, in part because of environmental risk factors. It is estimated that in 2009 (ACS, 2009) 35,720 men and women (25,240 men and 10,480 women) will be diagnosed with cancer of the oral cavity and pharynx, and 7600 will die. Oral malignancies can be linked to specific carcinogens, the most important one being tobacco use. Incidence rates are more than twice as high in men as in women and are greatest in men who are older than 50 years.

Benign or malignant lesions of the tongue, floor of the mouth, alveolar ridge, buccal mucosa, or tonsillar area are excised depending on extensiveness of disease, involvement of surrounding vessels and nerves, and candidacy for surgery (Figures 18-36 and 18-37). Benign or small malignant tumors of the oral cavity may be excised without a neck dissection, though in the presence of diagnosed or highly suspicious metastatic disease, a selective neck dissection may be performed in an effort to control a cancerous growth in the upper jugular lymphatic chain of the neck.

In the treatment of carcinoma of the floor of the mouth with involvement of the mandible, a CT scan and/or MRI of the face and neck should be obtained to evaluate extension of the disease. A portion of the tongue is resected and may require a combined operation with reconstructive surgeons. A tracheostomy, percutaneous endoscopic gastric tube, neck dissection, and composite resection of both the mandible and the tongue with free flap reconstruction must be considered for extensive disease. When the primary intraoral lesion is confined to the tongue, a neck dissection and a hemiglossectomy are performed without resection of the mandible. In the presence of a lesion of the tonsil or an extensive lesion of the base of the tongue with pharyngeal wall involvement, resection of the mass may require removal of portions of the base of the tongue, pharyngeal wall, and soft palate to secure an adequate margin of normal tissue around the lesion. In recent years nonsurgical management with chemoradiotherapy has advanced for select oropharyngeal tumors. A free flap may be considered to fill a soft tissue defect if one is created from surgical resection. Psychologic preparation of the patient is extremely important because these procedures may be done for a minor lesion in the oral cavity or may be the first stage of much more extensive surgery in the head and neck area. A supportive and accepting family is important to the patient because of the possibility of disfigurement after surgery.

Procedural Considerations. The patient is placed in a supine position with shoulders elevated. Generally, endotracheal anesthesia is used and a pharyngeal pack of moist gauze may be inserted in the mouth. Instruments and supplies vary, depending on the surgical intervention.

Operative Procedure. Although the procedure may be scheduled as a local excision, frequently lesions of the oral cavity require more extensive excision. The setup should be designed to include the instruments for a neck dissection, or they should be readily available. For some tumors of the oral cavity, a tracheostomy is performed to ensure a patent airway after surgery. A laser may be used to excise locally confined lesions of the oral cavity.

Salivary Gland Surgery

Disorders of the salivary glands typically fall into one of three categories: inflammatory, obstructive, and neoplastic. Inflammatory conditions, such as bacterial or viral infections, can

FIGURE 18-36 Carcinoma of the dorsal tongue.

lead to salivary gland abscesses and ductal stone formation. Obstructive conditions can be a secondary consequence of inflammatory processes. Masses of the salivary glands may be benign or malignant, and 70% of them occur in the parotid gland. Three fourths of these parotid masses are benign (Elluru and Kumar, 2005). Perioperative nurses will facilitate surgical care for patients experiencing any of these conditions.

Excision of the Submandibular Gland. Excision of the submandibular gland is performed to remove mixed tumors and calculi associated with extensive chronic inflammation. An incision is made below and parallel to the mandible and extending to beneath the chin to remove the gland and tumor.

PROCEDURAL CONSIDERATIONS. The patient is placed on the OR bed in a supine position, with the affected side up and is prepped for neck surgery. The instruments include a minor neck dissection setup. A set of lacrimal probes should also be added to the instrument setup if exploration of the submandibular (Wharton's) duct is necessary during surgery. The perioperative nurse must ensure that no local anesthetic is delivered to the sterile field if identification of major nerves is anticipated. A nerve stimulator and bipolar ESU may be requested.

OPERATIVE PROCEDURE

1. The surgeon makes a small skin incision below and parallel to the mandible, extending forward to beneath the chin (Figure 18-38, *A*). The platysma is incised with scissors; the skin flaps and undersurface of the platysma and cervical fascia covering the gland are undermined with fine hooks, tissue forceps, and Metzenbaum scissors (Figure 18-38, *B*).
2. The mandibular branch of the facial nerve is retracted with a small loop retractor or nerve hook.
3. The submandibular gland is elevated from the mylohyoid muscle (Figure 18-38, *C*). The edge of the muscle is retracted anteriorly to expose the lingual veins and nerve and the hypoglossal nerve, which is identified and preserved.

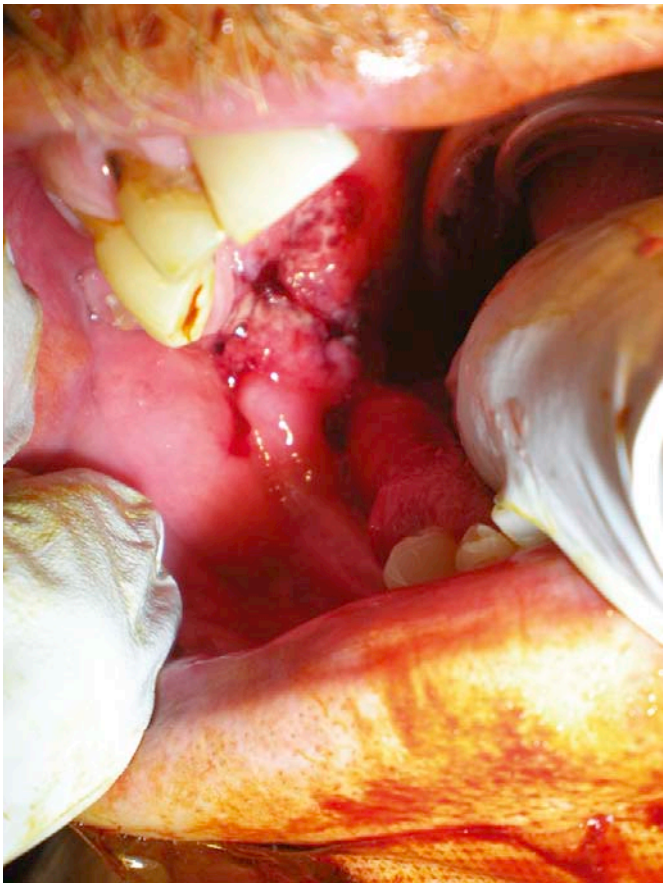


FIGURE 18-37 Carcinoma of the right tonsil.

4. The gland is freed by blunt dissection, and the submandibular duct is clamped, ligated, and divided with care to prevent injury to the lingual nerve.
5. The facial artery is clamped, ligated, and divided. The submandibular gland is removed (Figure 18-38, *D*).
6. The wound is closed with interrupted absorbable sutures. The skin edges are approximated with nonabsorbable sutures. A drain is inserted into the submandibular bed and secured to the skin. Dressings are applied.

Parotidectomy. Parotidectomy may be performed to treat recurrent parotiditis, but it is more commonly performed as part of the management of parotid gland tumors. In parotidectomy for tumor removal, the tumor and a portion of or the entire parotid gland are removed through a curved incision in the upper neck, in front of the earlobe, or through a Y type of incision on both sides of the ear and below the angle of the mandible. Even when a mass in the parotid gland is benign, the closeness of the facial nerve makes removing the entire mass surgically challenging (Figure 18-39). The facial nerve exits the stylomastoid foramen, enters the substance of the salivary gland, and then bifurcates into the temporofacial and cervicofacial branches, variably communicating with the gland. These branches then further divide into the temporal, zygomatic, buccal, and marginal mandibular and cervical branches near the edge of the parotid. The gland is divided artificially into a *superficial* and a *deep* lobe according to its relationship to the facial nerve. The possibility of damaging

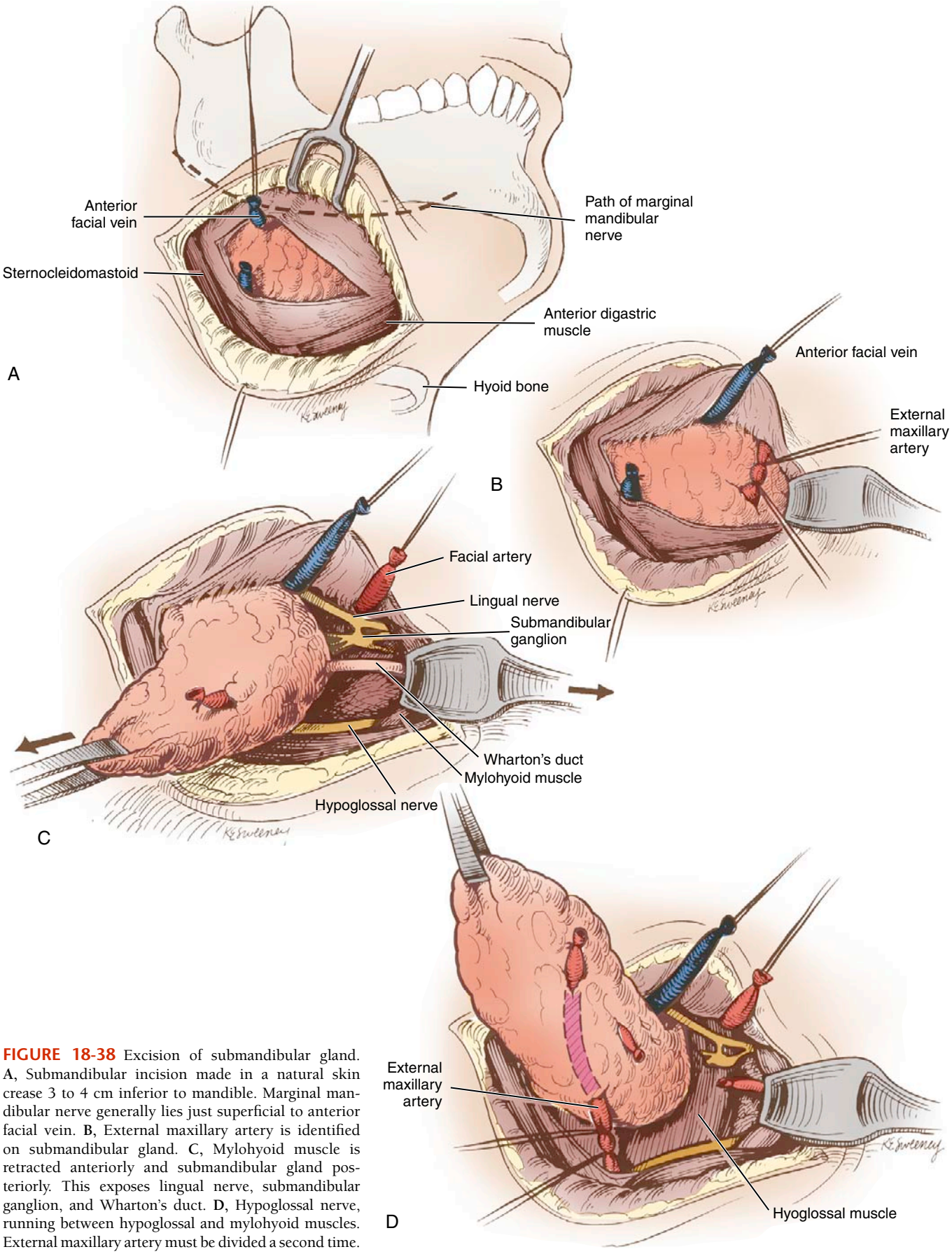


FIGURE 18-38 Excision of submandibular gland. **A**, Submandibular incision made in a natural skin crease 3 to 4 cm inferior to mandible. Marginal mandibular nerve generally lies just superficial to anterior facial vein. **B**, External maxillary artery is identified on submandibular gland. **C**, Mylohyoid muscle is retracted anteriorly and submandibular gland posteriorly. This exposes lingual nerve, submandibular ganglion, and Wharton's duct. **D**, Hypoglossal nerve, running between hypoglossal and mylohyoid muscles. External maxillary artery must be divided a second time.

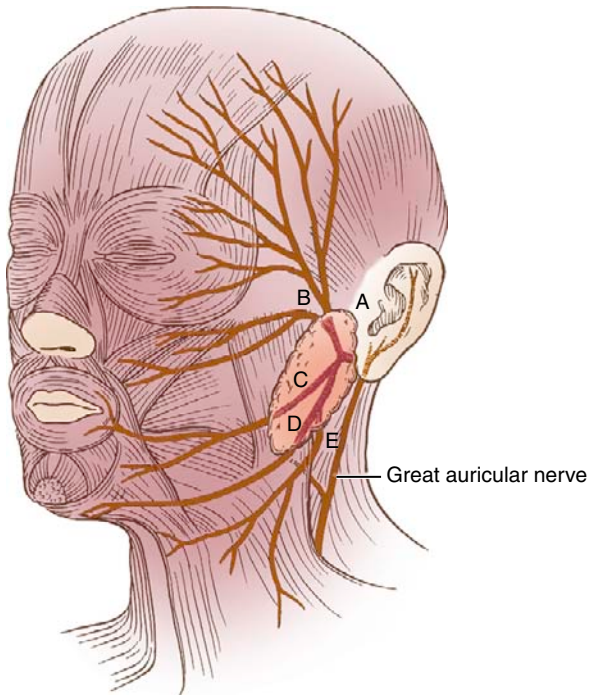


FIGURE 18-39 Branches of facial nerve. *A,* Temporal; *B,* zygomatic; *C,* buccal; *D,* mandibular; *E,* cervical.

the facial nerve (resulting in facial nerve weakness or paralysis) during the dissection of the gland should be considered carefully by all patients contemplating parotidectomy. Therefore the surgeon must understand that the most definitive way of avoiding damage to the facial nerve is to identify it early in the procedure. In addition, the patient should understand that a more radical procedure might be required if a malignant tumor is discovered to involve adjacent structures.

PROCEDURAL CONSIDERATIONS. The patient is placed on the OR bed in a supine position with the entire affected side of the face up. The entire side of the face, the mouth, the outer canthus of the eye, the ear, and the forehead are prepped and left exposed.

The instrument setup is a neck dissection set. A nerve stimulator or nerve integrity monitor should be available. A set of lacrimal probes should be included in the setup if exploration of the ductal system of the parotid is necessary during the course of surgery. Bipolar ESU may also be required.

OPERATIVE PROCEDURE

1. The incision (Figure 18-40) may extend from the posterior angle of the zygoma downward in front of the tragus of the ear and behind the lobule of the ear backward; the incision continues over the mastoid process and then downward and forward on the neck parallel to and below the body of the mandible. (A chin incision may also be used.) Bleeding vessels are controlled by hemostats and fine ligatures or with the ESU.
2. Using fine-toothed tissue forceps and scissors, the surgeon elevates the skin flaps as described for thyroidectomy (see Chapter 15) and retracts the flap with silk sutures fastened to clamps.
3. The upper portion of the sternocleidomastoid muscle is exposed and retracted, the auricular nerve is identified, and the lower part of the parotid gland is elevated with curved hemostats.
4. The superficial temporal artery and vein and external jugular vein are identified by means of blunt dissection. The parotid tissue is dissected from the cartilage of the ear and the tympanic plate of the temporal bone. The temporal, zygomatic, mandibular, and cervical branches of the facial nerve are identified and preserved.
5. The diseased portion of the parotid gland is removed, which can be superficial or deep.
   a. The *superficial portion* of the parotid gland containing the tumor is removed. In some cases the entire superficial portion is removed, followed by ligation and division of the parotid duct (Figure 18-41).
   b. When the *deep portion* of the parotid gland must be removed, the facial nerve is gently retracted upward and outward and then the parotid tissue is removed from beneath the nerve. Kocher retractors are used to retract the mandible. The external carotid artery is identified. In many cases the internal maxillary and superficial temporal arteries are clamped, ligated, and divided.
6. The wound is closed in layers with absorbable suture. If a divot is observed or anticipated overlying the resected portion of the parotid gland, abdominal fat may be harvested. A small drain is inserted, the skin is closed with fine nonabsorbable suture, and a pressure dressing may be applied depending on the surgeon's preference.

Uvulopalatopharyngoplasty. Uvulopalatopharyngoplasty (UPPP) is performed primarily to relieve obstructive sleep apnea (OSA) and snoring (Figure 18-42) (Research Highlight). UPPP is not a substitution for the use of continuous positive airway pressure (CPAP), though the procedure may be considered when conventional use of CPAP fails. Two or more of the following indications are reason to perform the operation:

- An O_2 saturation that drops below 80%
- Apnea index worse than 20
- Significant daytime sleepiness
- Heroic snoring, producing social or marital problems
- Cardiac dysrhythmias, other than tachycardia or bradycardia, during sleep

PROCEDURAL CONSIDERATIONS. On occasion, tracheostomy may be performed with UPPP because of postoperative edema with subsequent risk of airway obstruction. The tracheostomy tube is removed and the incision is closed when the danger of postoperative edema and bleeding has passed. Because some of these patients are obese (causing the tissue of the pharynx to sag during sleep), preoperative planning should include obtaining an assortment of tracheostomy tubes, including extra long tubes, before the start of the procedure. Care must be taken in positioning the obese patient to ensure proper body alignment. Emergency tracheotomy or bronchoscopy should be anticipated in the event of airway obstruction after anesthesia induction. The surgeon may choose to administer a local anesthetic with the anesthesia provider monitoring the patient. The ease of intubation should have already been determined by this time, choosing the safest method of intubation (i.e., fiberoptic intubation, GlideScope). Once the method of intubation has been established and an airway is secured, a general anesthetic may be delivered. If the tonsils are present, a tonsillectomy is performed along with the UPPP.

RESEARCH HIGHLIGHT

Obstructive Sleep Apnea and Surgical Risk

Obstructive sleep apnea (OSA) is the most prevalent sleep disorder. An estimated 82% of men and 92% of women with moderate-to-severe sleep apnea have not been diagnosed. Patients with undiagnosed OSA may have increased perioperative complications. The goal of this study was to determine whether a simple screening protocol for OSA-related signs and symptoms performed at the time of preoperative assessment for elective surgery, followed by home nocturnal oximetry in selected cases, could identify patients who were at increased risk of perioperative complications.

Participants for the study were identified during preanesthetic evaluation based on at least two clinical features suggestive of OSA as determined by a standardized screening questionnaire and physical examination (e.g., snoring, excessive daytime somnolence, witnessed apneas, or crowded oropharynx). Based on the initial screening, 172 patients, ranging in age from 27 to 85 years, were selected for home nocturnal oximetry testing. The oximetry results were interpreted by sleep medicine–trained physicians before the scheduled surgery and they established a baseline for the incidence of oxygen desaturation episodes at 4% or more.

Analysis of the data showed correlation between documented oximetric preoperative oxygen desaturation episodes and postsurgical complications. A complication was defined as an adverse event affecting a major organ system that required further monitoring, additional diagnostic testing, or direct therapeutic intervention. A significantly higher rate of complications was noted in patients who experienced five or more desaturation levels based on preoperative screening as compared to patients who had fewer than five episodes. The patients who had experienced 5 to 15 episodes of desaturation had a complication rate of 13.8% and those who had more than 15 episodes had a complication rate of 17.5%. The majority of complications were respiratory in nature, followed by cardiovascular, bleeding, and gastrointestinal complications.

While nocturnal oximetric testing does not confirm the presence of OSA, it may have usefulness as a screening tool for patients with this disorder. Effective screening will allow physicians to identify patients who are at risk for complications related to OSA and better plan their perioperative course to improve outcomes.

Modified from Hwang D et al: Association of sleep-disordered breathing with postoperative complications, *Chest* 133:1128-1134, 2008; Chung F, Elsaid H: Screening for obstructive sleep apnea before surgery: Why is it important? *Curr Opin Anaesthesiol* 22(3):405-411, 2009.

OPERATIVE PROCEDURE

1. The McIvor mouth gag is inserted.
2. The tissue to be resected may be outlined by an electrosurgical blade. A #3 knife handle with a #15 blade or a #7 knife handle with a #12 blade may be used to make the incision, though surgical technique has changed from resection with scalpel to completing the entire resection with the ESU. The incision is made in the soft palate and anteriorly to the tonsillar pillar (if the patient has not previously undergone a tonsillectomy) or posteriorly to the tonsillar pillars (if the patient has undergone a tonsillectomy) (Figure 18-43).

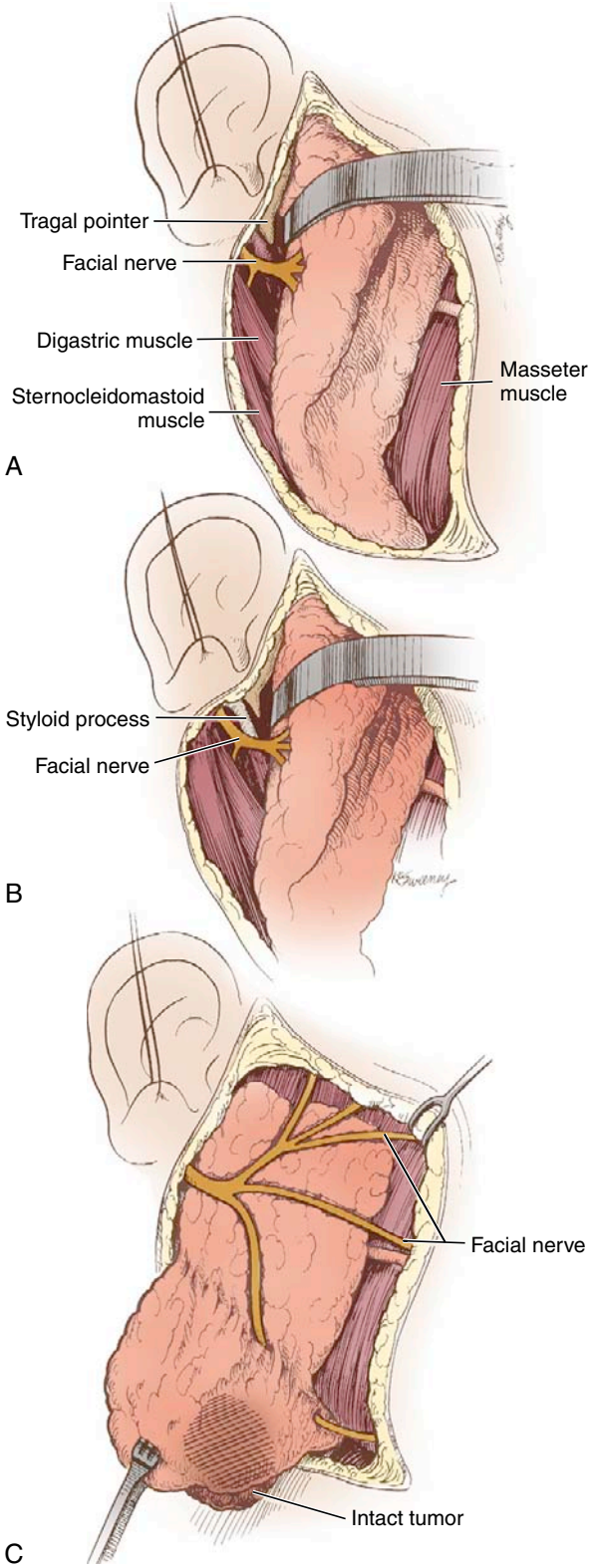


FIGURE 18-40 Operative technique for parotidectomy. **A**, Blunt dissection of parotid gland from external auditory canal cartilage exposes tragal pointer. Facial nerve lies approximately 1 cm deep and slightly anteroinferior to pointer and 6 to 8 mm deep to tympanomastoid suture line. **B**, Facial nerve exits stylomastoid foramen to run anteriorly between styloid process and attachment of digastric muscle to digastric ridge. **C**, Nearly completed process with tumor within intact superficial parotidectomy specimen.

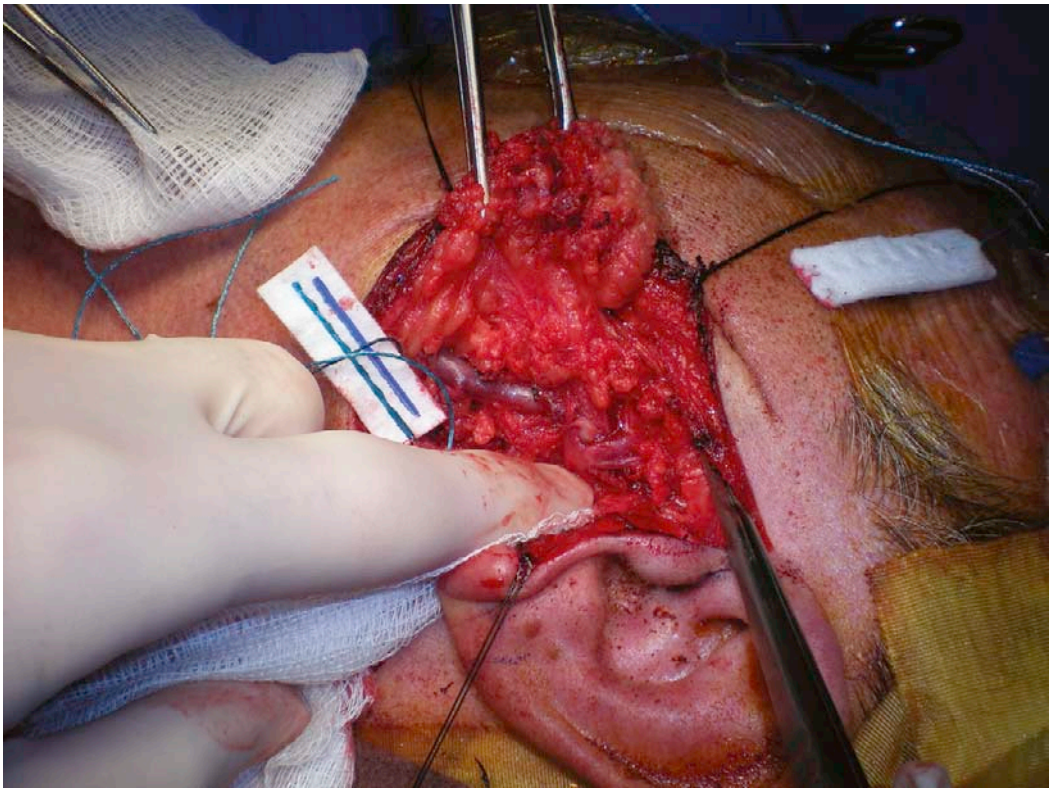


FIGURE 18-41 Surgical removal of superficial parotid mass.

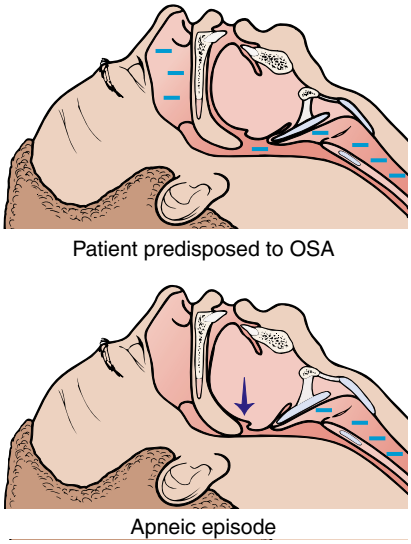


FIGURE 18-42 Sleep apnea syndrome is a condition in which airflow is temporarily obstructed during sleep. Airflow obstruction occurs when the tongue and the soft palate fall backward and partially or completely obstruct the pharynx. The obstruction may last from 10 seconds to as long as 2 minutes. During the apneic period, the patient experiences severe hypoxemia (decreased PaO_2), hypercapnia (increased $PaCO_2$), and acidosis. These changes interrupt sleep and cause the patient to partially awaken. When the patient begins to awaken, the tone of the muscles of the upper airway increases. The tongue and soft palate move forward, and the airway opens. Apnea and arousals occur repeatedly during the night, separated by several normal breaths. The cause of sleep apnea is not definitely known. However, three factors appear to be involved: (1) shape of the upper airway, (2) neural control of the respiratory muscles, and (3) hormonal balance. *OSA,* obstructive sleep apnea.

3. Larger blood vessels may be clamped until the tissue is removed, or a suction coagulator or hand-controlled electrosurgical pencil may be used to obtain hemostasis as the tissue is excised.
4. Once the tissue is removed and hemostasis is achieved, absorbable sutures are used to approximate the edges of the mucosa. Depending on the surgeon's preference, 2-0 and 3-0 absorbable suture should be available. Needle holders should be long enough to allow the surgeon ease in delivering the atraumatic needle to the edges of the mucosa.
5. The oral cavity should be rinsed of blood and debris and the incision inspected before the patient is transferred from the OR.

When inspecting the incision in the postoperative period, care should be taken not to disturb it with a tongue blade, if one is used to provide access for inspection. The patient must not use a straw for fluid intake because it might disturb the suture line. Gentle oral cavity rinsing is recommended several times daily to decrease the chance of postoperative infection and to increase patient comfort.

Laryngeal Surgery

Laryngeal surgery may be performed for diagnostic reasons or as a means of treatment for both benign and malignant conditions. This type of surgery involves both endoscopic and traditional "open" approaches and always has the potential to alter the patient's ability to communicate verbally in the postoperative period. As is the case with oral cavity malignancies, cancerous lesions within the laryngeal structures are often attributed to environmental factors, such as tobacco and alcohol use (Figure 18-44). Benign conditions, such as vocal cord polyps and nodules, are often treated with laryngeal surgery.

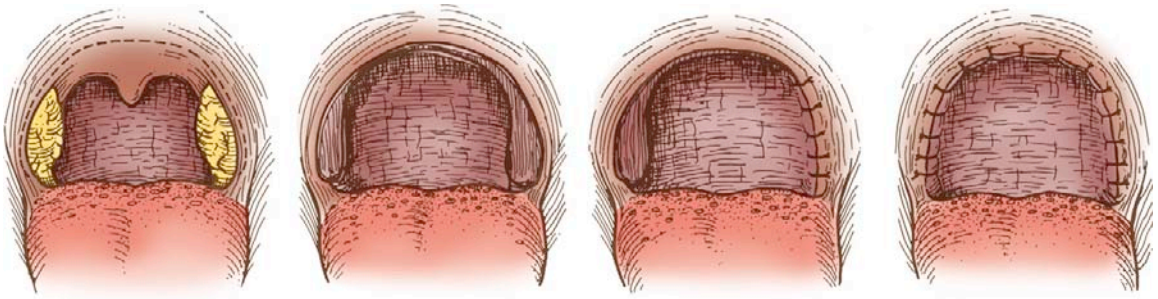


FIGURE 18-43 Technique of palatopharyngoplasty as advocated by Simmons and associates.

FIGURE 18-44 Large granular tumor on the true cord.

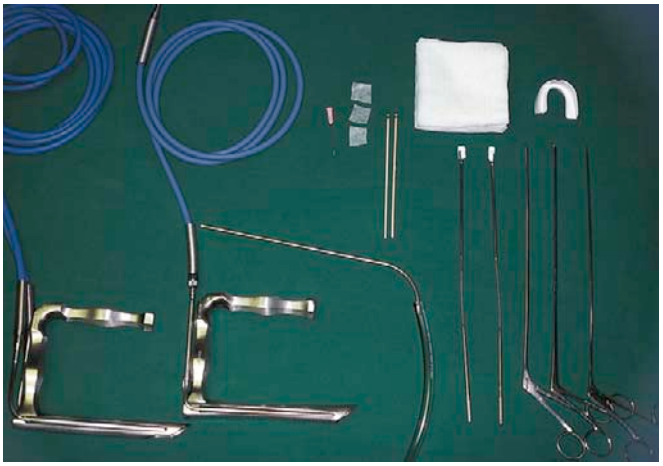


FIGURE 18-45 Instrument setup for direct laryngoscopy includes Jako and Dedo laryngoscopes, laryngeal suction, assorted laryngeal forceps, and sponge carriers.

ENDOSCOPIC PROCEDURES

Laryngoscopy

Laryngoscopy is direct visual examination of the interior of the larynx by means of a rigid, lighted speculum known as a *laryngoscope* (Figure 18-45) to obtain a specimen of tissue or secretions for pathologic examination. Vocal cord visualization may also be accomplished in the office setting with a flexible, fiberoptic nasopharyngoscope.

Procedural Considerations. Most rigid laryngoscopies are performed with the patient receiving a general anesthetic. If the patient is unable to tolerate general anesthesia, a local or topical anesthetic of lidocaine, tetracaine, cocaine, or benzocaine/tetracaine will be administered. The patient should be sufficiently relaxed by reassurance and by pharmacologic preparation if the procedure is performed using local anesthesia. Sedatives may be administered before surgery. Immediate preoperative assessment should include the presence of any dental appliances and loose teeth and the condition of dental work. Any stiffness or immobility of the neck or shoulders should be evaluated. Respiratory problems such as asthma must receive careful attention. The patient should be cautioned about not eating or drinking after surgery until the gag reflex has returned and swallowing occurs without difficulty.

The setup includes the following:

- Labels for all medications and solutions used in the sterile field
- Local anesthesia setup
- Gauze sponges, 4 × 4 inches
- Laryngeal mirror
- Cotton balls
- Small cup of hot water (to warm the laryngeal mirror so that it does not fog when inserted into the mouth to view the vocal cords) or an antifog solution
- Emesis basin
- Syringe, 5 ml; and Abraham cannula
- Medication cup
- Jackson laryngeal application forceps
- Anesthetic spray, with angulated tip, or other topical anesthetic for the oral mucosa
- Instrument setup:
  - One laryngoscope
  - Two laryngeal suction tubes
  - One light carrier, fiberoptic
  - Two laryngeal biopsy forceps, one straight and one up-biting
  - Two sponge-carrier forceps with extra sponges
  - One tooth guard
  - One fiberoptic light cord
  - Zero-degree telescope: may be requested for close visualization or attached to the camera for photographs of specific areas
  - One laryngeal probe: may be used to retract tissue or assess mobility of tissue

Accessory items include suction tubing, a specimen container, a basin with sterile saline, gauze sponges, sterile towels, and gloves.

If the surgeon wishes to perform a suspension laryngoscopy, a self-retaining laryngoscope holder is added to the instrument table, as well as microlaryngeal instruments, which include scissors, cup forceps, and alligator forceps. A special platform may be mounted onto the OR bed or a Mayo stand may be placed above the patient's chest and over the OR bed to provide a place for the laryngoscope holder to rest. The surgeon normally uses the operating microscope with a 400-mm lens during suspension laryngoscopy. The patient is placed in a supine position to facilitate visualization of the vocal cords. A shoulder roll should be available if slight hyperextension of the neck is necessary to assist in visualization of the larynx.

Operative Procedure

1. Moist gauze pads or tape should be placed over the patient's eyes to protect them from the instrumentation and to prevent injury and irritation from secretions during the procedure. The head may also be wrapped in a sterile towel. A sterile drape may be used to cover the patient. A tooth guard or moist 4-inch × 4-inch gauze sponge is placed to protect the patient's teeth.
2. The surgeon introduces the spatula end of the laryngoscope into the right side of the patient's mouth and directs it toward the midline; then the dorsum of the tongue is elevated so that the epiglottis is exposed.
3. The patient's head is first tipped backward and then lifted upward as the laryngoscope is advanced into the larynx.
4. The larynx is examined, a biopsy is taken, secretions are aspirated, and bleeding is controlled.
5. The patient's face is cleansed.

Laryngoscopy instrumentation should remain set up in the room until the patient is transferred because the equipment may be needed if the patient experiences laryngospasm postoperatively.

Microlaryngoscopy

Microlaryngoscopy facilitates improved diagnosis and allows the laryngologist to view with relative ease areas that previously were inaccessible or difficult to visualize. It may also be used for minor surgery of the larynx, especially for the removal of polyps or nodules on the vocal cords (Figure 18-46). Intralaryngeal surgery using the laryngoscope is often referred to as *phonosurgery*. Instrumentation may vary according to surgeon preference. Research is currently under way to determine the feasibility of using robotics for laryngeal surgery.

Procedural Considerations. If the procedure is done to remove polyps or nodules from the vocal cords, the patient must be cautioned to observe complete voice rest or to whisper postoperatively. The patient should be provided with a pencil and paper or erasable slate to aid in communication. The patient's restriction on speaking should be noted on the nursing plan of care and on the front of the chart.

The basic instrument setup for laryngoscopy is used. Microlaryngeal instruments are added to the setup and include the following:

- Self-retaining laryngoscope holder
- Jako microlaryngeal grasping forceps
- Jako microlaryngeal cup forceps, straight and up-biting cups

FIGURE 18-46 Bilateral vocal cord polyps.

- Jako microlaryngeal scissors, straight, angled, and up-biting
- Jako microlaryngeal knives, straight and curved
- Laryngeal probe
- Microlaryngeal mirror
- Open-ended microlaryngeal suction tube
- Laryngoscope (dual light channel)

The aforementioned instruments are 22 cm long to allow use with the microscope, and are long enough to keep the surgeon's hands out of the visual field. The patient's head is adjusted to allow visualization of the larynx. The surgeon usually adjusts the microscope. The microscope lens should have a 400-mm focal length. Focal length is the distance from the lens to the operative area and is the point at which the field can be clearly viewed through the microscope. Beyond this point the field becomes fuzzy. The 400-mm lens gives the surgeon a 40-cm focal length, or working distance.

Carbon Dioxide Laser Surgery of the Larynx

Laryngologists often use the CO_2 laser to treat lesions of the larynx and vocal cords. This laser is efficient and has a high power output. The beam destroys tissue at a precise point with minimal destruction of the surrounding tissue. It is especially useful in surgeries such as removal of webs in the larynx, vocal cord papillomas, and carcinoma in situ of the larynx, as well as benign endobronchial lesions.

Procedural Considerations. The basic setup for laryngoscopy and microlaryngoscopy is used. All instrumentation used for laser laryngoscopy should be ebonized. A general anesthetic is usually administered. The operating microscope with a 400-mm lens is used, with the laser micromanipulator attached to the microscope head. The beam should also be tested for proper working order before use on the patient. Extreme care should be used when handling this delicate piece of equipment. A smoke evacuator should be used to remove the laser plume—a smokelike steam rising from the impact site; high-filtration laser masks should be worn by personnel. Where minimal plume is generated, a central wall suction with an in-line filter may be used for plume evacuation (AORN, 2009c). All other laser precautions apply (see Chapter 7).

Adjunctive Procedures

Although the following procedures do not technically involve the larynx, they are often performed by otorhinolaryngologists in conjunction with laryngeal surgery and are of particular use in the diagnostic arena.

Bronchoscopy. The trachea, bronchi, and lungs are visualized directly with a rigid or flexible bronchoscope that has a fiberoptic lighting system. A rigid scope gives a larger viewing area, whereas a flexible scope is easily inserted into the patient and manipulated. Bronchoscopy is fully described in Chapter 22. The Nd:YAG laser may be used for lesions of the trachea or bronchi, depending on the type of lesion. Most diagnostic bronchoscopies are performed using topical anesthetics and moderate sedation, requiring careful patient monitoring by the perioperative nurse.

Esophagoscopy. Esophagoscopy is the direct visualization of the esophagus and the cardia of the stomach. This procedure is used to observe the area for extension of tumor, to remove tissue and secretions for study, or to evaluate for second primary tumor sites.

PROCEDURAL CONSIDERATIONS. Esophagoscopy facilitates the diagnosis of esophageal carcinoma, diverticula, hiatal hernia, stricture, benign stenosis, and varices. Patients with suspected obstruction, symptoms of bleeding, or regurgitation may require endoscopy. The Nd:YAG laser may be used in the treatment of some of these lesions. Esophagoscopy may also be used for therapeutic manipulations, such as removal of a foreign body or insertion of an esophageal bougie to treat esophageal stenosis.

The setup includes the following:

- Esophagoscopes of desired type, size, and length (Figure 18-47)
- Suction tubing
- Fiberoptic light source and light cords
- Bougies, if desired
- Forceps of desired type and length
- Specimen containers
- Water-soluble lubricating jelly
- Gauze sponges
- Basin with sterile saline
- Suction tips (with velvet-eyed tips to avoid suctioning the mucosa of the esophagus into the tip)

OPERATIVE PROCEDURE

1. The fiberoptic light carrier is inserted into the esophagoscope and the fiberoptic light cord attached. A thin layer of lubricant is applied to the scope. The scope is passed into the mouth. The tongue, epiglottis, laryngeal inlet, and cricopharyngeal lumen are identified. If necessary, a person holding the patient's head may be required to tip the head backward while extending the neck anteriorly. Usually the esophagoscope is passed to the right side of the tongue, and the patient's head is turned slightly to the left.
2. When the scope has passed the inferior constrictors, the patient's head is moved in various directions so that all areas of the esophageal wall may be examined.
3. Specimens of secretions from the esophageal lumen may be obtained with an aspirating tube and suctioning apparatus. In some cases, saline may be injected through the esophagoscope's aspirating channel and the fluid is withdrawn immediately for histologic study. A tissue biopsy may be taken. After biopsy, the area is assessed for bleeding and the esophagoscope is then removed.

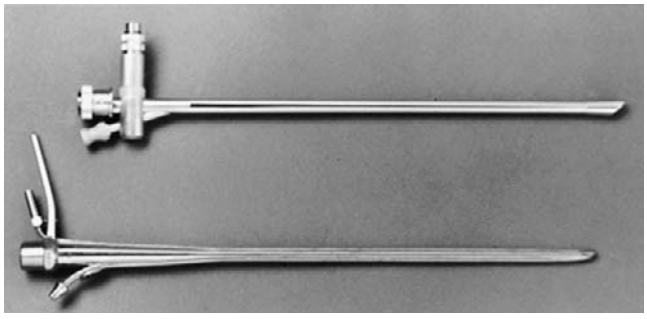


FIGURE 18-47 Pediatric and adult esophagoscopes.

Triple Endoscopy. When laryngoscopy, bronchoscopy, and esophagoscopy are performed in a single session on a patient, the procedure is termed *triple endoscopy* or *panendoscopy.* The order in which the procedures are performed depends on the surgeon's preference. The purpose of triple endoscopy is usually diagnostic. While inspecting for a malignancy, the surgeon views the structures, takes specimens for biopsy, and possibly makes smears or washings of the suspect areas. For any of the aforementioned endoscopy procedures, all equipment or instrumentation should be set up and be in working order (i.e., light carriers in place; light cables connected and working). Instrumentation to be used through the various scopes (i.e., suction tips, telescopes, biopsy forceps) should be checked for appropriate length. Specimens taken during endoscopic procedures should be labeled and removed from the back table as soon as possible. In some instances, it may be helpful to indicate on the label that the specimens are microscopic.

OPEN NECK AND LARYNGEAL PROCEDURES

Tracheostomy

Tracheostomy is the opening of the trachea and the insertion of a cannula through a midline incision in the neck, below the cricoid cartilage. A tracheostomy may be permanent or temporary. It is used as an emergency procedure to treat upper respiratory tract obstruction, which can be caused by bilateral vocal cord paralysis, swelling of the neck or airway caused by trauma, allergic reactions, or neoplasms. It is also used as a prophylactic measure in the presence of chronic lung disease, in extensive neck resections where massive upper airway edema is anticipated, or if radiation-induced edema is expected during the treatment of cancers involving the tongue and neck. Tracheostomy is also considered the "gold standard" in treating sleep apnea in which obstruction may occur. Tracheostomy may be performed to permit easy and frequent pulmonary toileting on patients having a difficult time managing and expectorating their own secretions. Additionally, tracheostomy should be performed on patient's experiencing prolonged intubation to avoid overgrowth of granulation tissue and subsequent subglottic stenosis.

The patient's psychologic status should be carefully evaluated because of the altered body image, which may be either temporary or permanent, depending on the disease entity

involved. Tracheostomy care should be explained carefully and thoroughly so that the patient will understand why self-care should be performed frequently. Reinforcement should be given regarding the ability to communicate with others by means of a pencil and paper or message board. As recovery progresses and secretions diminish, the patient can be shown how to occlude the opening of the tube for brief periods to be able to speak a few words. The patient also must be taught the mastery of tracheostomy self-care (Patient and Family Education). If a tracheostomy tube with a disposable inner cannula is inserted, the nursing staff must ensure that the patient has replacement cannulae in the event occlusion or blockage occurs in the immediate postoperative period

Procedural Considerations. Before tracheostomy tube cuffs are inserted, they should be tested for air leaks by inflating and then deflating the balloon. Cuffed tracheostomy tubes are used on patients at risk for aspiration, patients receiving positive-pressure ventilation, or patients who have undergone skull base surgeries involving open communication of the sinuses into the intracranium, where it is desirable to avoid pneumocephalus. The patient is placed in a supine position, with the shoulders raised by a small rolled sheet to slightly hyperextend the neck and head. Using a skin marker the surgeon marks a midline incision site, halfway between the sternal notch and the cricoid cartilage, between the second and third tracheal rings. The neck is prepped, and sterile drapes are applied. A soft suction catheter should be available on the sterile field for suctioning after the tube is inserted.

Operative Procedure

1. The surgeon injects lidocaine with epinephrine into the subcutaneous tissue across the tracheotomy site previously marked with a surgical marker.
2. A horizontal incision is made with a #10, #15, or #11 blade. Soft tissues and muscle are divided, using blunt hemostats and sharp dissection through the platysma and the overlying strap muscles. The thyroid gland is identified; attention is directed to the isthmus with the intention of transecting this area of the gland. Occasionally, the isthmus can be retracted from the surgical site without transection (Figure 18-48).
3. The plane between the isthmus and the trachea is separated by the surgeon with a blunt hemostat, exposing the thyroid gland so the surgical assistant can carefully transect it with the ESU knife. This exposes the underlying tracheal rings—usually the second and third. In some cases, two curved clamps may be inserted through this incision across the isthmus and then the isthmus is transected.
4. The transected ends of the isthmus are oversewn or suture-ligated with absorbable sutures.
5. Once the trachea is identified, a horizontal incision is made with a #11 blade through the second and third tracheal rings. The incision is extended and the tracheotomy tube is inserted. Two 2-0 silk sutures are then sewn into the trachea for future use during the first tracheostomy change. In two motions, one silk suture is inserted into the trachea, and then retrieved with the needle driver through the horizontal incision. This is then repeated with another silk suture through the bottom half of the horizontal incision. Air knots are tied into each of the sutures and secured with tape onto the chest so they are ready for easy retrieval for retraction during the first tracheostomy change, about 5 to 7 days later. By tradition, one air knot is placed in the upper stay suture and two air knots are placed in the lower stay suture to allow for easy identification and proper retraction at the time of tracheostomy tube change or in the event of tracheostomy tube dislodgement. The air knots are cut and removed once the first tracheostomy change takes place.

An additional tracheostomy tube of the same size and the obturator should be kept with the patient at all times, in the event the tube becomes dislodged or plugged with secretions. This practice expedites changing the tracheostomy tube with minimal potential for complications to the patient.

Laryngofissure

Laryngofissure is an opening of the larynx for exploratory, excisional, or reconstructive procedures that cannot be accomplished endoscopically.

Procedural Considerations. A laryngofissure may be performed when access to the intrinsic larynx is necessary. The thyroid cartilages are split in the midline, and the true vocal cords and false vocal cords are incised at the midline anteriorly. A neck dissection instrument set is required, plus an oscillating power saw.

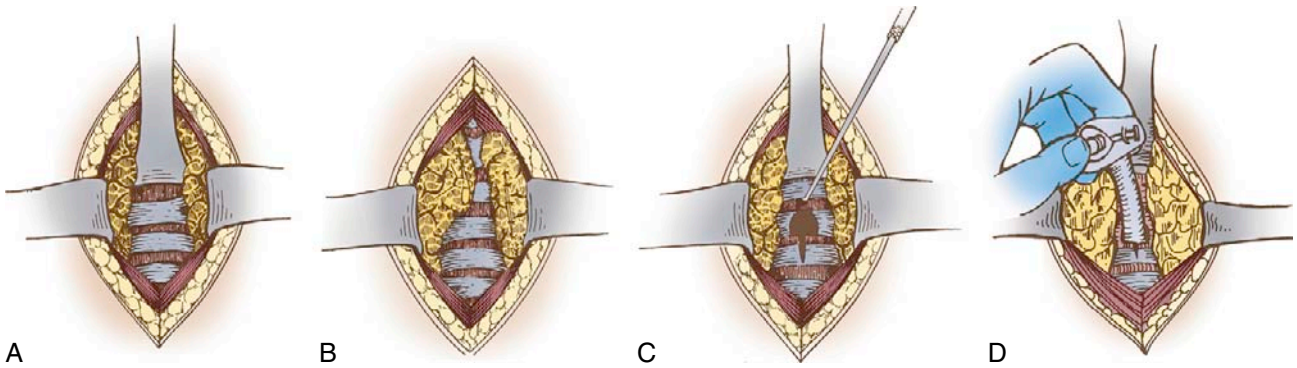


FIGURE 18-48 Operative technique for elective tracheostomy. **A**, Retractor exposing trachea by drawing isthmus of thyroid upward. **B**, Alternative method to that shown in (**A**). Isthmus of thyroid is divided to expose trachea. **C**, Two tracheal rings are cut, and upper ring is partially resected. Tracheal hook pulls trachea from depth of wound nearer surface. **D**, Insertion of tube.

PATIENT AND FAMILY EDUCATION

Patient Education for Tracheostomy Patients

The following information is a sample of a printed teaching tool that can be provided to patients and their caregivers after tracheostomy procedures.

GOAL #1: SAFETY
- Know how to call your nurse for help.
- Use handheld call button.
- Do not get out of bed alone.

GOAL #2: PAIN CONTROL
- If you are having pain, ask for pain medicine.

GOAL #3: COUGH AND BREATHE DEEPLY
- Coughing and deep breathing speed your recovery. If you feel pain when you cough or deep breathe ask your nurse or doctor for pain medicine.
- Coughing clears your lungs and airway.
- Deep breathing helps keep your oxygen levels high and helps prevent pneumonia.

GOAL #4: LEARN
- The nurses will teach you, and your family, how to take care of yourself.
- Learning as much as possible should speed your recovery.
- It is normal to have lots of secretions (mucus) coming out of your tracheotomy (neck) for a few days after surgery. The secretions should decrease shortly thereafter.

WHAT YOU NEED TO KNOW

Airway

You breathe through your mouth or nose. The air goes down your trachea. The trachea (windpipe) is the tube that runs down the inside of the front of your neck. The trachea connects to your lungs. This path is called your airway.

Tracheostomy

A tracheotomy is surgery to put a plastic or metal tube in your trachea. An incision (cut) called a tracheostomy is made in your neck. A tracheotomy tube is placed through the incision into the trachea. This tube allows air to reach your lungs so you can breathe easier and safely.

Secretions

Fluids that come out of your tracheostomy can be a combination of mucus, blood, and saliva (spit). Secretions can be the result of the surgery or infection. You may have large amounts of secretions right after surgery for a few days. They will decrease as you heal and learn how to clear them from your airway.

Stoma

The opening in the trachea where the trach tube is placed.

Trach

Trach is short for tracheotomy tube—the plastic or metal tube that maintains the opening in your neck. When first placed, the cuff may be inflated and you may not be able to talk.

Daily Care Routine (Every Hour While Awake)
- Every hour while awake, take 10 deep breaths.
- Every 3-4 hours, or when you feel congested:
  - Remove and clean your inner cannula.
  - Instill with saline bullets (pink squirts).
  - Change your position (get out of bed with help).
  - Rinse your mouth if allowed by your doctor twice a day, or more if large amounts of secretions.

Stoma Care (Cleaning Around Your Trach)

Once a day, check your neck for signs of infection:
- Redness
- Swelling
- Tenderness
- Drainage

Check to see if your temperature is greater than 101.5° F.
Check your trach ties and change when soiled if allowed by the doctor.

SPECIAL CONSIDERATIONS

Avoid irritants that may hamper your breathing. Things to avoid include smoke-filled rooms, powders (e.g., baby powder) and dust, and all aerosols (spray deodorants, hair sprays, spray perfumes, or after shaves). Avoid anything that creates a cloud, or can be breathed in through your trach tube.

Continued

PATIENT AND FAMILY EDUCATION

Patient Education for Tracheostomy Patients—cont'd

INSTILLING AND COUGHING

Instilling sterile saline solution and coughing is the best way to clear your secretions. Deep breathing and coughing will help keep your lungs and trach tube clear. Coughing can reduce your need for suctioning.

1. Gather supplies: 4 × 4 gauze and lavage bullets (pink squirts).
2. Wash your hands.
3. Twist off lavage bullet cap, and place bullet point in the inner cannula of the trach tube.
4. Take 3-4 deep breaths.
5. While inhaling, squeeze the lavage bullet to squirt the saline solution into your trach tube (this will make you cough).
6. Immediately cover your trach tube with gauze to catch your secretions. Do not use tissues.
7. Throw out gauze promptly and properly wash your hands.

REMOVING AND CLEANING THE INNER CANNULA

1. Gather supplies: 4 × 4 gauze and trach cleaning kit.
2. Wash your hands.
3. With one hand, hold the flat plate on one side of the trach tube with your thumb and forefinger. Then turn the inner cannula to your right. This releases the lock.
4. Slowly pull the inner cannula out. Continue to hold the flat plate; this helps to prevent stimulating a cough.
5. Rinse the inner cannula under cool running tap water and clean the inside with a small narrow brush or pipe cleaner. Wipe or shake off excess water.
6. Hold the flat plate on one side of the trach tube. Replace the inner cannula into the trach tube. Align the notch with the opening; when the cannula is completely inserted, turn the tube counterclockwise until you feel the lock snap. The inner cannula is locked when the two blue dots are in line.

STOMA CARE (CLEANING)

1. Gather supplies: 4 × 4 gauze, Q-tips, cleaning solutions, and cleaning kit.
2. Wash your hands.
3. Breathe deep cough/self-instillation (if needed).
4. Apply cleaning solution #l (½ hydrogen peroxide, ½ pure saline solution) with Q-tips to areas around trach.
   a. Allow solution to bubble in order to loosen crusting and secretions.
   b. Be sure to clean under trach back plate.
   c. Use a new Q-tip after it touches your skin or trach (prevents contamination of solution).
5. Apply rinse solution #2 (all pure saline solution) with Q-tips to same areas.
   a. Rinse all areas that have been cleaned with solution #1.
   b. Use a new Q-tip after it touches your skin or trach (prevents contamination of solution).
   c. Rolling the Q-tip between your fingers helps to remove loosened crust.

CLEARING YOUR AIRWAY

1. Breathe deeply.
2. Cough to bring up secretions.
3. Remove, clean, and replace inner cannula.
4. Instill yourself (with a pink squirt).
5. Suction yourself.

CALL THE DOCTOR/NURSE

Call your doctor/nurse if you begin to have any difficulty breathing or if you have any of the following:

1. Increased redness, local pain, and discomfort around your stoma
2. Increase in body temperature (fever) to 101° F or more for 2 days
3. Change in color, odor, amount, or thickness of secretions
4. Persistent cough or change in normal coughing pattern
5. Congestion, wheezing, or chest discomfort or pain
6. Coughing up food or liquids

From Merek J: Tracheostomy and airway patients, Thomas Jefferson University Hospital.

Operative Procedure

1. A tracheotomy is performed, and an endotracheal tube is inserted. A general anesthetic is administered.
2. A transverse incision is made through the skin and first layer of the cervical fascia and platysma muscles, approximately 2 cm above the sternoclavicular junction or in the normal skin crease. The upper skin flap is undermined to the level of the cricoid cartilage, and the lower flap is undermined to the sternoclavicular joint.
3. Bleeding vessels are clamped with mosquito hemostats and ligated. The strap muscles are elevated and incised in the midline.
4. The thyroid cartilages are cut with an oscillating saw, and the true vocal cords are visualized through an incision into

the cricothyroid membrane. The true vocal cords are divided in the midline (anterior commissure), and the interior of the larynx is exposed.

5. The tracheostomy tube must be left in place after surgery to ensure an airway.

Phonosurgery

Phonosurgery refers to various operations on the laryngeal framework to improve phonation for patients with communication disorder. Type I thyroplasty is used to change or improve the voice. Thyroplasty types II and III are used to alter vocal cord tension and voice pitch.

Thyroplasty. Type I thyroplasty is a form of phonosurgery for the treatment of unilateral vocal cord paralysis, which may be caused by trauma, neoplasms, paralysis from thyroidectomy, paralysis after extensive aortic and mediastinal vascular surgery, and mechanical and central nervous system dysfunctions. A window is created surgically in the thyroid cartilage, into which a silicone implant is placed. The implant pushes the paralyzed cord medially, which allows the moving cord to touch the paralyzed cord and close the opening.

PROCEDURAL CONSIDERATIONS. As the preoperative assessment is being done, the perioperative nurse explains to the patient that his or her voice will need to be rested postoperatively in an effort to minimize edema and stress of the vocal cords. An alternative method of communicating can be determined, such as writing.

The procedure is done using monitored local anesthesia to allow the patient to speak during surgery. This allows the surgeon to evaluate the quality of the patient's voice in an effort to attain the best result.

OPERATIVE PROCEDURE

1. The patient is positioned on the OR bed in a semisitting position. A laryngoscopy is done by means of a flexible fiberoptic laryngoscope.
2. As the patient is asked to speak, the surgeon determines the extent of approximation of the vocal cords as well as the patient's breath control. After a thorough evaluation, the patient is then prepped and draped.
3. A local anesthetic is injected into the surgical site. A horizontal incision is made at the middle level of the thyroid ala. Gelpi retractors are used to maintain exposure as dissection to the thyroid cartilage is completed. Measurements for the placement of the window are taken and marked with a marking pencil. A #15 blade is used to create a window in the thyroid cartilage. In some cases, a power drill with a cutting burr may be used. A periosteal elevator may be used to displace the vocal cords during phonation in an effort to determine voice quality.
4. When voice quality is satisfactory, the implant is placed into the window. Final laryngoscopy is done to view approximation of the vocal cords with the implant in place. The incision is then closed, and a dressing is applied.

Partial Laryngectomy

Partial laryngectomy is removal of a portion of the larynx. It is done to remove superficial neoplasms that are confined to one vocal cord or to remove a tumor extending up into the ventricle or the anterior commissure or a short distance below the cord. A cancer confined to the intrinsic larynx is generally a low-grade malignancy and tends to remain localized for long periods. The patient should be prepared for an altered voice quality postoperatively as well as for the possibility of total laryngectomy if the tumor proves too extensive for partial resection (Table 18-2). Types of partial laryngectomies include a vertical hemilaryngectomy, supraglottic laryngectomy, and supracricoid laryngectomy. With the advancements of cancer treatment (including the surgical excision of the tumor along with postoperative administration of chemotherapy concurrently with external beam radiation therapy), cure rates have increased while preserving some function of the larynx. The goal of partial laryngectomy is to avoid removing the entire larynx and to preserve the patient's natural swallowing ability. A successful partial laryngectomy should leave the patient with the ability to phonate, though usually with a more hoarse voice quality. The otolaryngologist must carefully stage the laryngeal cancer via a panendosopy with biopsy and determine the overall candidacy of the patient who may receive a partial laryngectomy. If tumor extension does not warrant a partial laryngectomy, a total laryngectomy must be performed. Steps and procedural considerations for a total laryngectomy are described next.

Total Laryngectomy

Total laryngectomy is the complete removal of the cartilaginous larynx, the hyoid bone, and the strap muscles connected to the larynx and possible removal of the preepiglottic space with the lesion. A wide-field laryngectomy is done when there is a loss of mobility of the cords and to treat cancer of the extrinsic larynx and hypopharynx (Figure 18-49). Malignant tumors of the extrinsic larynx are more anaplastic and tend to metastasize. When laryngeal carcinoma involves more than the true cords, a prophylactic (preventive) modified, or selective, neck dissection is done to remove the lymphatics. Depending on the extent and severity of disease in the neck, a radical neck dissection may be warranted though rarely routinely performed.

Laryngectomy presents many psychologic problems. The loss of voice that follows total laryngectomy is traumatic for the patient and family. The patient may be taught to talk by using either an esophageal voice or an artificial larynx. The esophageal voice is produced by the air contained in the esophagus rather than by that in the trachea. Speech requires a sounding air column. With instruction and practice, the patient is able to control the swallowing of air into the esophagus and the reintroduction of this air into the mouth with phonation. The sounding air column is then transformed into speech by means of the lips, tongue, and teeth. A tracheoesophageal fistula facilitates insertion of a Blom-Singer duckbill prosthesis for the purpose of speech (Figure 18-50, *A*). This fistula may be created during the initial surgical procedure (primary tracheoesophageal puncture [TEP]) or at a later date when healing has occurred (Figure 18-50, *B*).

Because the stump of the trachea is exteriorized to the skin of the neck to form a permanent stoma, all the patient's breathing is done directly into the trachea and no longer through the nose and mouth. The nose no longer moistens this air. Drying and crusting of the tracheal secretions occur. Humidification may be provided with a humidified tracheostomy collar or a humidified moisture exchange system later during the healing process. The patient will be anxious to know about postoperative voice quality, which depends on the specific procedure performed.

TABLE 18-2

Surgical Procedures for Laryngeal Carcinomas and Predictions of Vocal Quality after Surgery

Structures Removed	Structures Remaining	Postoperative Condition
TOTAL LARYNGECTOMY		
Hyoid bone	Tongue	Loses voice
Entire larynx (epiglottis, false cords, true cords)	Pharyngeal walls	Breathes through tracheostoma
Cricoid cartilage	Lower trachea	No problem swallowing
Two or three rings of trachea		
SUPRAGLOTTIC OR HORIZONTAL LARYNGECTOMY		
Hyoid bone	True vocal cords	Normal voice
Epiglottis	Cricoid cartilage	May aspirate occasionally, especially liquids
False vocal cords	Trachea	Normal airway
VERTICAL LARYNGECTOMY (OR HEMILARYNGECTOMY)		
One true vocal cord	Epiglottis	Hoarse but serviceable voice
One false cord	One false cord	Normal airway
Arytenoid	One true vocal cord	No problem swallowing
Half thyroid cartilage	Cricoid	
PARTIAL LARYNGECTOMY		
One vocal cord	All other structures	Hoarse but serviceable voice; occasionally almost normal voice No airway problem No swallowing problem
TRANSORAL CORDECTOMY		
Portion or all of one vocal cord	All other structures	May have normal/hoarse voice No other problems
LASER SURGERY		
Tumor only removed	All other structures	Normal/hoarse voice

From Workman ML: Interventions for clients with noninfectious problems of the upper respiratory tract. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, Philadelphia, 2010, Saunders.

Procedural Considerations. The patient is placed on the OR bed in a supine position with the neck extended and shoulders elevated by a shoulder roll or folded sheet. A general anesthetic is administered. Airway considerations are paramount when approaching a patient with laryngeal cancer. An awake tracheostomy may be performed initially to control the airway, and occasionally patients have previously placed tracheostomy tubes. If the tracheostomy is performed initially or is pre-existing, the use of a cuffed, wire-reinforced, flexible endotracheal tube will ensure effective delivery of the anesthetic and give the surgical team flexibility as the larynx and trachea are manipulated during the surgical procedure. An effective suction apparatus is essential. The proposed operative site, including the anterior neck region, the lateral surfaces of the neck down to the outer aspects of the shoulders, and the upper anterior chest region, is prepped and draped in the usual manner. The instrument setup is a neck dissection set.

Operative Procedure

1. The surgeon makes a midline incision from the suprasternal notch to just above the hyoid bone. Skin flaps are undermined on each side. The sternothyroid, sternohyoid, and omohyoid muscles (strap muscles) on each side are divided by means of curved hemostats and a knife.
2. The suprahyoid muscles are severed from the portion of the hyoid to be divided. The hyoid bone is skeletonized with care to preserve the hypoglossal nerves. Bleeding vessels are clamped and ligated.
3. The superior laryngeal nerve and vessels are exposed and ligated on each side with long, curved fine hemostats and fine ligatures.
4. The isthmus of the thyroid gland is divided between hemostats. Each portion of the thyroid gland is dissected from the trachea with Metzenbaum scissors and fine tissue forceps. The superior pole of the thyroid is retracted. The superior thyroid vessels are freed from the larynx by sharp dissection. Sometimes, one or both lobes of the thyroid gland are included in the resection for oncologic purposes.
5. The larynx is rotated. The inferior pharyngeal constrictor muscle is severed from its attachment to the thyroid cartilage on each side.
6. The endotracheal tube is removed. The trachea is transected with care to keep an adequate margin from the tumor. The upper resected portion of the trachea and the cricoid cartilage are held upward with Lahey forceps. A balloon-cuffed, wire-reinforced endotracheal tube is inserted into the distal portion of the trachea.
7. The larynx is freed from the cervical esophagus and attachments by sharp and blunt dissection. A moist pack is placed around the endotracheal tube to help prevent leakage of blood into the trachea.
8. The pharynx is entered. In most cancers of the intrinsic larynx, the pharynx is entered above the epiglottis. The mucous membrane incision is extended along either side of the epiglottis; the remaining portion of the pharynx and cervical esophagus is dissected well away from the tumor

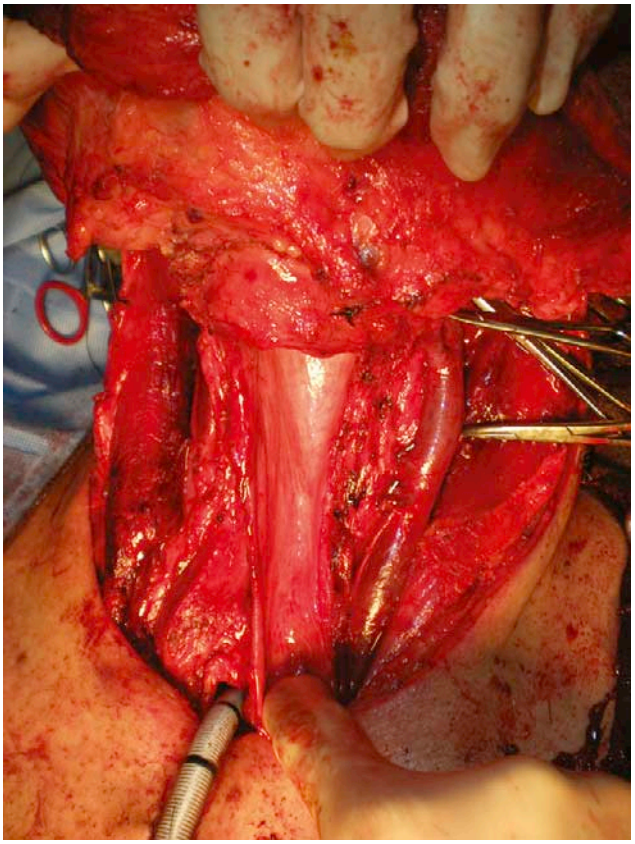


FIGURE 18-49 Wide-field defect following removal of the larynx.

by means of fine-toothed tissue forceps, Metzenbaum scissors, knife, and fine hemostats. The specimen is removed en bloc (Figure 18-51).

9. A nasal feeding tube is inserted through one naris into the esophagus; closure of the hypopharyngeal and esophageal defect is begun with continuous inverting fine 3-0 absorbable sutures. The nasal tube is guided down past the pharyngeal suture line.
10. The pharyngeal suture line is reinforced with running horizontal or vertical mattress Vicryl sutures; the suprahyoid muscles are approximated to the cut edges of the inferior constrictor muscles.
11. The diameter of the tracheal stoma is increased by means of a knife and heavy scissors. The two portions of the thyroid behind the tracheal opening are approximated with interrupted nonabsorbable sutures, thereby obliterating dead space posterior to the upper portion of the trachea.
12. Using a scalpel, the surgeon makes a small puncture wound through the neck, lateral to the incision, using the tips of a hemostat inserted on the inner wound bed as a guide.
13. The hemostat is then switched into the puncture wound, grasping the distal drain tubing and pulling it through until the fluted portion of the drain is visible in the wound bed. The drain is trimmed and measured to fit into the wound.
14. The drain is secured to the skin just lateral to where the puncture wound was made and an air knot is tied using square knots.
15. The edges of the deep cervical fascia and the platysma are closed separately.

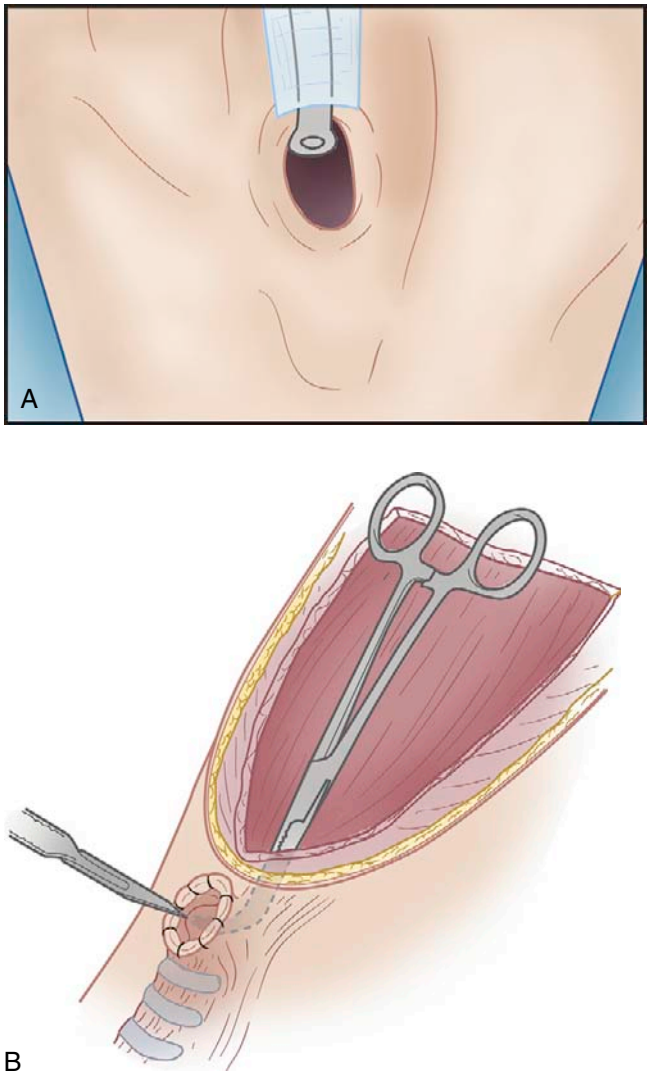


FIGURE 18-50 Artificial larynx to facilitate speaking. **A**, Speech valve in place. **B**, Primary tracheoesophageal puncture technique. Note preliminary repair of stoma to allow accurate positioning of puncture site before pharyngeal closure. Feeding tube (14F) is inserted through puncture down esophagus to the stomach.

16. A laryngectomy tube of desired size is inserted into the tracheal stoma; a pressure dressing may be applied to the wound and neck, although some surgeons prefer leaving the wound without dressings to observe the skin flaps.

Radical Neck Dissection

In a radical neck dissection, the tumor, all soft tissue from the inferior aspect of the mandible to the midline of the neck to the clavicle end posterior to the trapezius muscle, and lymph nodes are removed en bloc from the affected side of the neck. This procedure is done to remove the tumor and metastatic cervical nodes present in malignant lesions as well as all nonvital structures of the neck (Figure 18-52). Metastasis occurs through the lymphatic channels by way of the bloodstream. Diseases of the oral cavity, lips, and thyroid gland may spread slowly to the neck. Radical neck surgery is done in the presence of cervical node metastasis from a cancer of the head and neck that has a reasonable chance of being controlled. Sentinel node

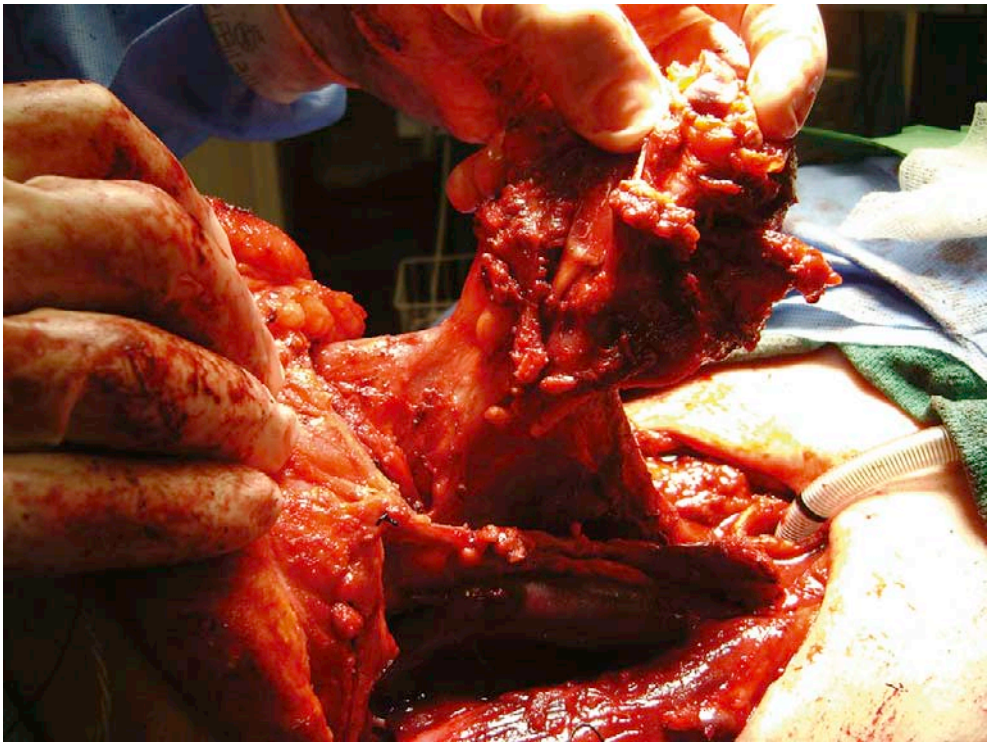


FIGURE 18-51 Removal of the larynx en bloc.

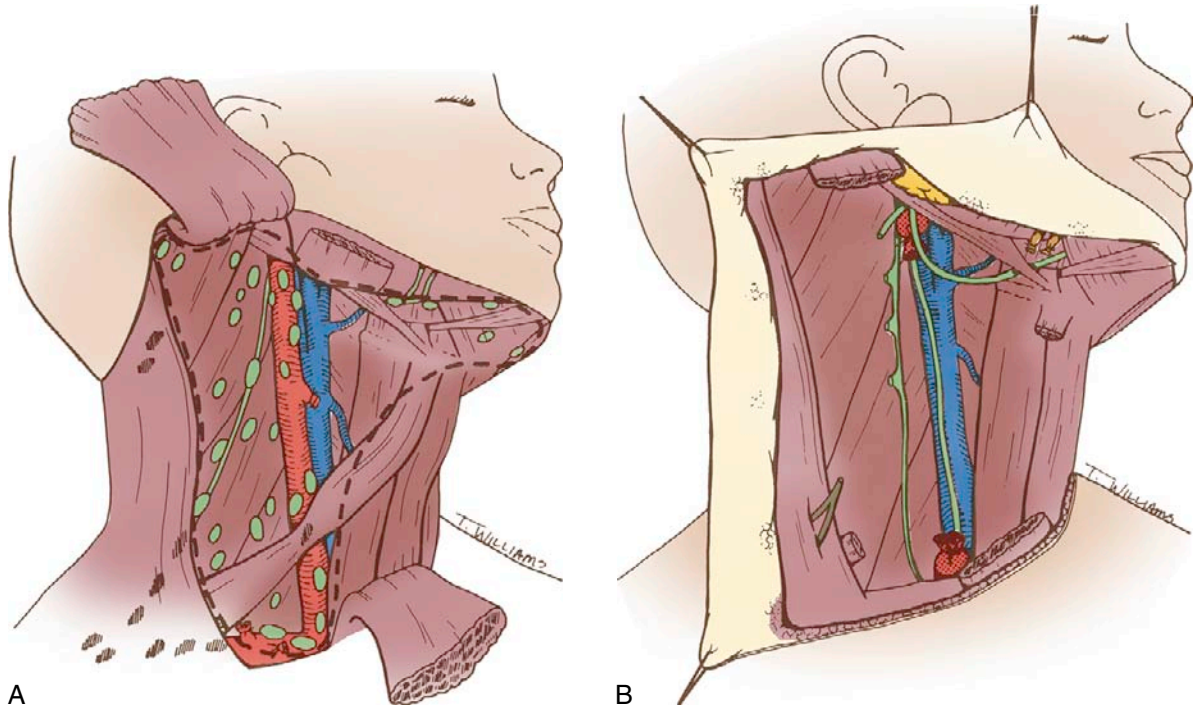


FIGURE 18-52 Radical neck dissection. **A**, Diagram of extent of operation. **B**, Diagram of operation.

biopsy may also be performed in conjunction with a neck dissection (Box 18-2).

A prophylactic neck dissection implies an elective neck dissection when there is no clinical evidence of metastatic cancer in the cervical lymph nodes.

Procedural Considerations. The patient is placed on the OR bed in a supine position. General endotracheal anesthesia is induced before the patient is positioned for surgery. A shoulder roll may be placed to slightly hyperextend the neck with the head slightly turned to the contralateral side. The

BOX 18-2

Sentinel Lymph Node Mapping and Biopsy

In many oral cancers, the nearby lymph nodes are routinely removed during surgery (known as a lymph node dissection). The sentinel node procedure can help the surgeon determine whether the cancer has already spread to these nodes, which may allow the patient to avoid more extensive surgery if the cancer has not metastasized. Sentinel node mapping and biopsy allow the surgeon to identify and examine the "sentinel node(s)"—the first node(s) affected by the cancer before metastasis to other lymph nodes. If the sentinel node does not contain cancer, it is very unlikely that any other nodes would contain cancer.

In this procedure, the surgeon injects a radioactive material around the tumor, usually the day before surgery. The material will travel the same route that any cancer cells would likely have taken if they had spread to the lymph nodes. On the day of surgery a blue dye is injected into the tumor site, which will also travel to the nearby lymph nodes.

During surgery, the surgeon can use a radiation detector to identify the lymph node region that is the source of radioactivity (and presumably cancer). The surgeon then cuts into the area to look for radioactive or blue-stained lymph nodes. These are removed and examined by a pathologist. If there is no cancer, then no further surgery is needed. If there is cancer, then all the lymph nodes in the area will be removed.

This procedure is still experimental, and more work is needed to determine if this can replace routine lymph node removal.

Modified from *What's new in oral cavity and oropharyngeal cancer research and treatment?*, available at www.cancer.org/docroot/CRI/content/CRI_2_4_6X_Whats_new_in_oral_cavity_and_oropharyngeal_cancer_research_and_treatment_60.asp. Accessed August 9, 2009.

head of the bed may be slightly elevated to reduce venous bleeding.

During the operation the anesthesia provider works behind a sterile barrier at the patient's unaffected side. The preoperative skin prep is extensive, including the neck, lower face, and upper chest. The patient's neck is draped so as to leave a wide operative field. On occasions, local muscle flaps are harvested to cover and protect the carotid artery (as when a patient has received extensive previous radiation therapy). If this is the case, the thigh area is also prepped and draped with sterile towels in readiness for obtaining a dermal graft before closure of the neck wound. It is usually more convenient to use the thigh on the same side as the neck dissection. Patient and family education includes tracheostomy care (if applicable), pain management, care of the surgical incision, reportable signs and symptoms, healthful behaviors, and review of physical therapy exercises.

Operative Procedure

1. One of several types of incisions may be used, including the Y-shaped, H-shaped, or trifurcate incision (Figure 18-53), all of which aim for complete lymphadenectomy while preserving good, viable skin flaps.
2. The upper curved incision is made through the skin and platysma with a knife, tissue forceps, and fine hemostats; ligatures are used for bleeding vessels. The upper flap is retracted; then the vertical portion of the incision is made, and the skin flaps are retracted anteriorly and posteriorly with retractors. The anterior margin of the trapezius muscle is exposed by means of curved scissors. The flaps are retracted to expose the entire lateral aspect of the neck. Branches of the jugular veins are clamped, ligated, and divided.
3. The sternal and clavicular attachments of the sternocleidomastoid muscle are clamped with curved Péan forceps and then divided with a knife. The superficial layer of deep fascia is incised. The omohyoid muscle is severed between clamps just above its scapular attachment.
4. By sharp and blunt dissection, the carotid sheath is opened. The internal jugular vein is isolated by blunt dissection and then doubly clamped, doubly ligated with medium silk, and divided with Metzenbaum scissors. A transfixion suture is placed on the lower end of the vein.
5. The common carotid artery and vagus nerve are identified and protected. The fatty areolar tissue and fascia are dissected and removed using Metzenbaum scissors and fine tissue forceps. Branches of the thyrocervical artery are clamped, divided, and ligated.
6. The tissues and fascia of the posterior triangle are dissected, beginning at the anterior margin of the trapezius muscle and continuing near the brachial plexus and the levator scapulae and scalene muscles. During the dissection, branches of the cervical and suprascapular arteries are clamped, ligated, and divided.
7. The anterior portion of the block dissection is completed. The omohyoid muscle is severed at its attachment to the hyoid bone. Bleeding is controlled. All hemostats are removed, and the operative site may be covered with warm, moist laparotomy packs.
8. The sternocleidomastoid muscle is severed and retracted. The submental space is dissected free of fatty areolar tissue and lymph nodes, from above downward.
9. The deep fascia on the lower edge of the mandible is incised; the facial vessels are divided and ligated.
10. The submandibular triangle is entered. The submandibular duct is divided and ligated. The submandibular glands with surrounding fatty areolar tissue and lymph nodes are dissected toward the digastric muscle. The facial branch of the external carotid artery is divided. Portions of the digastrics and stylohyoid muscles are severed from their attachments to the hyoid bone and on the mastoid. The upper end of the internal jugular vein is elevated and divided. The surgical specimen is removed.
11. The entire field is examined for bleeding and then irrigated with warm saline solution. Although rarely necessary, a skin graft may be placed to cover the bifurcation of the carotid artery, extending down approximately 4 inches, and sutured with 4-0 absorbable suture on a very small cutting needle.
12. Closed wound suction drains are placed into the wound.
13. The flaps are carefully approximated with interrupted fine nonabsorbable sutures or with skin staples. A bulky pressure dressing may be applied to the neck, depending on surgeon preference.

Modified Neck Dissection

Modified neck dissection (Figure 18-54) is removal of neck contents, except for the sternocleidomastoid muscle, internal jugular vein, and eleventh cranial nerve.

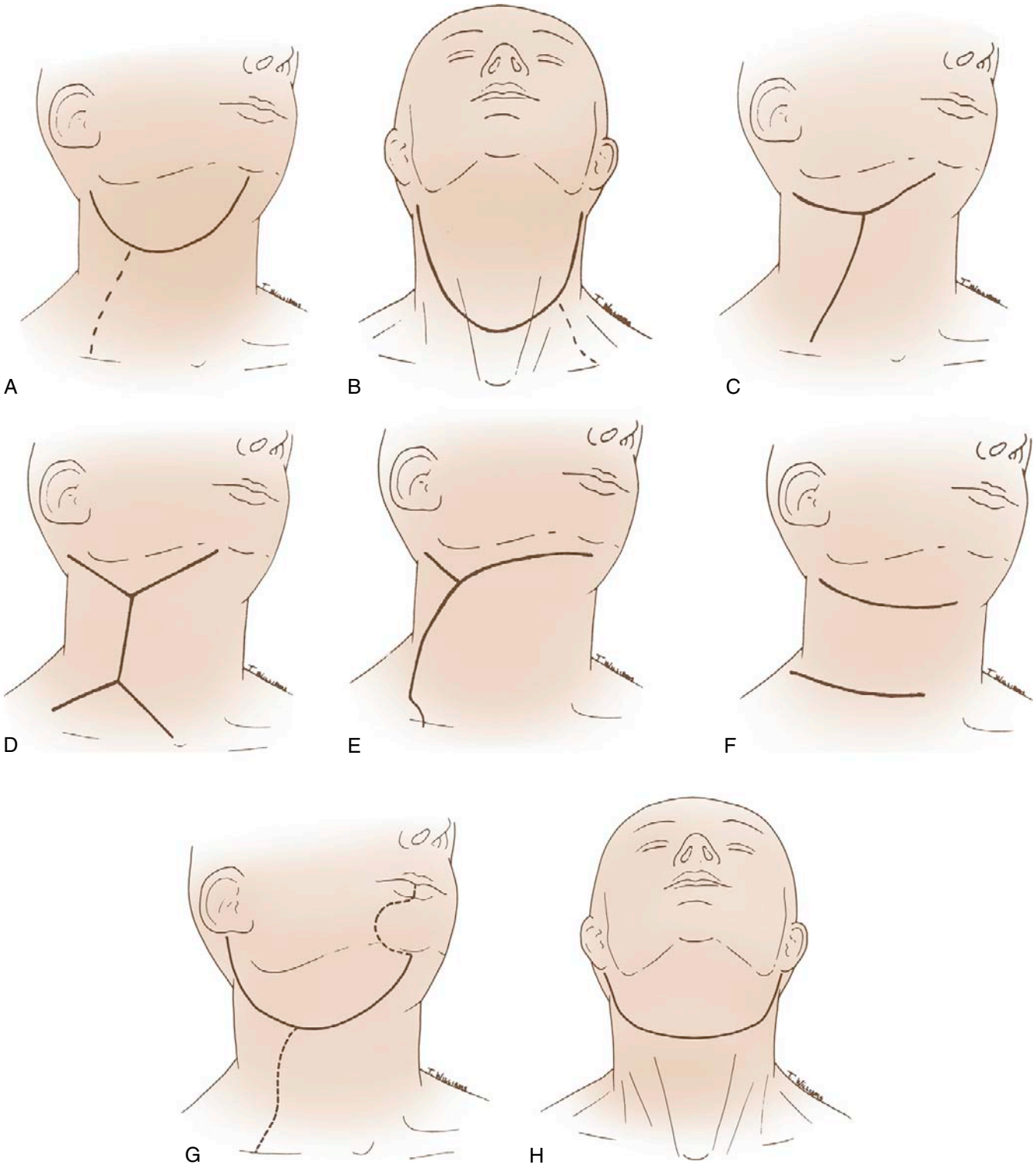


FIGURE 18-53 Dissection incisions. **A**, Latyshevsky and Freund. **B**, Freund. **C**, Crile. **D**, Martin. **E**, Babcock and Conley. **F**, McFee. **G**, Incision used for unilateral supraomohyoid neck dissection. **H**, Incision used for bilateral supraomohyoid neck dissection.

Procedural Considerations. This modified type of neck dissection facilitates removal of a tumor and lymph nodes suspected of metastases and allows the patient a minimal defect and minimally impaired shoulder function. With radical and modified neck dissection, the surgeon and medical and radiation oncologists may decide on a course of postoperative radiation therapy or chemotherapy. The decision depends on the type and location of tumor, stage of disease, and condition of the patient. Research on chemotherapy protocols to avoid extensive surgical dissection is ongoing.

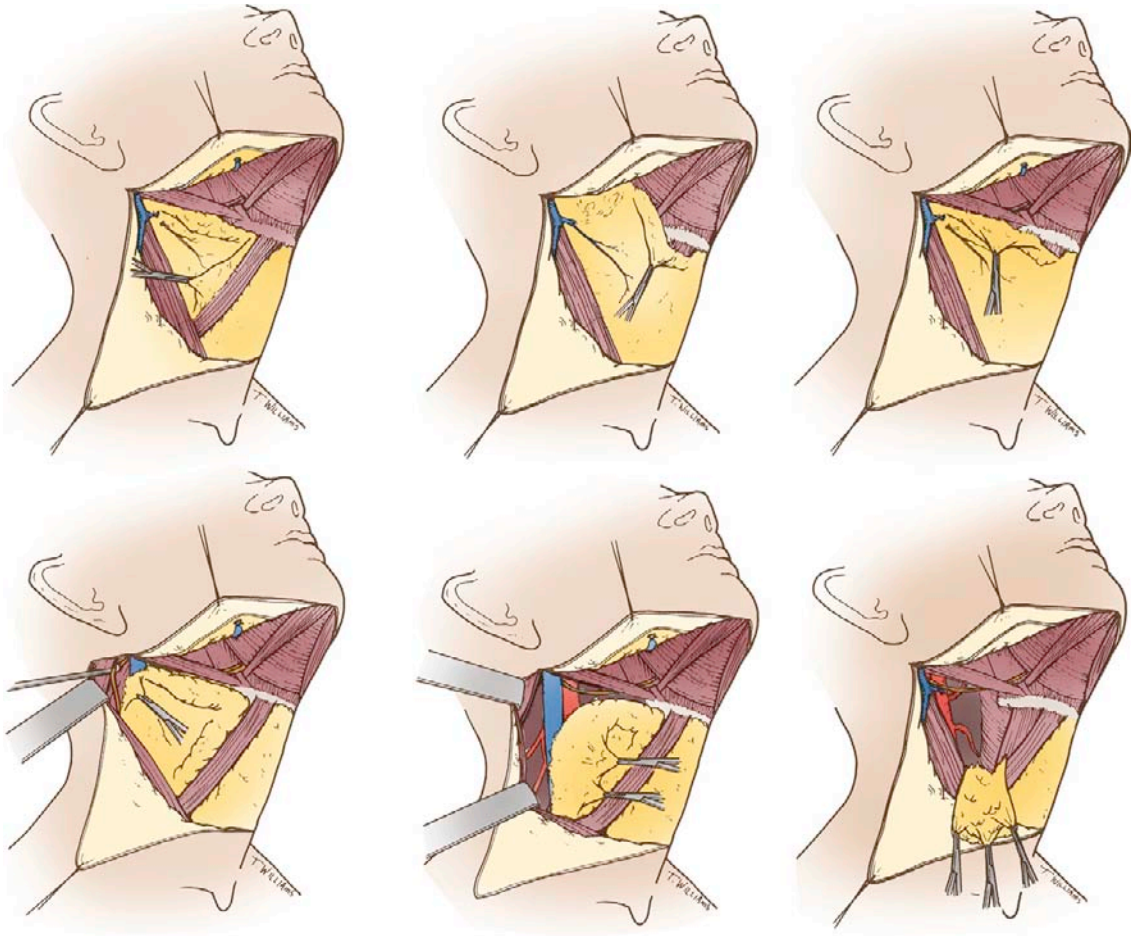


FIGURE 18-54 Steps of modified radical neck dissection with preservation of spinal accessory nerve, internal jugular vein, and sternocleidomastoid muscle.

Reconstructive Procedures

Depending on the surgical defect, head and neck surgical procedures to remove malignant tumors also involve reconstructive procedures. The wound may be closed primarily, or local flaps and split-thickness skin grafts (as for facial and intraoral defects) or full-thickness skin grafts (as for nasal and facial defects) may be used. Regional flaps (e.g., pectoralis major musculocutaneous flap), microvascular tissue transfer (e.g., radial forearm, lattisimus dorsi, anterior lateral thigh free flap), or microvascular osteocutaneous flaps (e.g., fibula free flap) may be used to restore function as well as cover defects. Combinations of these grafts and flaps are often necessary when large defects are created. Skin grafts and flaps are discussed in Chapter 24.

If microvascular flaps are used, surgical and anesthesia time is extended significantly (approximately 8 to 12 hours); since veins and arteries are microscopically connected, nerve grafts may be used, and bone must be connected with the use of plates and screws.

The use of a Doppler unit (intraoperatively and postoperatively) and thorough nursing assessment skills are paramount in detecting occlusions or spasms of the vessels and subsequent survival of the transplanted flap.

REFERENCES

American Cancer Society (ACS): *Cancer facts and figures 2009*, Atlanta, 2009, The Society.

Association of periOperative Registered Nurses: Recommended practices for documentation of perioperative nursing care, *Perioperative standards and recommended practices*, Denver, 2009a, The Association.

Association of periOperative Registered Nurses: Recommended practices for the care and handling of specimens in the perioperative environment, *Perioperative standards and recommended practices*, Denver, 2009b, The Association.

Association of periOperative Registered Nurses: Recommended practices for laser safety in practice settings, *Perioperative standards and recommended practices*, Denver, 2009c, The Association.

Canobbio MM: *Mosby's handbook of patient teaching*, ed 3, St Louis, 2006, Mosby.

Chole RA, Suddath HH: Chronic otitis media, mastoiditis and petrositis. In Cummings CW et al, editors: *Otolaryngology: head and neck surgery*, ed 4, Philadelphia, 2005, Mosby.

Denholm B: Tucking patient's arms and general positioning, *AORN J* 89(4):755–757, 2009.

Elluru RG, Kumar M: Physiology of the salivary glands. In Cummings CW et al, editors: *Otolaryngology: head and neck surgery*, ed 4, St Louis, 2005, Mosby.

Furman JM: Episodic vertigo. In Rakel RE, Bope ET, editors: *Conn's current therapy 2008*, ed 60, Philadelphia, 2008, Saunders.

Gantz BJ, Meyer TA: Auditory brainstem implants, In Cummings CW et al, editors: *Otolaryngology: head and neck surgery*, ed 4, Philadelphia, 2005, Mosby.

House JW, Cunningham CD: Otosclerosis. In Cummings CW et al, editors: *Otolaryngology: head and neck surgery*, ed 4, Philadelphia, 2005, Mosby.

Mahlan ME et al: Neurologic monitoring. In Miller RD, editor: *Miller's anesthesia*, ed 6, Philadelphia, 2005, Churchill Livingstone.

National Institute on Deafness and Other Communication Disorders (NIDCD): *Quick statistics*, available at www.nidcd.nih.gov/health/statistics/quick.htm. Accessed August 2, 2009.

Pagana KD, Pagana TJ: *Mosby's diagnostic and laboratory test reference*, ed 9, St Louis, 2009, Mosby.

Palmer CV, Ortmann A: Hearing loss and hearing aids, *Neurol Clin* 23: 901–918, 2005.

Santina CC, Lustig LR: Surgically implantable hearing aids. In Cummings CW et al, editors: *Otolaryngology: head and neck surgery*, ed 4, Philadelphia, 2005, Mosby.

Schessel DA et al: Meniere's disease and other peripheral disorders, In Cummings CW et al, editors: *Otolaryngology: head and neck surgery*, ed 4, Philadelphia, 2005, Mosby.

Thrasher RD: Middle ear, otitis media with effusion, August 2009, available at: http://emedicine.medscape.com/article/858990-overview. Accessed August 5, 2009.

Wackym PA et al: Patient evaluation and device selection in cochlear implantation. In Cummings CW et al, editors: *Otolaryngology: head and neck surgery*, ed 4, Philadelphia, 2005, Mosby.

CHAPTER 19

Orthopedic Surgery

BARBARA BOWEN

The word *orthopédie* is derived from the Greek *orthos,* meaning "straight," and *paideia,* meaning "rearing of children." It was first used by Nicholas Andry in 1741 in the title for a book addressing the prevention and correction of skeletal deformities in children. Orthopedic surgery has been defined by the American Association of Orthopaedic Surgeons' Board of Orthopaedic Surgery as "a broad based medical and surgical specialty dedicated to the prevention, diagnosis, and treatment of diseases and injuries of the musculoskeletal system" (American Board of Orthopaedic Surgeons [ABOS], 2009).

Orthopedic surgery is an ever-changing field that is a challenge for the perioperative nurse. Technologic advances in the multitude of systems and hardware used have resulted in improved treatment of orthopedic disorders. In addition to understanding anatomic and physiologic responses, the perioperative nurse should have a general understanding of the concepts and purposes of these systems to provide the most safe and efficient care. Knowledge of the principles of bone fixation and healing and the relationship of bone and soft tissues will provide a strong basis to ensure continued understanding of the care required for the orthopedic patient.

Surgical Anatomy

Anatomic Structures

The 206 bones of the body form the appendicular or axial framework that supports soft tissues, provides storage areas and reservoirs for minerals, and serves as a site for formation of blood cells (Figure 19-1). The skeletal system is composed of varied elements, including bone, muscle, and associated structures.

Bone remains in a constant state of formation and resorption, preventing development of excessive thickness or thinness. These processes are related to individual metabolism and absorption of calcium, vitamin D, and phosphorus. Levels of minerals affect disease processes, causing bone changes. A layer of connective tissue called *periosteum* covers all bone.

Muscles are masses of tissue that cover bones and provide movement to the skeletal system. Muscles interact with nerves, minerals, skin, and other connective tissue to contract and extend. Individual muscles are short or long and vary in diameter, depending on their position on a specific bone.

Ligaments, tendons, and cartilage also form the skeletal structures. Ligaments are bands of dense connective tissue that hold bone to bone. They provide stability to a joint by encircling or holding ends of bone in place. Tendons are tough, long strands of fibers that form the ends of muscles. They transmit forces to bone or cartilage without being damaged. Cartilage is a layer of elastic, resilient supporting tissue found at the ends of the bones. It forms a cap over the bone end to protect and support the bone during weight-bearing activities and provides a smooth gliding surface for joint movement. Cartilage is aneural (without nerves), alymphatic (without lymph tissue), avascular (without blood vessels), and high in water content. The lack of vascularity and loss of water from cartilage during a lifetime are causes of resulting degenerative disease, such as arthritis. Weight bearing and joint movements keep cartilage from becoming thin or damaged and help prevent degenerative conditions.

Joints are articulations where bones are joined to one another or where two surfaces of bones unite. Joints are classified by the type of material between them or according to movement. Material between joints is fibrous, cartilaginous, or synovial. The type of movement is synarthrotic (immovable), amphiarthrotic (slightly movable), or diarthrotic (freely movable). Synarthrotic joints are connected by fibrous tissue or ligaments (e.g., the suture type of joints holding the bones of the skull; connections between two bones, such as the radius and ulna). Amphiarthrotic joints are connected by cartilage. Joints of this type include the symphysis pubis, intervertebral joints, and manubriosternal joint. The majority of joints are diarthrotic; these are the only joints with one or more ranges of motion. These joints are lined with a synovial membrane and are called *synovial joints.* Examples include the knee, cervical vertebrae 1 and 2 (C1 and C2), the radius articulating on the wrist bones, the hip, and the shoulder.

The two types of bone tissue are *cortical* and *cancellous.* Cortical bone is the hard bone forming the outer shell—the main supporting tissue. Cancellous bone is soft and spongy—located at the iliac crest, tibia, sternum, and ends of long bones. It contains the red bone marrow for hematopoiesis.

Bones are divided according to their shape: long, short, flat, irregular, and round (Figure 19-2). Long bones are present in the limbs and consist of a shaft and two ends; the ends generally flare out, are covered with articular cartilage, and provide a surface for articulation and musculotendinous attachment. Short bones, such as the carpals and tarsals (in the wrist and midfoot areas, respectively), are present where the structure is strong but limited movement is required. Flat bones are the scapula, the sternum, and the pelvic girdle. Irregular bones are found in the skull and vertebral column. Round bones, or sesamoid bones (resembling a sesame seed), are found within tendons. The patella is a large sesamoid bone; however, most are small, such as the two found on the head of the first metatarsal, which form the "ball" of the foot.

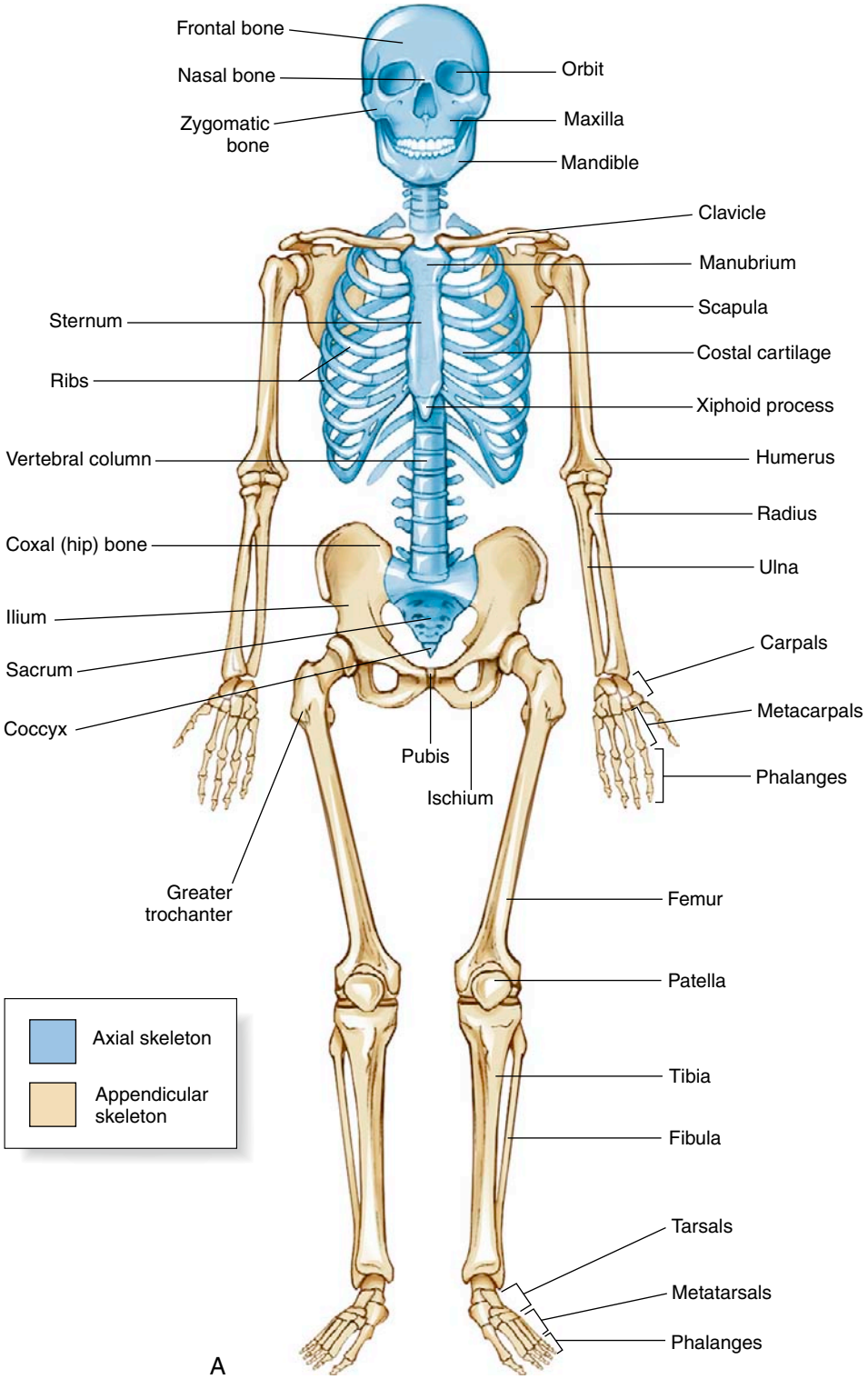


FIGURE 19-1 A, Anterior view of the skeleton.

Long bones consist of a shaft (diaphysis) and two ends (epiphyses). The shaft is composed of compact bone. The epiphyses flare out and consist of cancellous bone. They are covered by cartilage, which provides a cushion and offers protection during weight bearing and movement. Until skeletal maturity, a line of cartilage called the *epiphyseal plate* separates the epiphysis from the diaphysis. Fractures in this region by children can be devastating because they often lead to malformation and permanent limb shortening.

Trabeculae are located within cancellous bone and consist of an interconnecting network of bone oriented along the lines

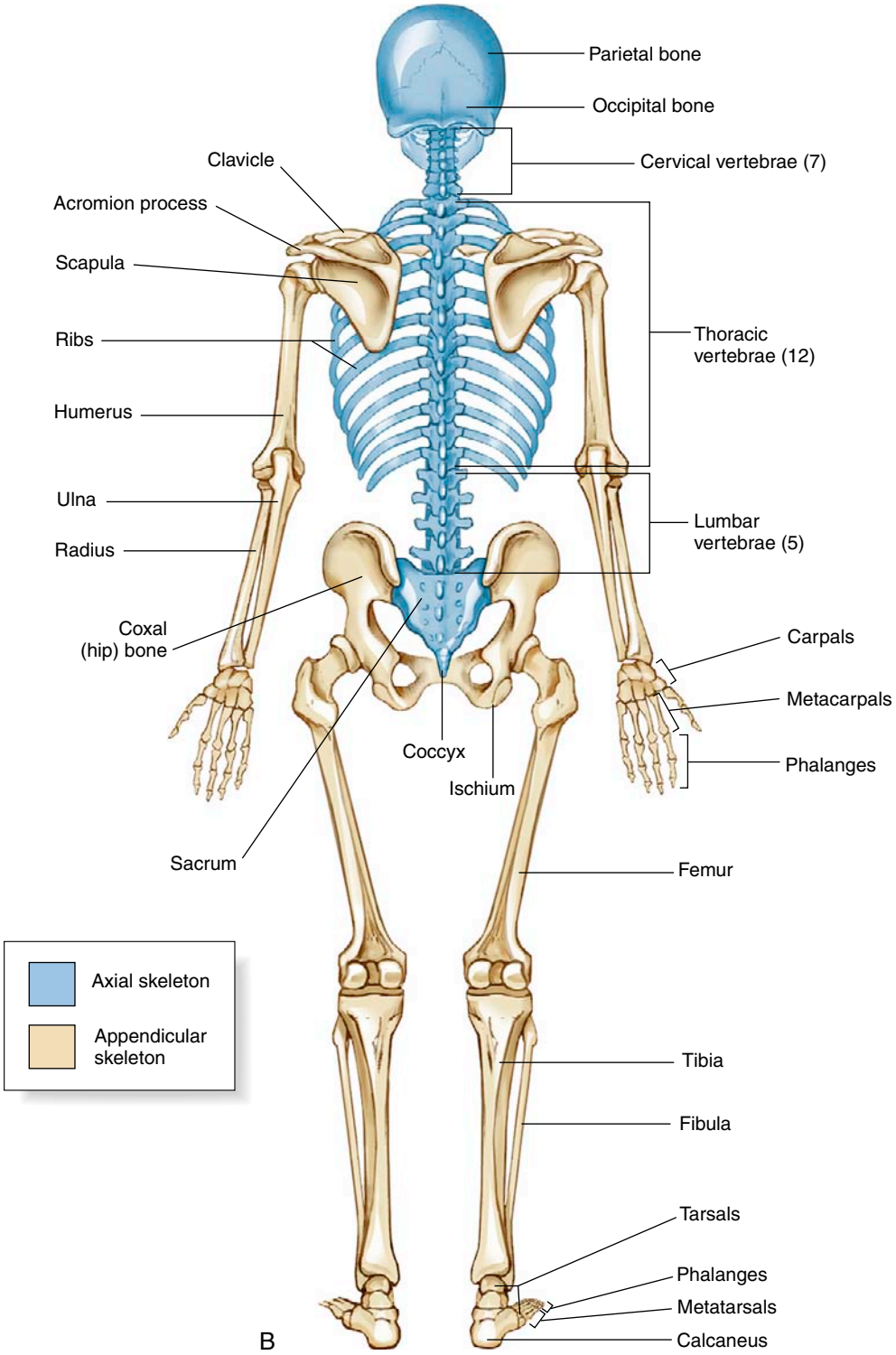


FIGURE 19-1, cont'd B, Posterior view of the skeleton.

of stress. These structures are important for weight bearing, providing strength to withstand stress placed on the bone. The periosteum is a thin, outer covering of bone containing nutrient arteries for nourishment of bone cells. Disruption of these periosteal vessels after bone trauma can influence the ability of bone to heal. The haversian system consists of thousands of microscopic units found in the cortical bone. These units of matrix cells, canals, and conduits allow flow of nutrients and facilitate calcium absorption.

Vertebrae

Vertebrae form the longitudinal axis of the skeleton. The vertebral bodies are connected by several cartilaginous joints, which enable the vertebrae to flex, extend, or rotate

while being held together. Intervertebral discs and ligaments connect the bodies of adjacent vertebrae. The ligamenta flava bind the laminae of adjacent vertebrae together. Other ligaments connect the spinous processes and vertebral bodies.

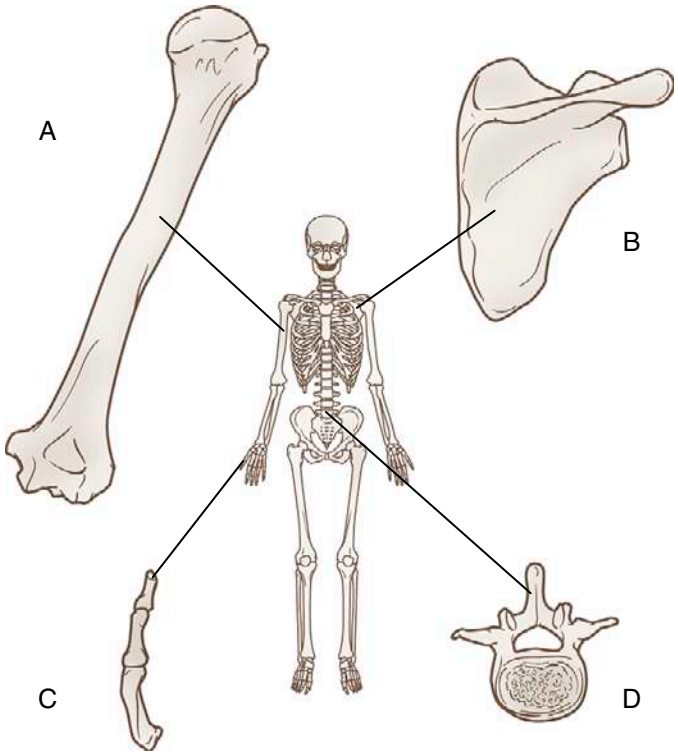


FIGURE 19-2 Types of bones, as examples. **A**, Long bones (humerus). **B**, Flat bones (scapula). **C**, Short bones (phalanx). **D**, Irregular bones (vertebra).

Seven cervical vertebrae form the skeletal framework of the neck. Twelve thoracic vertebrae support the thoracic region, and five lumbar vertebrae support the small of the back. Below the lumbar vertebrae lie the sacrum and coccyx. Each of these bones is composed of fused vertebrae—five for the sacrum and four for the coccyx.

The vertebral column is curved. After birth, there is a continuous posterior convexity. As development occurs, secondary posterior concavities develop in the cervical and lumbar regions, resulting in improved balance.

Each area of the vertebral column has specific bony structures. General features include a body (except the first two cervical vertebrae) on the anterior part. The posterior portion of the vertebrae consists of a neural arch formed by pedicles and laminae and the spinous and transverse processes.

Shoulder and Upper Extremity

The clavicle, which is a long, doubly curved bone, serves as a prop for the shoulder and holds it away from the chest wall. The clavicle rests almost horizontally at the upper and anterior part of the thorax, above the first rib. It articulates medially with the manubrium of the sternum and laterally with the acromion of the scapula; it is tethered to the underlying coracoid process of the scapula by the coracoclavicular ligaments.

The scapula (shoulder blade) is a flat, triangular bone that forms the posterior part of the shoulder girdle, lying superior and posterior to the upper chest. The glenoid cavity on the lateral side of the scapula provides a socket for the humerus (the bone of the upper arm). The acromion process articulates with the clavicle medially. The scapula is attached to the thorax by muscles.

The shoulder (pectoral) girdle consists of the glenohumeral, sternoclavicular, and acromioclavicular (AC) joints (Figure 19-3). The glenohumeral joint has a multidirectional range of motion, whereas the latter two joints have limited motion.

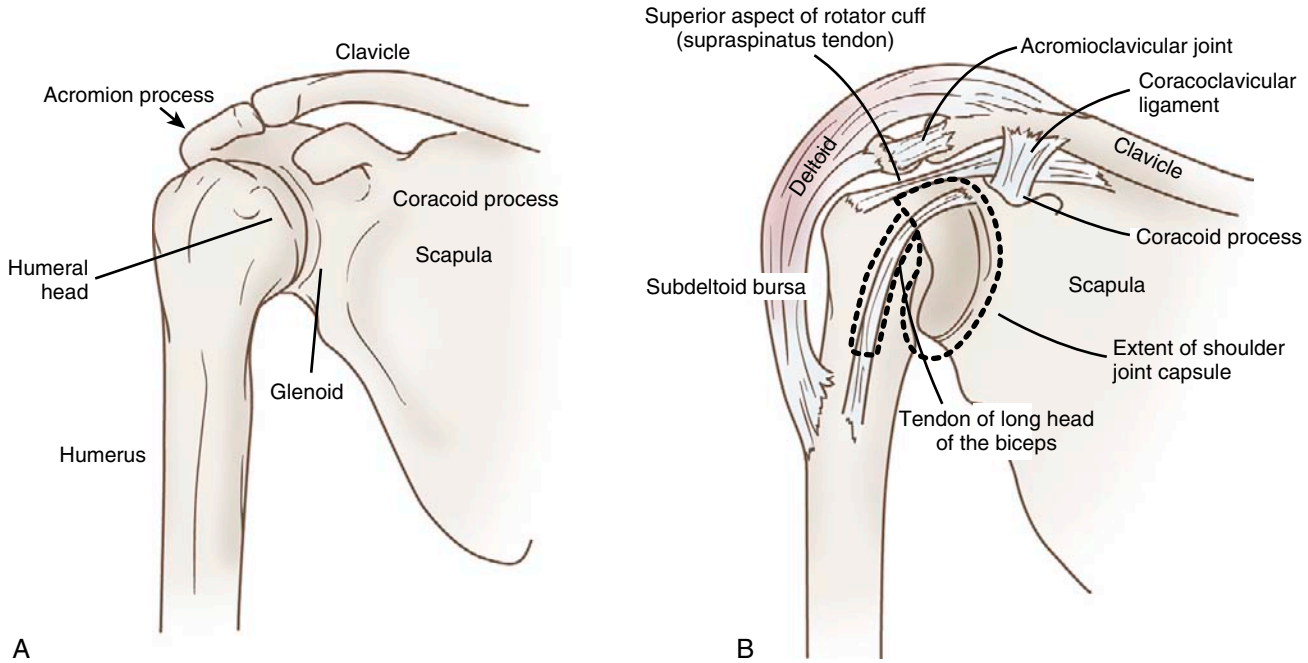


FIGURE 19-3 Shoulder. **A**, Joint showing anterior view. **B**, Girdle showing articulations.

The AC joint, located at the top of the shoulder, is the articulation between the outer end of the clavicle and a flattened articular facet situated on the inner border of the acromion. The muscles immediately surrounding the shoulder joint are the supraspinatus, infraspinatus, teres minor, and subscapularis muscles; together they are referred to as the *rotator cuff*. These muscles stabilize the shoulder joint, whereas the powerful deltoid, pectoralis major, teres major, and latissimus dorsi muscles move the entire arm. Shoulder girdle strength and stability are maintained by the soft tissue integrity—not the bony structures. A pathologic condition in this area can be the result of bone, soft tissue, or combined injury.

The humerus is the longest and largest bone of the upper extremity. It is composed of a shaft and two ends. The proximal end, or head, has two projections—the greater and lesser tuberosities (Figure 19-4). The circumference of the articular surface of the humerus is constricted and is termed the *anatomic neck*. The anatomic neck marks the attachment to the capsule of the shoulder joint. The constriction below the tuberosities is called the *surgical neck* and is the site of most fractures.

The greater tuberosity is situated at the lateral aspect of the humeral head. Its upper surface has three impressions where the supraspinous, infraspinous, and teres minor tendons insert. The lesser tuberosity is situated in the anterior neck and has an impression for the insertion of the tendon of the subscapular muscle. The attachment sites for the rotator cuff, the tuberosities, are separated from each other by a deep groove (bicipital groove), in which lies the tendon of the long head of the biceps muscle of the arm. The tendon of the pectoralis major inserts on the lateral margin of the bicipital groove, and the latissimus dorsi and teres major insert on the medial margin.

The distal humerus flattens and ends in a broad articular surface. The surface is divided into the medial and lateral condyles, which are separated by a slight ridge. On the lateral condyle, the rounded articular surface is called the *capitulum,* which articulates with the head of the radius. On the medial condyle, the articular surface is termed the *trochlea,* which articulates with the ulna.

The ulna is located medial to the radius. The proximal portion of the ulna, the olecranon, articulates with the trochlea of the humerus at the elbow. The radius rotates around the ulna. At the proximal end is the head, which articulates with the capitulum of the humerus and the radial notch of the ulna. The tendon of the biceps muscle is attached to the tuberosity just below the radial head. The distal end of the radius is divided into two articular surfaces. The distal surface articulates with the carpal bones of the wrist, and the surface on the medial side articulates with the distal end of the ulna.

Wrist and Hand

The skeletal bones of the wrist and hand consist of three distinct parts: (1) the carpals, or wrist bones; (2) the metacarpals, or bones of the palm; and (3) the phalanges, or bones of the digits (Figure 19-5).

The eight carpal bones are arranged in two rows. The distal row, proceeding from the radial to the ulnar side, includes

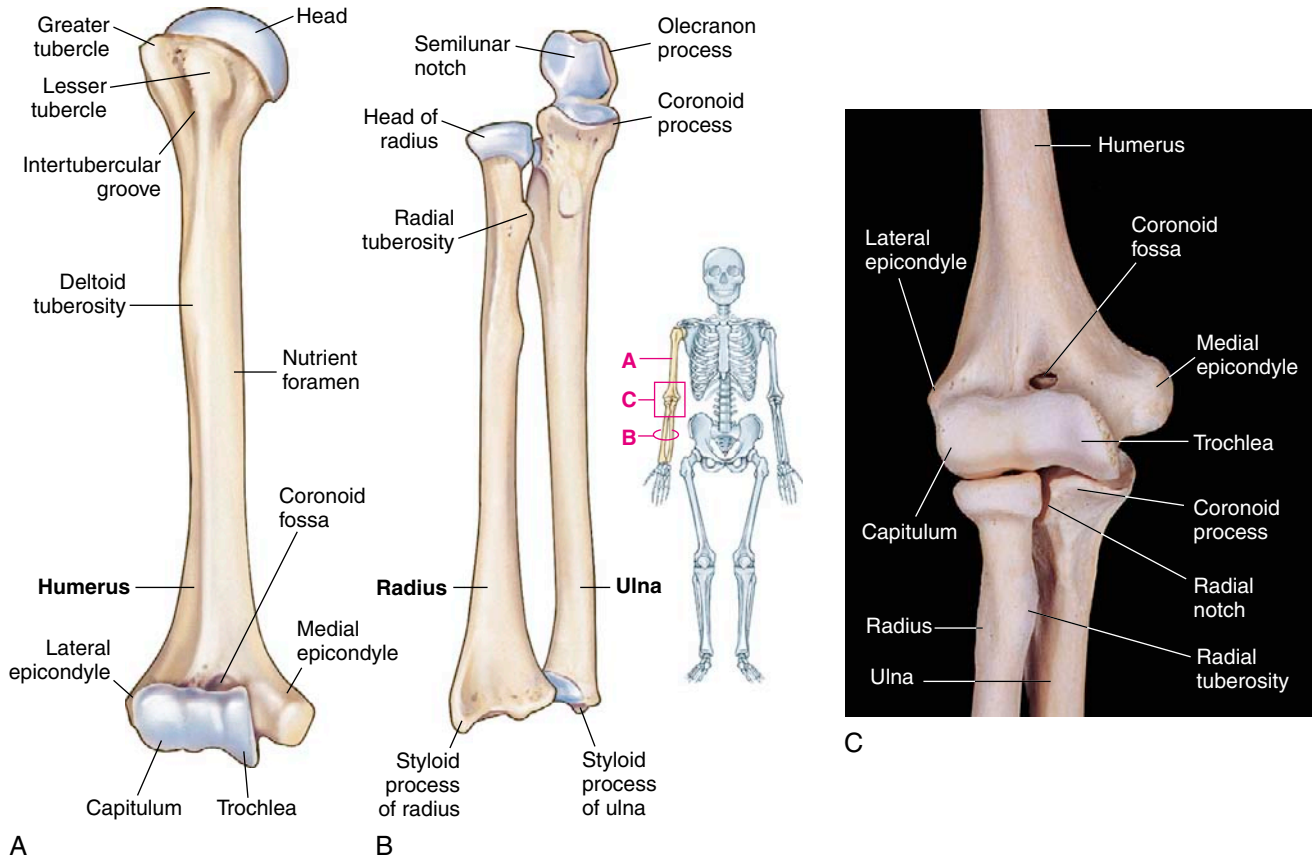


FIGURE 19-4 Bones of the arm, anterior view, showing the humerus, radius, and ulna.

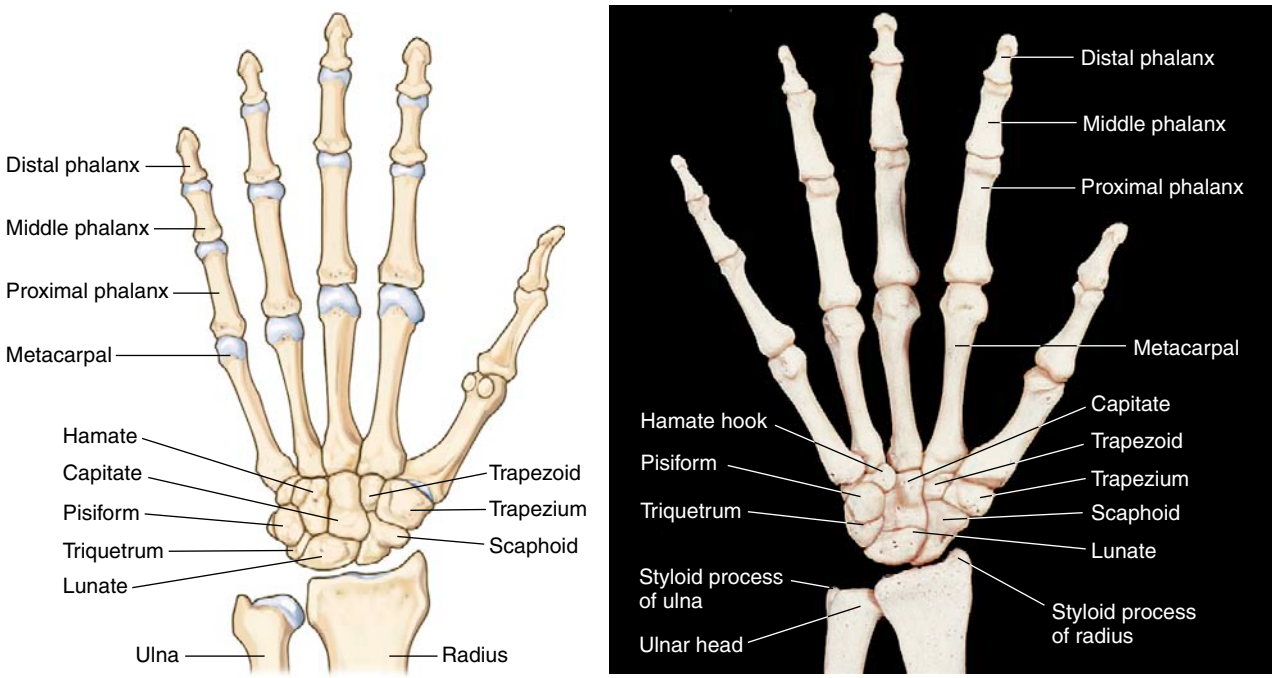


FIGURE 19-5 Bones of the wrist and hand, palmar view.

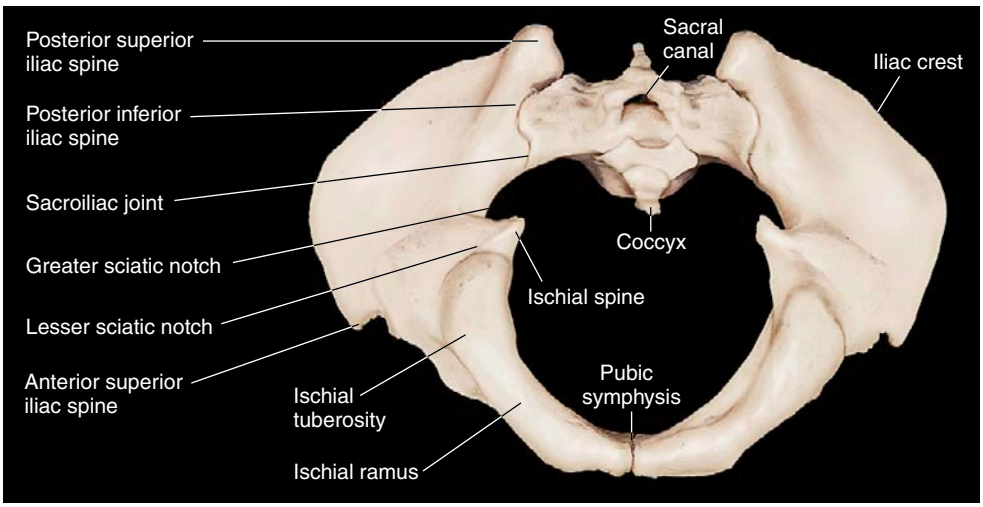


FIGURE 19-6 Pelvis, superior view.

the trapezium, trapezoid, capitate, and hamate; the proximal row consists of the scaphoid (also called the *navicular*), lunate, triquetrum, and pisiform. Functionally, the scaphoid links the rows as it stabilizes and coordinates the movement of the proximal and distal rows. Each carpal bone consists of several smooth articular surfaces for contact with the adjacent bones, as well as rough surfaces for the attachment of ligaments. The five metacarpal bones (long bones) are situated in the palm. Proximally they articulate with the distal row of carpal bones, and distally the head of each metacarpal articulates with its proper phalanx. The heads of the metacarpals form the knuckles. The phalanges, or fingers, consist of 14 bones in each hand—2 in the thumb and 3 in each finger. Each phalanx consists of a shaft and two ends.

Pelvis, Hip, and Femur

The pelvis (Figure 19-6) is a stable circular base that supports the trunk and forms an attachment for the lower extremities. It is a massive, irregular bone created by the fusion of three separate bones. The largest and uppermost of the three bones is the ilium, the strongest and lowermost is the ischium, and the anterior-most is the pubis. Together these are termed the *os coxae,* or innominate bone.

The acetabular portion of the innominate bone and the proximal end of the femur (Figure 19-7) form the hip, which is a ball-and-socket joint. The hip joint is surrounded by a capsule, ligaments, and muscles that provide stability. The iliofemoral ligament connects the ilium with the femur anteriorly and superiorly, and the ischiofemoral and pubofemoral

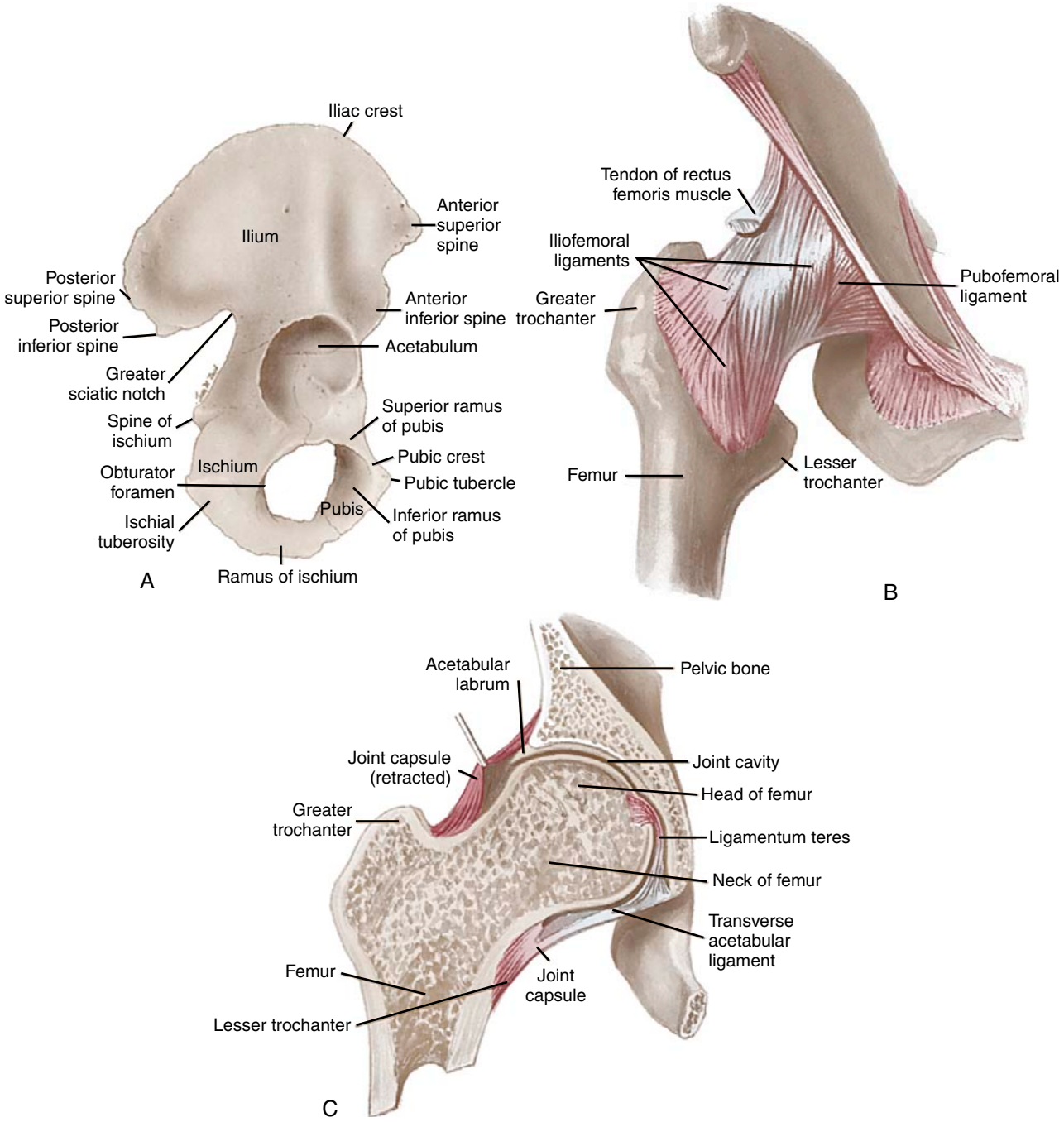


FIGURE 19-7 Hip joint. **A**, Coxal bone disarticulated from the skeleton. **B**, Ligamentous structure. **C**, Bone structure.

ligaments attach the ischium and pubis to the femur, respectively. The acetabulum is a deep, round cavity that articulates with the head of the femur. The proximal end of the femur consists of the femoral head and neck, the upper portion of the shaft, and the greater and lesser trochanters (Figure 19-8).

The greater trochanter is a broad process that protrudes from the outer, upper portion of the shaft and projects upward from the junction of the superior border of the neck with the outer surface of the shaft. It serves as a point of insertion for the abductor and short rotator muscles of the hip.

The lesser trochanter is a conical process projecting from the posterior and inferior portion of the base of the neck of the femur at its junction with the shaft. It serves as a point of insertion for the iliopsoas muscle. The lower end of the femur terminates in the two condyles. Anteriorly, the condyles are separated from one another by a smooth depression, called the *intercondylar,* or *patellar, groove,* forming an articulating surface for the patella. Posteriorly, they project slightly, and the space between them forms the intercondylar fossa—a supporting structure for neurovascular structures.

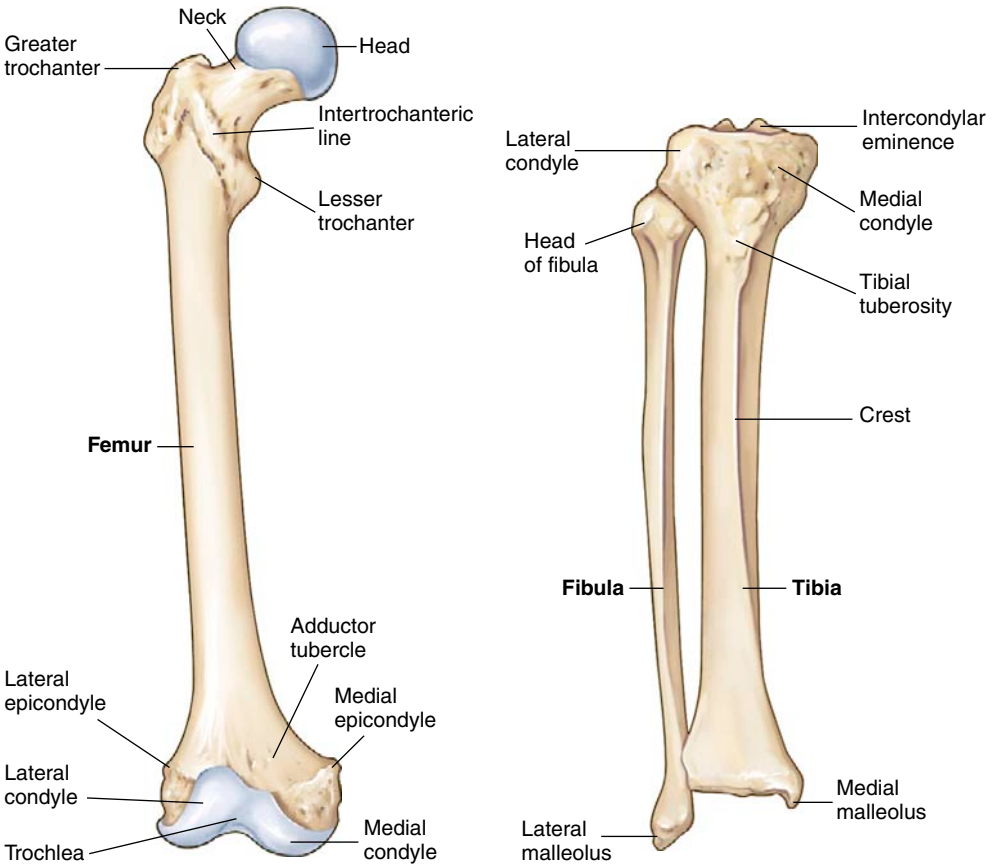


FIGURE 19-8 Bones of the upper and lower leg.

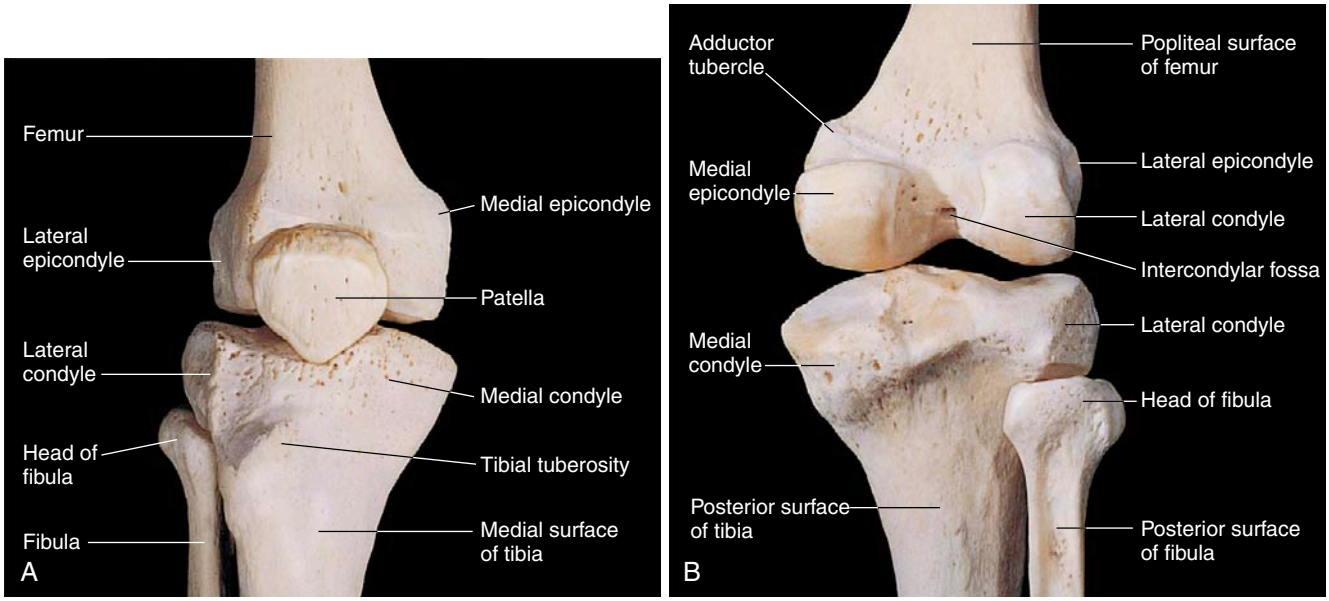


FIGURE 19-9 Bones of the knee showing the tibia and fibula. **A**, Anterior aspect. **B**, Posterior aspect.

The upper or condylar end of the tibia presents an articular surface corresponding with those of the femoral condyles. The articular surface of the two tibial condyles forms two facets, which are deepened by the semilunar cartilage into fossae for the femoral condyles.

Knee, Tibia, and Fibula

The knee joint (Figure 19-9) consists of two articulations. One articulation is between each condyle of the femur and the tibial plateau; the other is between the patella and the femur. These areas are subject to degenerative changes, often requiring

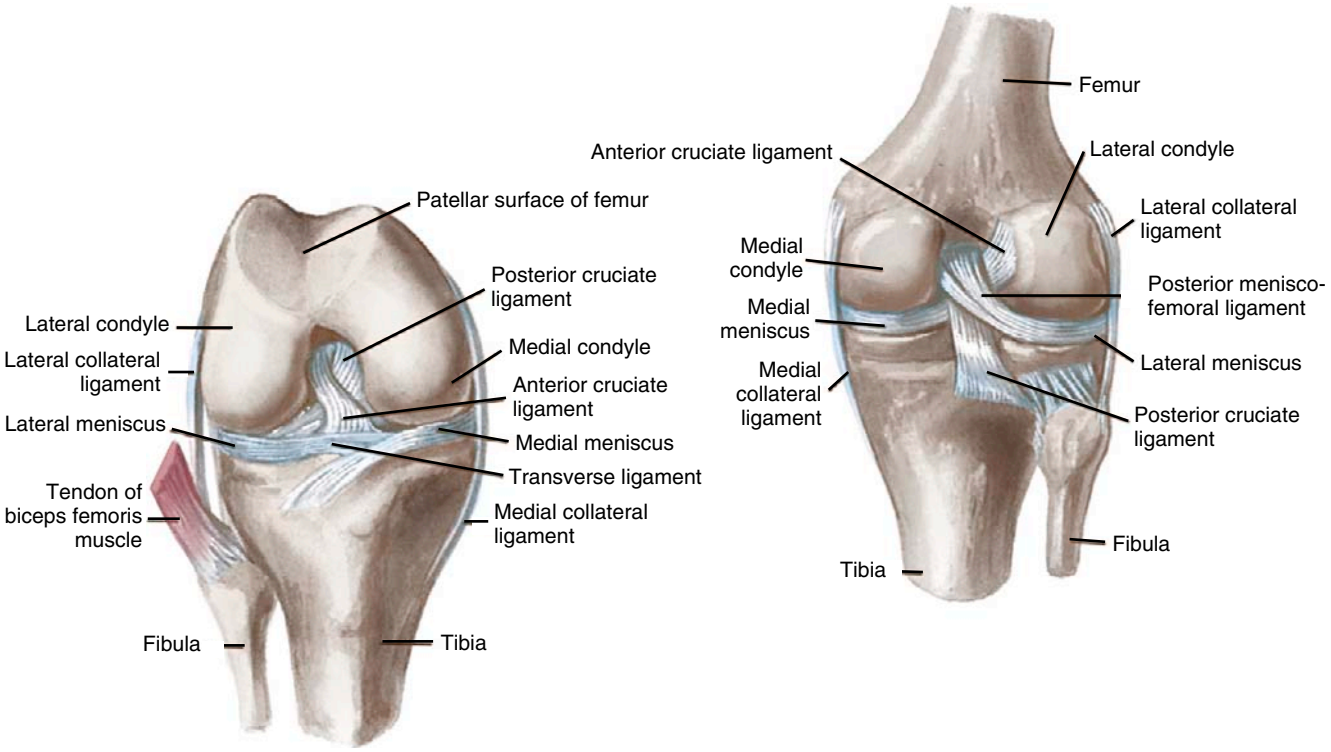


FIGURE 19-10 Bony structures of the knee joint.

reconstructive surgery. The bones of the knee joint are connected by extraarticular and intraarticular structures. The extraarticular attachments consist of the joint capsule, multiple muscular attachments, and two collateral ligaments. The intraarticular ligaments consist of the two cruciate ligaments and the attachments of the menisci.

The patella, or kneecap, is anterior to the knee joint in the intercondylar groove, or trochlea, of the distal femur. It is a sesamoid bone contained within the quadriceps tendon. The anterior surface of the patella is united with the patellar tendon as the tendon originates and inserts above and below the knee joint. The posterior surface of the patella articulates with the femur.

The capsule of the knee joint is attached proximally to the femoral condyles, and it is attached distally to the condyles of the tibia and to the upper end of the fibula. The capsule is reinforced anteriorly by the patellar and quadriceps tendon, on the sides by the medial and lateral collateral ligaments, and posteriorly by the popliteus and gastrocnemius muscles.

The cruciate ligaments (Figure 19-10), consisting of two fibrous bands, extend from the intercondylar fossa of the femur to attachments anterior and posterior on the intercondylar surface of the tibia.

The menisci are interposed between the condyles of the femur and those of the tibia (see Figure 19-10). Each meniscus is attached to the joint capsule. The ends of the cartilage are attached to the tibia in the middle of its upper articular surface. These structures are almost totally avascular, and degenerative changes are usually permanent.

Synovial membrane lines the capsule of the joint and covers the infrapatellar fat pad, parts of the cruciate ligaments, and portions of the bone. The portion of the knee joint cavity that extends upward in front of the femur is called the *suprapatellar pouch*, or *bursa* (Figure 19-11).

The tibia is the larger and stronger of the lower leg bones. The fibula is smaller and located more laterally, articulating at the proximal end with the lateral condyle of the tibia. The proximal end of the tibia articulates with the femur to form the knee joint. Distally the tibia articulates with the fibula and with the talus, forming the ankle joint.

Ankle and Foot

The ankle is a hinge joint, formed by the distal end of the tibia and fibula and the proximal end of the talus. The tibia (medial and posterior malleoli) and fibula (lateral malleolus) form a mortise (notch) for the reception of the upper surface of the talus and its facets. The talus is an irregular bone consisting of a body, neck, and head. The bones are connected by ligaments, which spread out from the malleoli to attach to the talus, calcaneus, and navicular bones (Figure 19-12). A thin capsule surrounds the joint.

The bony framework of the foot (Figure 19-13) comprises 7 tarsal bones, 5 metatarsal bones, and 14 phalanges. The calcaneus forms the heel and gives support to the talus. The cuboid bone articulates proximally and posteriorly with the calcaneus and distally with the fourth and fifth metatarsals and the third cuneiform bones.

The navicular bone articulates with the cuneiform bones, which lie side by side just anterior to it. The metatarsal bones articulate proximally with the tarsal bones and distally with the bases of the first phalanges of the corresponding toes. There are two phalanges for the great toe and three for each of the other toes.

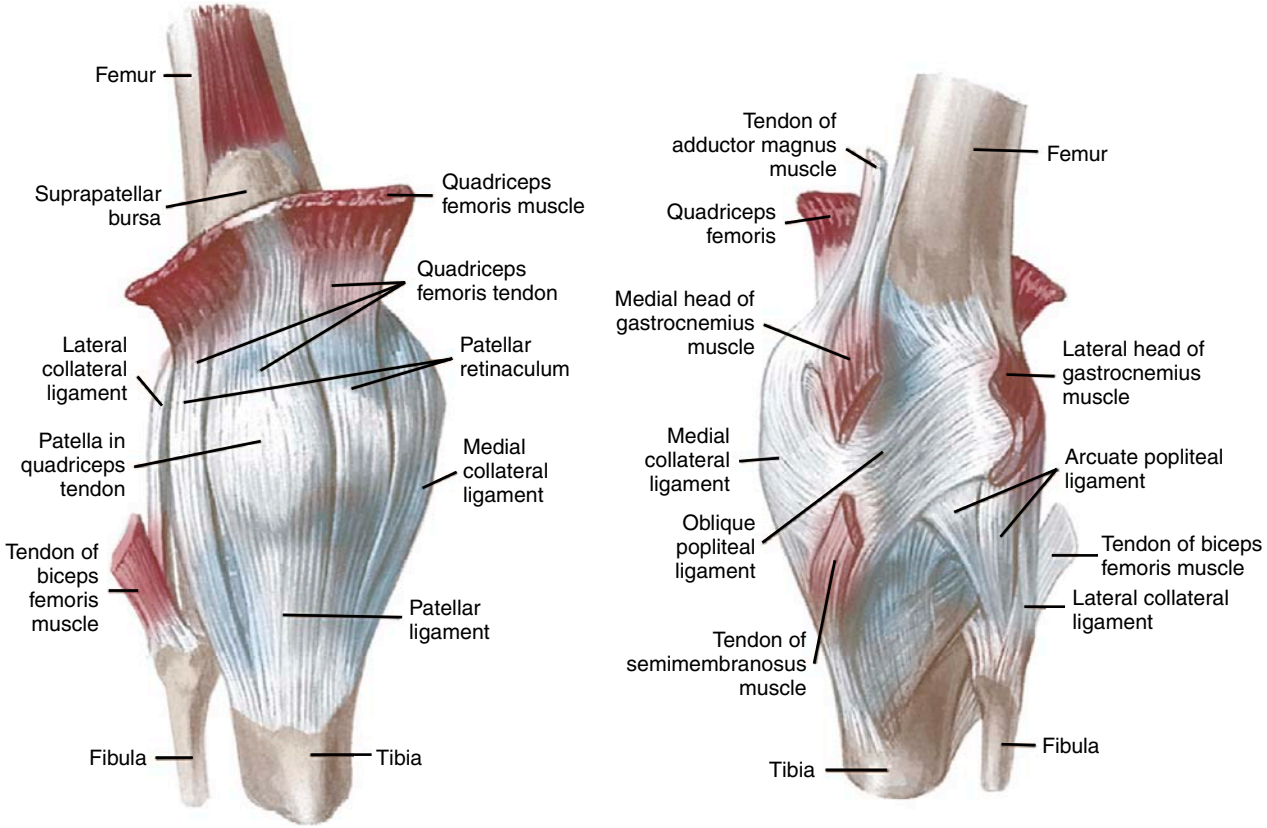


FIGURE 19-11 Superficial aspect of the knee joint.

Perioperative Nursing Considerations

Assessment

Assessment of the orthopedic patient is dynamic, beginning with initial patient consultation. The history and physical are done in the usual fashion. Preoperatively, the nurse takes special care to document any functional losses that are caused by the disability. The social situation of the patient should also be documented both in the physician's office and again in the hospital chart, as this may impact discharge planning. Familiarity with orthopedic procedures and anticipated patient outcomes improves the ability to gather appropriate information and complete the nursing process. Obtaining patient-specific information from the physician also enhances the perioperative nursing assessment. The signed operative consent provides information to confirm the scheduled procedure or procedures and verify the operative site and side as discussed by Guido (2005) and per The Joint Commission's (TJC) standards of universal protocol for correct site surgery (TJC, 2009). The consent is usually obtained before admission to the surgery suite and should be reviewed for accuracy and completeness.

Additional measures that should be undertaken to verify the correct operative side and site include marking the surgical site and having the patient verify the site with the surgeon during the marking process; using a verification checklist (which includes documents such as the medical record, x-ray films, imaging studies); using verbal verification by the patient of his or her identity, surgical site/side, and planned surgical procedure; confirming this information during the time-out by each member of the surgical team; and monitoring safe site protocol compliance with these procedures (Evidence for Practice).

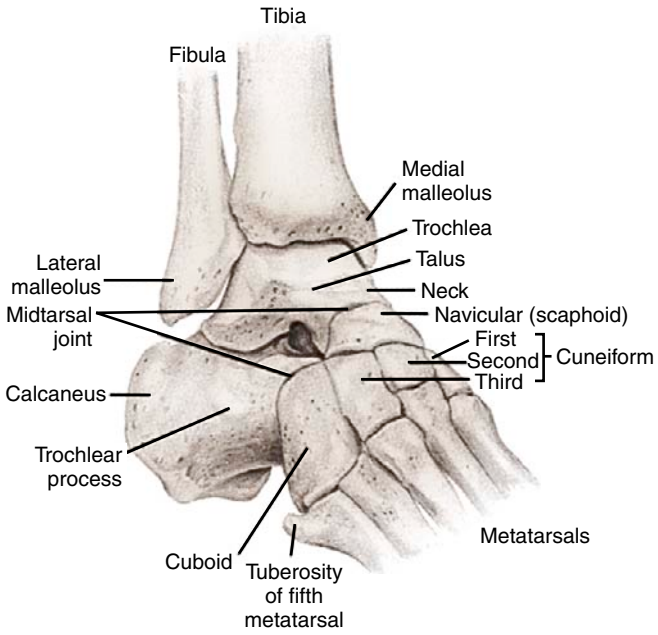


FIGURE 19-12 Anatomy of the ankle.

EVIDENCE FOR PRACTICE

Universal Protocol for Preoperative Site Verification As Indicated for Orthopedic Surgery

The Joint Commission's Universal Protocol for correct patient, procedure, and surgical side and site as well as the AORN Position Statement on correct site surgery both emphasize verification and marking of the surgical site (or invasive procedure site), especially when it involves laterality, levels, or multiples. As part of this process, protocols are used to verify the correct patient, correct procedure, correct patient position, and availability of necessary equipment, implants, imaging studies/equipment, or other special requirements. These protocols are part of the preoperative verification process as well as the time-out before the start of the surgical procedure.

For surgery, a recommended protocol may involve these additional steps:

- Preoperative skin marking of the procedure site is present.
- Preoperative films or images are present in the OR or procedure room.
- The time-out includes patient identity (using two unique identifiers); procedure to be performed; correct patient position; correct procedure side, level, or site; and presence of necessary implants, imaging, equipment, or other special requirements.
- If there are any discrepancies by any members of the surgical team the procedure will not proceed until the institution's reconciliation procedure is initiated and the results of the reconciliation should be documented.
- Should intraoperative imaging be necessary, opaque instruments marking the specific bony landmarks are placed accordingly and x-rays are taken and compared with the preoperative films or images by the surgeon performing the procedure.

Modified from Institute for Clinical Systems Improvement: *Health care protocol—safe site protocol for all invasive, high-risk, or surgical procedures,* January 2006, available at www.icsi.org/perioperative_protocol_36011/perioperative_protocol.html. Accessed June 23, 2009; The Joint Commission: *Universal protocol UP.01.01.01,* available at www.jointcommission.org/NR/rdonlyres/E5943278-3B89-469F-A265-E5AFB8729AD0/0/NPSG_UniversalProtocol_AHC_20090512.pdf. Accessed March 15, 2009.

The perioperative nurse reviews the patient record, noting relevant aspects of the history and physical examination; the nature of the problem and its onset; and results of radiographic studies, laboratory data, and other findings. The nursing history is reviewed to determine physical, psychosocial, cultural, spiritual, and other needs. The nurse assesses the patient's range of motion, neurovascular status, and general condition. The patient's understanding of the surgical procedure and postoperative rehabilitation is determined, and patient education is begun.

Assessment information helps the nurse to determine specific needs related to surgical positioning, skin preparation, equipment, instrumentation, and supplies. Environmental safety is also considered, including room temperature, traffic flow, lighting, and personnel attire.

The nurse communicates information with other members of the perioperative team. The information collected helps the perioperative nurse plan and coordinate activities, facilitate a smooth transition, and reduce operative time.

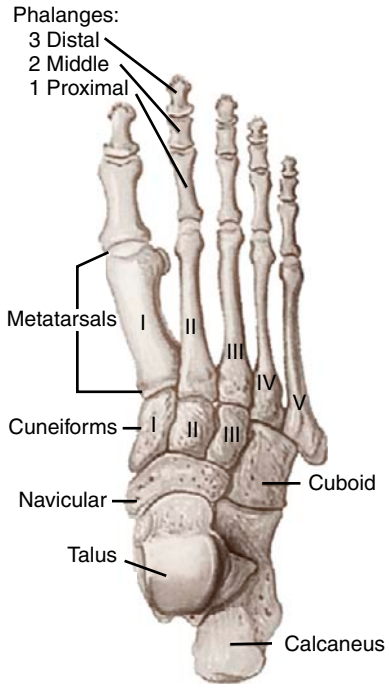


FIGURE 19-13 Bones of the foot viewed from above.

Nursing Diagnosis

Nursing diagnoses related to the care of patients undergoing orthopedic surgery might include the following:

- Anxiety
- Risk for Peripheral Neurovascular Dysfunction
- Risk for Perioperative Positioning Injury
- Impaired Gas Exchange
- Risk for Infection
- Risk for Imbalanced Body Temperature

Outcome Identification

Outcomes identified for the selected nursing diagnoses could be stated as follows:

- The patient will verbalize concerns and apprehension related to surgery and recovery.
- The patient will be free from peripheral neurovascular dysfunction.
- The patient will be free from perioperative positioning injury.
- The patient will maintain adequate ventilation and oxygen exchange.
- The patient will be free from postoperative surgical site infection.
- The patient will maintain appropriate body temperature intraoperatively.

Planning

The care of surgical patients undergoing any type of surgery requires planning for routine procedures that are always followed, as well as anticipating the unexpected. The perioperative nurse should be consistent and systematic in the planning process to expedite actual steps required to facilitate the surgical procedure. Care of the orthopedic patient presents unique challenges because of the psychosocial, physical, and technical

aspects of patient care. Planning includes attention to environmental factors, positioning, transfusion supplies, equipment, and instrument needs, in addition to practices that will prevent complications.

The optimal environment is comfortable for the patient and surgical team. The patient should feel relaxed and secure enough to allow the surgical team to become his or her advocates during the procedure. Physical preparation of the environment changes with individual patients. At the time the procedure is posted in the OR, traffic flow is considered to determine room location. The temperature is selected for the procedure with consideration given to the age and general health of the patient, attire worn by the operative personnel (body exhaust suits), or use of polymethylmethacrylate (PMMA) (bone cement). Temperature should be monitored for all but very brief surgical procedures, such as those lasting less than 30 minutes. To maintain normothermia, the perioperative nurse might consider using warming blankets preoperatively to prewarm the patient in the holding area, warming the ambient room temperature, warming intravenous fluids, warming the skin surface with a forced-air warming device intraoperatively, and using warm cotton blankets at the end of the surgical procedure.

Equipment and instrumentation needed for the procedure are planned before the patient's arrival in the OR; orthopedic procedures may vary significantly because of the patient's physical condition or age. It may be necessary to communicate with the manufacturer's representative to facilitate obtaining items needed for the procedure. It is common for healthcare industry representatives to bring requisite orthopedic instruments to the OR or to act as a product resource regarding new equipment. However, industry representatives must comply with all institutional policies and AORN standards defining requirements and procedures and restrictions that govern their presence in the OR (AORN, 2006).

The nurse reviews the procedural information to plan positioning and protective measures. Aseptic technique is essential in the perioperative environment and should be considered a priority when caring for the orthopedic patient. Osteomyelitis is an infection of the bone that can remain unrecognized for a long time and requires expensive, intensive treatment. Osteomyelitis can lead to severe bone loss and possible loss of a limb. Preventive measures, including administration of antibiotics within 60 minutes of the initial incision, have been demonstrated to be efficacious in preventing surgical site infection.

OR equipment such as defibrillators and resuscitative equipment must always be available, functional, and familiar to staff. This includes supplies needed for emergency treatment of a patient condition, such as malignant hyperthermia or unanticipated blood loss. All medications and solutions along with their containers should be labeled both on and off the surgical field. Equipment alarms should be activated with appropriate settings and should be sufficiently audible. Orthopedic procedures may also require a change in the plan of care in the event of a fracture, damage to vascular integrity, or changes in the patient's condition, requiring an understanding of methods and equipment needed to manage these situations.

The nursing process requires continual reassessment and modifications. An effective plan entails communication, creating a culture that supports patient safety, creation of an optimal environment, and effective use of human and physical resources (AORN, 2007). A Sample Plan of Care for a patient undergoing orthopedic surgery follows.

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Anxiety

OUTCOME
The patient will verbalize concerns and apprehension related to surgery and recovery.

INTERVENTIONS
- Encourage verbalization of feelings, expression of fear, and questions about procedure, anticipated outcome, postoperative rehabilitation, pain management, and home care/self-care requirements.
- Explain anticipated routine activities (diagnostic studies, OR environment, preoperative holding area, postanesthesia care unit [PACU]), and encourage questions.
- Encourage patient and family participation in decision-making activities related to discharge planning.
- Demonstrate respect, and attend to patient's individual needs and those of the family or significant others.
- Remain with patient; ensure other personnel are introduced.
- Provide comfort and care, for example, through the use of warm blankets, touch, hand holding.
- Discuss any other concerns with the patient and family, and initiate appropriate referrals.

NURSING DIAGNOSIS
Risk for Peripheral Neurovascular Dysfunction

OUTCOME
The patient will be free from peripheral neurovascular dysfunction.

INTERVENTIONS
- Complete and document a preoperative neurovascular assessment including skin color and temperature, pulses, motor strength and movement, and sensation; reassess and document at procedure conclusion.
- Position patient with proper body alignment, considering range of motion or any limitations in mobility.
- Protect vulnerable neurovascular structures and prevent pressure by properly padding bony prominences and pressure points.
  - For the brachial plexus, pad the elbow, avoid excessive abduction, secure arm gently on locked armboard.
  - For the radial nerve, pad the wrist and secure it gently on an armboard or at the patient's side.
  - For the medial or ulnar nerves, pad and tuck the arm carefully at the patient's side or on an armboard.
  - For the peroneal nerve, place a pillow at the knee (but not under it) and support the lower extremities; ensure that restraining straps are not tight and do not compress the knee.
  - For the tibial nerve, keep equipment off the lower extremities.

SAMPLE PLAN OF CARE—cont'd

- Apply pneumatic tourniquet correctly, observing, verifying, and documenting pressure settings and tourniquet inflation time.
- Provide padding (air mattress or gel pads) when long surgical times are expected or patients are predisposed to peripheral vascular compromise.
- Anticipate patient's and surgical team's needs to minimize surgical time.

NURSING DIAGNOSIS
Risk for Perioperative Positioning Injury

OUTCOME
The patient will be free from perioperative positioning injury.

INTERVENTIONS
- Assess range of motion; identify joints at risk for injury caused by immobilization, pain, trauma, or arthritic or other disease processes.
- Position arthritic joints carefully to prevent strain.
- Observe and document condition of patient's skin before transfer to the OR bed and again at conclusion of procedure.
- Use proper lifting and transfer techniques when transferring the patient to and from the OR bed to prevent shearing forces on skin.
- Keep sheets on OR bed dry and wrinkle-free.
- Ensure that personnel with knowledge of the patient's condition and equipment are available to supervise and assist with transfer of the patient.
- Use proper restraint devices to protect patients from falls or movement of the extremities.
- Avoid extending or flexing extremities beyond range of motion when there is resistance.
- Protect skin in dependent areas from pooling of solutions.
- Use positioning devices, such as pillows, to maintain position; use a small head pillow under the head if head and neck are normally bent slightly forward.
- Pad all dependent pressure sites; provide extra padding for patients with decreased circulation.
- Protect vulnerable neurovascular areas from compression.

NURSING DIAGNOSIS
Impaired Gas Exchange

OUTCOME
The patient will maintain adequate ventilation and oxygen exchange.

INTERVENTIONS
- Review preoperative evaluation of the patient's pulmonary status.
- Assist anesthesia provider in airway management.
- Ensure full chest excursion when positioning, particularly in the lateral and prone positions.
- Collaborate with anesthesia provider in monitoring vital signs, oxygen saturation, ventilation, cardiac rhythm, and blood loss.
- Complete a vascular assessment (pulse, sensation, movement, temperature, and color check) preoperatively, and compare with postoperative status.

NURSING DIAGNOSIS
Risk for Infection

OUTCOME
The patient will be free from postoperative surgical site infection.

INTERVENTIONS
- Confirm that the patient has complied with preoperative skin cleansing (as appropriate).
- Implement strict aseptic practices for preparing the patient's skin, draping the patient and equipment, opening supplies and equipment for the procedure, removing hair (as necessary), and controlling traffic patterns in the OR.
- Prepare for pulsatile lavage or irrigation (as needed).
- Initiate antibiotic therapy preoperatively and/or intraoperatively per physician's orders; check for medication allergies before antibiotic administration.
- Implement procedure-specific activities, such as using body exhaust systems and pulsatile lavage.
- Anticipate equipment needs, and check equipment function; implement safety precautions when using equipment.
- Sterilize instruments according to policy and procedure and the manufacturer's guidelines.
- Handle implants according to manufacturer's recommendations.

NURSING DIAGNOSIS
Risk for Imbalanced Body Temperature

OUTCOME
The patient will maintain normothermia intraoperatively.

INTERVENTIONS
- Obtain and document baseline preoperative temperature.
- Initiate preoperative warming with either warmed blankets or forced hot air warming device.
- Maintain temperature in the OR between 68° and 73° F (20°–23° C) if possible.
- Monitor patient temperature throughout the procedure.
- Use warming devices and warming blankets during the procedure.
- Warm fluids as necessary.
- Minimize patient exposure to room air.
- Place warm blankets on patient immediately after surgery.

Implementation

Implementing care for the orthopedic surgical patient requires an understanding of anatomic, physiologic, psychologic, cultural, spiritual, and technical patient needs. Orthopedic surgical procedures demand special equipment, instruments, and psychomotor skills that differ from those required by other specialties. Implementation includes an understanding of the procedures, patient needs, perioperative practices, and perioperative nursing interventions to protect the patient while delivering care.

The nurse should provide explanations to the patient about the intraoperative phase, including the anticipated sequence of events, personnel, environment, required positioning, and procedures such as administration of a regional anesthetic and application of a tourniquet. The patient may be alert during the procedure; therefore noise from power equipment and activities that will occur should be explained. Immobilization devices, such as splints, casts, braces, and drains, should also be explained.

Positioning and Positioning Aids. The orthopedic patient requires proper positioning on the OR bed or specialty bed to provide adequate exposure of the operative area, maintain body alignment, minimize strain or pressure on nerves and muscles, allow for optimal respiratory and circulatory function, and provide adequate stabilization of the body. Selection of position depends on several factors, including the type of procedure, the location of the injury or lesion, and the preference of the surgeon. Guidelines for placing the patient in the supine or recumbent position are followed (see Chapter 5), with modifications to facilitate the specific orthopedic procedure.

Procedures performed in lateral, prone, or modified positions require use of positioning aids and devices to support these positions. Patients undergoing surgical procedures risk neuromuscular and skin injury. The nurse's preoperative assessment should be thorough to plan the position, taking into consideration the prevention of neurovascular compromise, the potential for impaired chest excursion, and the danger of falls. The safety strap does not always provide adequate security, and other methods of securing the patient on the OR bed may need to be implemented. The surgeon is responsible for selecting the position and ensuring that adequate exposure can be obtained. The perioperative staff must understand the meaning of terms such as *flexion, extension, abduction,* and *adduction* when positioning the patient. The staff must also be thoroughly familiar with the function of the orthopedic surgical bed and its various attachments (e.g., the leg attachment for arthroscopy, the three-point positioner for lateral position, and positioning devices for shoulder procedures).

Many orthopedic operations require a device for holding the extremities. Various holders are available for both upper and lower extremities. Positioners used intraoperatively can be sterilized for the procedure, resulting in the ability to reposition as needed throughout the procedure. These types of positioners include the shoulder positioner (Figure 19-14), Alvarado foot holder (Figure 19-15), and ankle distractor (Figure 19-16). Many other orthopedic positioning devices are also available.

The lateral position is sometimes used for a total hip arthroplasty. Padded anterior and posterior supports may be positioned at the umbilicus and lumbar regions, respectively, to hold the patient in the lateral position. A vacuum beanbag can also achieve this position. Pressure points on the lateral area of the skull, ear, axilla, hip, knee, and ankle should be adequately padded. The feet are placed in the neutral position to prevent excessive plantar flexion or dorsiflexion. A conscientious effort should be made by the surgical team to avoid leaning on the patient during the procedure.

The patient is positioned prone for surgery on the posterior aspect of the body, including the back; posterior portion of the shoulder, arms, and legs; and Achilles tendon; and for posterior iliac bone graft harvesting. This position presents a challenge for the anesthesia team to monitor and manage the airway because of the potential for impaired chest excursion and gas exchange. Extremities need to be moved through a normal range of motion when transferring and positioning into the prone position. Vascular integrity is always assessed before the patient is moved into position and reassessed after the patient is positioned; the nurse should note the quality of pulses, extremity warmth, and capillary refill.

The prone position is often attained with the use of adjunctive frames, such as the Wilson, Hastings, Canadian, Relton-Hall, Cloward saddle, or Andrews, or with the Andrews bed (Figure 19-17). Each frame has qualities that meet the patient's or physician's needs. The Hastings and Andrews frames and the Andrews bed maintain the patient in a modified knee-chest position. The frames require assembly and are labor-intensive when positioning; some can be used only with certain beds. The Andrews bed is similar to the Andrews frame but has the attachments built in and is used exclusively for this position.

On an OR fracture bed (Figure 19-18), generally used for femoral neck and shaft fixation, the team places the patient in

FIGURE 19-14 Shoulder positioner allows distraction of the joint for visualization.

FIGURE 19-15 Alvarado foot holder used during total joint procedures to position the extremity for exposure.

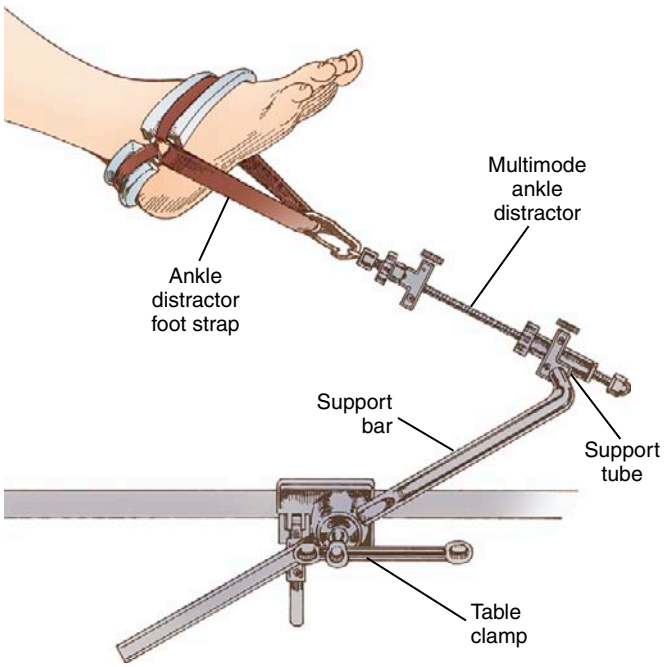


FIGURE 19-16 Ankle distractor, noninvasive, for distraction of the joint and visualization.

FIGURE 19-17 Andrews bed used for prone positioning.

supine or lateral position to allow exposure of the surgical site while maintaining alignment. The patient's legs are positioned on outriggers, allowing access by the image intensifier to obtain multiple radiographic views. Applying or releasing traction can be done to reduce the fracture or aid in intramedullary surgical techniques. Like all positioning devices, the fracture bed must be set up by experienced personnel and padded adequately. There are several moving parts, which can lead to injury if not operated properly.

If the patient is positioned supine, special attention must be paid to the arms. Arms are placed on padded armboards with the palms up and fingers extended. Armboards are maintained at less than a 90-degree angle to prevent brachial plexus stretch. If there are surgical reasons to tuck the arms at the side, the elbows are padded to protect the ulnar nerve, the palms face inward, and the wrist is maintained in a neutral position (Denholm, 2009). A drape secures the arms. It should be tucked snuggly under the patient, not under the mattress. This

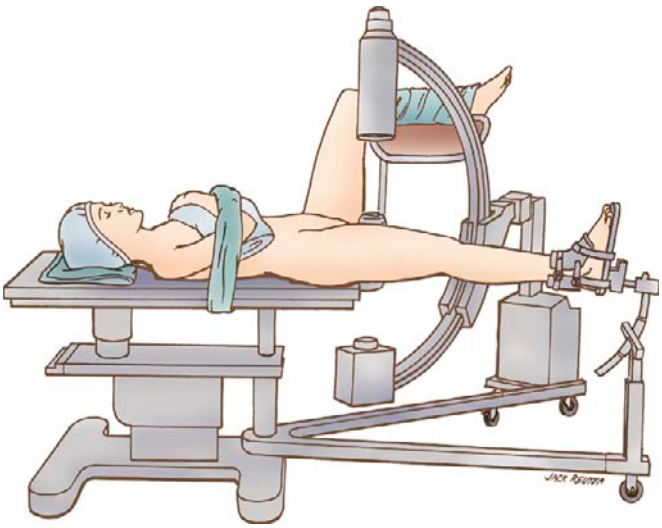


FIGURE 19-18 Patient positioned on the orthopedic fracture bed for femoral neck, femoral shaft, or tibial fixation, with image intensifier in position.

prevents the arm from shifting downward intraoperatively and resting against the OR bed rail.

Surgical Prep. A primary concern in orthopedic surgery is the prevention of infection. The orthopedic surgical prep must be meticulously carried out using aseptic technique. Physicians often instruct patients to complete a scrub prep with an antimicrobial agent before arrival for surgery. The surgical prep for the orthopedic patient may include preoperative removal of hair from the surgical site. Surgical shave preps contribute to the possibility of infection caused by abrasion and cutting of the skin. If hair removal from the incisional site is ordered, it should occur immediately before surgery, using clippers or a depilatory. If a razor is required, the site should be lathered with soap before shaving. Trauma patients require precautions during the skin prep to prevent further injury caused by solution contact with membranes or injury to the bone and soft tissue from movement.

Skin preparation is performed to remove microorganisms from the operative site. The site should be prepped with a broad-spectrum antimicrobial agent. The prep proceeds from the incision site to the periphery. Pooling of the prep solution beneath the patient or tourniquet must be avoided. Prep solutions should be allowed to dry before draping; this is a fire safety precaution and may be included in the time-out. The groin and anal areas should be isolated when the surgical site is on the upper third of the leg.

Devices such as leg stirrups may help support an extremity to complete a circumferential prep. When multiple extremities or other areas, such as a bone graft site, are prepped, cross-contamination of previously prepped areas must be prevented. Knowledge of aseptic technique and the ability to organize the activity are important in proper preparation of the surgical site.

Draping. Application of sterile drapes is the final step in preparing the patient for the operation. The surgeon and surgical technologist cover the patient's extremities with a cloth or water-impervious stockinette—a cylindric drape that is rolled up the arm or leg. Impervious sheets are essential when large

amounts of fluid are used, such as during arthroscopy and wound irrigation. Prefabricated disposable drapes with fenestrations for the upper and lower extremities are available.

Antimicrobial incise drapes can be used to isolate the surrounding area from the incisional site. Many of these drapes contain iodophor-impregnated adhesive, which slowly releases iodine during the procedure, inhibiting proliferation of organisms from the patient's skin. They are contraindicated for patients with an allergy to iodophors. An alcohol skin wipe may be done before placement of the antimicrobial incise drape.

Equipment and Supplies. Orthopedic ORs require a variety of special equipment and accessories in addition to routine OR equipment. Nitrogen-powered, battery-powered, and electrically powered equipment, video systems, pneumatic tourniquets, laminar airflow systems, x-ray equipment, lasers, and special orthopedic tables are included in the operative armamentarium. Manufacturers' pamphlets with illustrations and directions on equipment use and sterilization should be readily available for reference.

RADIOGRAPHIC INTERVENTION. Radiographic intervention is widely used in orthopedic surgery (History box). Many procedures require portable x-ray or fluoroscopy machines. Fluoroscopy, also known as *image intensification* or *C-arm,* allows the team to view the progression of the procedure, confirming fracture reduction or intramedullary reaming of the humerus, femur, or tibia. An x-ray technician operates radiographic equipment. An understanding of equipment placement, function, and safety precautions is necessary. The perioperative nurse is responsible for communicating with the radiology personnel concerning the procedure, aseptic technique, and traffic flow in the OR. X-ray cassettes brought onto the sterile field are draped with a sterile plastic cover. Lead aprons and thyroid shields are to be worn by all personnel in proximity to the x-ray equipment, and personnel should be monitored for exposure to radiation. Measures should be taken to protect patients from direct and indirect radiation exposure, and these should be documented on the perioperative nursing record.

PNEUMATIC TOURNIQUETS. Pneumatic tourniquets are frequently used for procedures involving the extremities (Figure 19-19). A tourniquet is a fabric-covered cylindric bladder inflated by compressed gas or ambient air. It applies circumferential pressure on arterial and venous circulation, which results in a relatively bloodless surgical field; this promotes visualization of structures during the procedure. Limb exsanguination is achieved by elevating the limb or by wrapping it, distally to proximally, with an Ace or Esmarch rubber bandage before tourniquet inflation. The majority of tourniquets used today are run by a microprocessor for regulation of pressure and time setting, providing both auditory and visual feedback for the user.

Tourniquet safety should be a priority; the surgical team should understand recommended parameters and precautions. Safety guidelines for the use of tourniquets include preventive measures and evaluation (AORN, 2009). Preoperative assessment of the patient includes determining contraindications for use, including compartment syndrome, McArdle disease (e.g., glycogen storage disease), hypertension, or other vascular problems. If the tourniquet must be used for patients with these conditions, specific guidelines must be observed.

Before application, the nurse checks tourniquet equipment for proper functioning. Inflation pressures are established

HISTORY

History of Medical Imaging

As humans became more aware of injuries and how to treat them, certain people in each culture accepted the responsibility and honor of healing. In some tribal cultures, that person was a medicine man, or bonesetter. Neolithic people may have had fractures splinted—probably with bark and sticks. Other tribes used clay, soaked strips of rawhide, and linen. Hippocrates described using a wooden rack to treat a fracture of the femur and using techniques such as traction and countertraction. However, bone healing as we know it today depended much on the development of imaging techniques.

The era of medical imaging began with the publication of *De Humani Corporis Fabrica* in 1543 by Andreas Vesalius. This comprehensive, detailed, and accurate set of anatomic illustrations set new standards in the art of medical observational science and research. Through direct observation, Vesalius conveyed his knowledge of the anatomy of the human body. These works were undisputed and stood the test of time until 1895, when Wilhelm Konrad Roentgen accidentally discovered x-rays (roentgenograms). Composed of high-energy electrons, x-rays are absorbed in varying degrees by structures in the body, based on their density and mass. The image is produced in two dimensions on photographic film and allows for indirect observation through a noninvasive technique. For the next 70 years, x-rays remained the standard in medical imaging until computerized axial tomography, or CAT scan, was introduced in 1972 by Godfrey Hounsfield. Detailed images of the body could be created by directing narrow x-ray beams at various angles. This was the first technique that incorporated computers into medical imaging. Since then, medical imaging has dramatically expanded, facilitating the surgical team's understanding of anatomy, physiology, and pathophysiology.

Modified from Gray JE, Orton CG: Medical physics: some recollections in diagnostic x-ray imaging and therapeutic radiology, *Radiology* 217(3):619-625, 2000.

FIGURE 19-19 Pneumatic gauge.

based on the systolic blood pressure, age of the patient, and circumference of the extremity. Duration of tourniquet inflation should be kept to a minimum. It is recommended in the average, healthy 50-year-old person to apply continuous tourniquet pressure less than 1 hour on the upper extremity and less than 2 hours on the thigh. Tourniquet pressure should not exceed the recommended maximum cuff pressure limits of 300 to 350 mm Hg for the thigh and 250 to 300 mm Hg for the arm and the lower leg. Kleinert and colleagues (2007) notes the interval between inflation and deflation should be 5 minutes for every 30 minutes of tourniquet ischemia to minimize effects on muscle and nerves.

The tourniquet should be placed on the extremity without compression on bony structures and superficial neurovascular structures. The person placing the cuff should ensure it is positioned as high as possible without pinching skinfolds. Soft padding or stockinette is wrapped around the extremity and kept free of wrinkles and gatherings beneath the cuff. Cuffs should overlap a minimum of 3 inches and a maximum of 6 inches; excess overlap can pinch skinfolds. A tourniquet cuff that is too short can loosen after inflation. Care must be taken to ensure that the line from the air supply to the cuff is not kinked.

Tourniquet equipment should be checked periodically and serviced when problems arise. Injury from tourniquets may result from inadequate precautions, faulty preparation, or use of inaccurate equipment. The gauges and other related equipment should be checked with commercially available test equipment. Patient evaluation requires assessment of the extremity (skin color, temperature, pulses, movement, sensation) after removal of the tourniquet. Abnormal findings need to be reported to the surgeon and documented (Evidence for Practice).

TRACTION. The surgeon uses traction preoperatively, intraoperatively, or postoperatively for prevention or reduction of muscle spasm, immobilization of a joint or body part, reduction of a fracture or dislocation, and treatment of a joint disorder. Traction alignment must be constant.

EVIDENCE FOR PRACTICE

Tourniquet Use

Recommended practices from AORN help the OR nurse effectively manage cases that involve tourniquets. Patient safety is the primary concern when using tourniquets intraoperatively. All OR personnel responsible for the tourniquet should be familiar with current standards. The primary purpose of the tourniquet is to occlude blood flow to the extremity, providing a bloodless surgical site. Competency associated with the use of tourniquets should be demonstrated by the OR staff. All tourniquets should be maintained according to manufacturers' guidelines including cleaning, sterilizing, and testing. Disposable tourniquets are now available for single use. The integrity and function of the base unit should be tested before each use. Personnel should be familiar with the application of the tourniquet, recommended pressures, maximum times for inflation for extremities, and contraindications for tourniquet use. OR personnel should be aware of the risks of exceeding the time limits and should inform the surgeon at regular intervals of the tourniquet inflation time. The nurse is responsible to assess and document patient outcomes at the end of the procedure.

Modified from Association of periOperative Registered Nurses (AORN): *Perioperative standards and recommended practices,* Denver, 2009, The Association.

Various traction techniques can be used, including manual, skin, and skeletal (Figure 19-20). In manual traction, the hands provide the forces pulling on the bone being realigned. Skin traction uses strips of tape, digital straps, moleskin, or an elastic bandage applied directly to the skin. Common forms of skin traction are Buck's extension and Russell traction. Skeletal traction applies forces directly to the bone, using pins. Manual and skin traction can be applied in the emergency department or patient room, whereas skeletal traction is applied preoperatively in the emergency department or in the OR.

Skeletal traction is often used in conjunction with the OR fracture bed, using the traction attachment to aid in reduction of a long bone fracture. Postoperatively the patient may be confined to bed with balanced skeletal traction using a Thomas splint (Figure 19-21) and a Pearson attachment. Some cervical spine fractures or injuries may require Crutchfield or Gardner-Wells tongs or a cervical halo inserted directly into the skull to stabilize the vertebrae and reduce spinal cord damage or further injury. Application of skeletal traction requires the use of sterile supplies, including a traction bow, pins, and drill.

The perioperative nurse ensures the patient's postoperative bed is prepared with the correct traction frames. Nursing care of the patient in traction should include ensuring that the traction is continuous and skin tapes or skeletal pins are secured. Neurovascular status should be checked routinely, including skin color, pulse, temperature, and sensation. Changes from baseline or normal value must be reported.

POSTOPERATIVE IMMOBILIZATION. Postoperative immobilization may require use of a cast, splint, or other supplies designed for the specific anatomic part. A cast is a common method of immobilizing a fractured bone during healing (Patient and Family Education). The forces of distraction, rotation, and malalignment can be overcome with the application of a cast. Closed reduction with a cast may be an option, thus minimizing the disadvantages and complications of open reduction, such as infection and tissue damage.

The surgeon uses plaster or synthetic materials such as fiberglass for casting. Plaster is less expensive, with a greater weight/strength ratio (it requires a greater weight of plaster to produce the same strength of fiberglass). Plaster casts may be burdensome if the casts are too heavy. They are routinely used as the primary cast after surgical procedures and are replaced later with a lighter fiberglass cast to promote patient mobility.

Casting material sets up and hardens rapidly once activated with water, and such a property necessitates that it be prepared with all necessary materials. Soft padding or stockinette should be applied to the extremity before the cast is applied to protect the skin from thermal injury while the plaster sets, as well as to protect the skin from undue abrasion and pressure. The plaster must be prepared, applied, and handled carefully and safely.

Figure 19-22 shows types of casts. After wrist fractures, the surgeon applies a short arm cast from below the elbow to the metacarpal heads. A long arm cast extends from the axilla to the metacarpal heads, immobilizing forearm or elbow fractures. The surgeon uses a short leg cast, applied from the tibial tuberosity to the metatarsal heads, to immobilize the ankle and foot. The long leg cast is used for fractures involving the femur, tibia, or fibula or for complicated ankle fractures. The femoral cast brace is used in the treatment of femoral shaft fractures.

PATIENT AND FAMILY EDUCATION

Casts

EXPLANATION OF THE CAST

The cast is only one of several devices used to promote the healing of broken bones. Surgeons also use traction and pins, or a combination of these three devices, to help heal broken bones. The cast has the advantage of being less expensive, requiring little care on the patient's part, and allowing them to move around. The cast also encloses and immobilizes the broken bone and injured soft tissues to prevent movement that could cause further injury and to keep the bone in place for proper healing. The cast may be made of plaster or of a synthetic material, such as fiberglass. Although the plaster cast is heavy, the surgeon can mold a plaster cast more easily for a close fit over severe injuries. The synthetic cast is lightweight and easier to move around.

CAST CARE

- Keep a plaster cast dry; cover it or wrap it in a plastic bag when bathing or going out in the rain or snow.
- Check with the surgeon about immersing a fiberglass (or other synthetic) cast in water. The surgeon may permit immersion if there are no surgical wounds under the cast.
- Maintain good skin care around the cast. However, do not:
  - Insert objects, such as a coat hanger, under your cast.
  - Put any creams, lotions, or powder inside the cast.

THINGS TO WATCH FOR AND REPORT TO YOUR SURGEON OR NURSE

The skin under the cast will feel warm at first because of the reaction that occurs during the setting process. However, warm areas on the cast later may indicate infection, and notify the surgeon or nurse at once.

Watch for increased pain or soreness under the cast, particularly around a bony prominence such as the wrist or ankle, that is not relieved by repositioning the body. Check the skin color and temperature periodically. When the tip of a finger or the big toe that extends from the cast is squeezed until it is white, the pink color should return within 4 to 6 seconds. If skin color does not return within 4 to 6 seconds or if the skin is red, blue, white, or otherwise discolored, notify the physician. If fingers or toes are cool, cover them. If they do not warm up in 20 minutes, call the physician. Call the physician immediately if any of these other symptoms occur:

- An increase in swelling and pain. Some swelling is common at first. The surgeon may have advised to elevate the cast after it was applied. The cast should feel snug for the first 48 hours. If it continues to feel too snug and causes pain and swelling, call the surgeon.
- A tingling or burning sensation.
- An inability to move muscles around the cast.
- A foul odor detected around the edges of the cast.
- Any drainage that may show through the cast.
- Any cracks or breaks in the cast.
- Marked loosening of the cast, allowing the parts inside the cast to move fairly easily.

Modified from Canobbio MM: *Mosby's handbook of patient teaching,* ed 3, St Louis, 2006, Mosby.

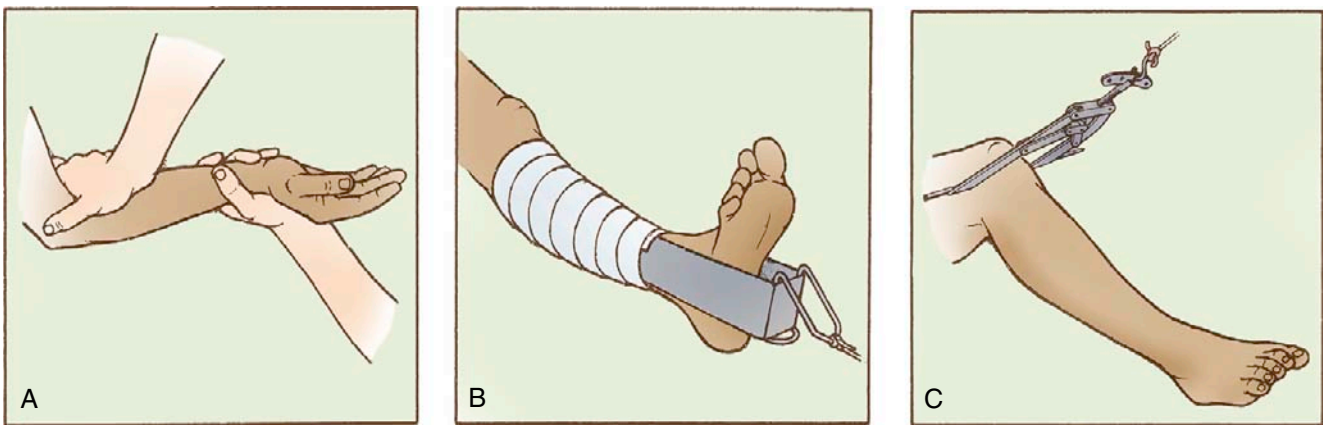


FIGURE 19-20 Traction techniques. **A**, Manual. **B**, Skin. **C**, Skeletal.

A snug-fitting thigh cast and short leg cast are hinged at the knee joint. The cast brace is generally used after 4 to 6 weeks of skeletal traction after initiation of callus formation at the fracture site. A cylinder cast incorporates the leg from the groin to the ankle and is applied when complete knee immobilization is required. This is often required after surgery involving soft tissue reconstruction around the knee.

The hip spica cast is used when complete leg immobilization is desired. The patient's trunk, affected side, and unaffected side may all be incorporated into the cast. Spinal immobilization is accomplished with a body jacket.

Splints may also be employed for postoperative immobilization but are not circumferential and allow for swelling and closer observation of the surgical site.

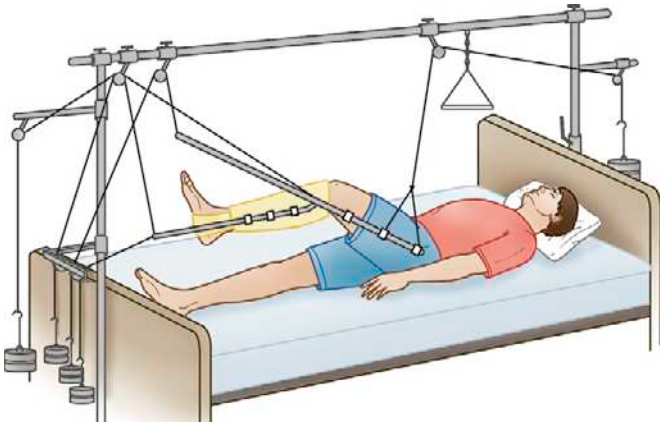


FIGURE 19-21 Thomas splint balanced suspension.

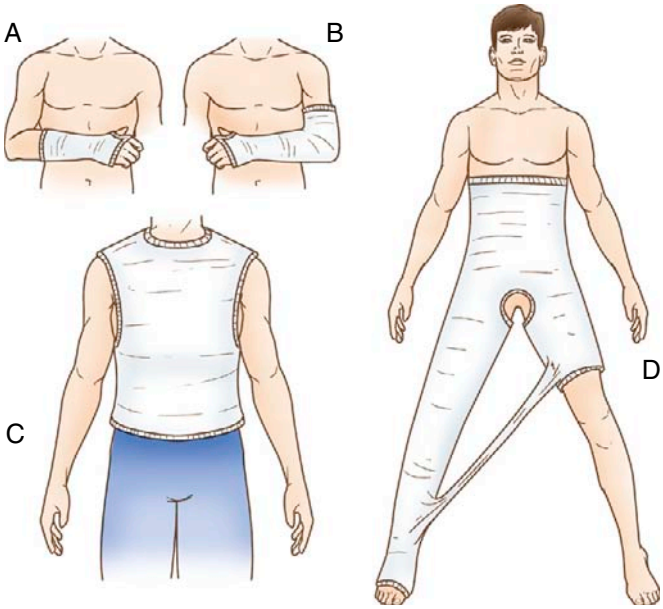


FIGURE 19-22 Types of casts. **A**, Short arm cast. **B**, Long arm cast. **C**, Plaster body jacket cast. **D**, One and one half hip spica cast.

Another immobilization device is the abduction pillow, used after total joint replacement. This prevents the patient's leg from adducting, or rotating internally, and the hip from flexing, which could cause dislocation of the hip. Further discussion of this and other devices is included with the description of various surgical interventions.

LASERS. Laser application has been increasing in the field of orthopedics. Their use mandates safety precautions, certification, patient consent, and protective attire (see Chapter 7 for a full discussion of lasers and laser safety). Laser types include carbon dioxide, holmium:yttrium-aluminum-garnet (Ho:YAG), neodymium:YAG (Nd:YAG), potassium titanyl phosphate (KTP), erbium:YAG (Er:YAG), and excimer. Laser technique differs for use on bone, muscle, tendon, and cartilage. Lasers have been used successfully for osteotomy, revision arthroplasty (removal of polymethylmethacrylate), nerve and tendon repair, arthroscopy, and discectomy.

AIRFLOW CONTROL. Airflow control in the orthopedic OR is critical to prevent introduction of microorganisms.

FIGURE 19-23 Body exhaust system used in arthroplasty.

FIGURE 19-24 Continuous passive motion (CPM) machine used for passive range of motion.

Surgical site infections may result from airborne bacteria or transient bacteria from the patient or surgical team (AORN, 2009). Laminar airflow is a system designed to provide highly filtered air and continuous air exchange for reducing airborne bacteria. Body exhaust suits are also used as a defense against airborne bacteria (Figure 19-23). Aseptic practices, sterile technique, and conscientious behaviors in ORs using conventional airflow can be used to maintain low rates of surgical site infections.

POSTOPERATIVE MANAGEMENT. The nurse begins planning the patient's postoperative management during the preoperative period. Special equipment may include continuous passive motion (CPM) machines, pain management devices and techniques, compression devices, and blood salvage. CPM machines (Figure 19-24) stimulate the healing effect on articular tissues, including cartilage, tendon, and ligaments, without interfering with healing incisions over the moving joint. The benefits of CPM include inhibition of adhesion formation and joint stiffness, decreased pain and swelling, early functional range of motion, and decreased effects of immobilization. The device is applied early in the postoperative period.

PATIENT AND FAMILY EDUCATION

Educating the Patient and Family on Pain Management at Home

Give the patient and the caregiver both *verbal* and *written* instructions. After reviewing instructions, have the patient or caregiver "repeat back" the instructions in his or her own words. Provide the patient or caregiver with the name and telephone number of a physician or nurse to call if questions arise.

GENERAL INFORMATION

- Explain the relationship of pain to the disease process. Assist the patient to understand the source of pain.

SPECIAL INSTRUCTIONS

- Assist the patient to identify factors or actions that trigger pain, such as activity, movements, and temperature extremes.
- Discuss past effective and ineffective pain-relief measures and their effects, such as sleepiness, lethargy, and decreased energy or sexual activity.
- Assist the patient to localize and describe the intensity of pain using a scale (e.g., 0 to 10, with 0 meaning absence of pain and 10 meaning intense pain) and to identify any alleviating or aggravating factors.
- Encourage use of a log to record pain rating and effectiveness of management strategies.
- Discuss alternative strategies patients can use to relieve pain without taking prescribed drugs, and explain that these techniques may also augment the effect of pain medication (see Pain Management Techniques below).
  - *Sensory interventions: massage*—to relax muscular tension and increase local circulation; *range-of-motion exercises* (passive, assistive, or active)—to relax muscles, improve circulation, and prevent pain related to stiffness and immobility; *cold application*—used initially to decrease tissue injury response (swelling) and decrease pain; *heat application*—used after cold to aid in clearance of tissue toxins and mobilize fluids; *transcutaneous electrical nerve stimulation (TENS)*—pocket-size, battery-operated device used to send mild continuous electrical impulses through the skin by means of electrodes placed on the body
  - *Emotional interventions:* to increase pain threshold by controlling or reducing anxiety, fatigue, or depression: prevention or control of anxiety—to reduce muscle tension and increase pain tolerance through relaxation exercises and slow, controlled breathing; *promotion of self-control*—to reduce feelings of helplessness and lack of control that contribute to anxiety and pain; pacing of activities
  - *Cognitive interventions: distraction*—focus on something unrelated to pain (e.g., conversing, watching television or videos, listening to music); *humor; guided imagery*—use of images to alter a physical or emotional state, promote relaxation, and decrease pain sensation
- Discuss the need to identify body positions of comfort; encourage attention to proper posture and body alignment. Advise the patient to immobilize or rest the affected area.
- Tell the patient to relieve pressure areas by turning or using pressure-reduction devices.

PAIN MANAGEMENT TECHNIQUES

- *Relaxation:* relieves pain by easing muscle tension. This can also help you feel less tired and nervous and help other pain-relieving methods work better.
- How to relax:
  - Sit or lie down in a quiet place. Be sure you are comfortable. Do not cross your legs or arms. Take a deep breath, and tense your muscles (you may tense your entire body or concentrate on one set of muscles at a time, such as your facial muscles or those in your arms and hands).
  - Hold your breath, and keep your muscles tense. Release your breath and your muscles at the same time. Let your body go limp (repeat for other muscle areas if you are concentrating on one set at a time).
  - You can add imagery or music to help you relax. Relaxation tapes are available from your healthcare agency or local music store.
  - Do not be discouraged if relaxation does not help immediately. Practice the relaxation technique for at least 2 weeks before you give it up. If you find that it aggravates your pain, try another method.
- *Imagery:* involves using your imagination to create mental scenes that use all your senses: sight, sound, touch, smell, and taste. You can imagine exotic locations or revisit one of your favorite places. You can create stories and characters to add to your scenes. Imagery can take your mind off your fear, boredom, and pain.
- How to use imagery:
  - Close your eyes. A few moments of the relaxation techniques (see above) will help your body and mind prepare for imagery. Let your mind begin forming its image. The following is an example of imagery: Imagine that you are at the seashore. You are sitting in the wet sand; the afternoon sun is warm on your shoulders. The ocean rolls into the shore in gentle waves, and the water laps teasingly at your toes. A hungry pair of seagulls cries overhead and takes swift, darting dives at a dog that is scavenging along the shore. Your tension lessens with each wave that touches your toes and retreats. You close your eyes and take a deep, slow breath of air. You are completely relaxed. Stay on the beach as long as you like. To end the image, count to three and open your eyes. Resume your regular activities slowly.
- *Distraction:* any activity that takes your mind off your pain and focuses your attention elsewhere. Doing crafts, reading a book, watching television, or listening to music through headphones can distract your mind. Distraction works well when you are waiting for drugs to take effect or if you have brief bouts of pain. Sometimes people can take their minds off their pain for long periods, especially if the pain is mild.
- *Skin stimulation:* used to block pain sensation in the nerves. Pressure, massage, hot and cold applications, rubbing, and mild electrical current are all ways to stimulate the skin. If you are having radiation therapy, consult your physician before applying any skin stimulation. You can do the stimulation at the site of the pain, near it, or on the side opposite the pain. For example, stimulating the left wrist when the right wrist is in pain can actually ease the pain in the right wrist.

PATIENT AND FAMILY EDUCATION

Educating the Patient and Family on Pain Management at Home—cont'd

PAIN MANAGEMENT TECHNIQUES—cont'd

- How to use skin stimulation:
  - *Pressure:* using your entire hand, the heel of your hand, your thumb, your knuckles, or both hands, apply pressure for at least 15 seconds at the point where you feel pain. Keep trying spots around the painful area if you find no relief the first time. You may extend the time you apply pressure to 1 minute.
  - *Massage:* you or someone else can perform the slow, circular motions of massage. The feet, back, neck, and scalp can be massaged to relieve tension and pain anywhere in the body. Some people prefer to use oils or lotions during the massage. If deep massage is too uncomfortable, try light stroking. Do not massage red, raw, or broken skin.
  - *Heat and cold:* some people prefer cold; others prefer heat. Use whichever works better for you. A convenient way to use cold is to freeze gel-filled packs and wrap them in towels. Ice cubes can also be used. Heat can be applied with a heating pad; hot, moist towels; or a hot water bottle; or by taking a hot bath. Be careful not to burn your skin with water that is too hot or to go to sleep with a heating pad on. Do not expose your skin to intense cold for long periods.

MEDICATIONS

- Explain the purpose, dosage, schedule, and route of administration of any prescribed drugs, as well as side effects to report to a physician or nurse. Be sure the patient or caregiver knows the name of the medication.
- Give the patient general guidelines for the use of pain medication.
- Explain that a variety of pain-relief measures may be necessary for some types of pain.
- Instruct the patient to use pain-relief measures before pain becomes severe.
- Encourage the patient to try a pain-relief measure at least twice before abandoning it as ineffective.
- Urge the patient to keep trying to relieve the pain and not to become discouraged.
- Discuss the use of non-narcotic analgesics:
  - Inform the patient that non-narcotic analgesics include acetaminophen, aspirin, and nonsteroidal antiinflammatory drugs, such as ibuprofen, indomethacin, and naproxen.
  - Explain that these medications are generally well tolerated but have the potential to cause gastrointestinal ulceration, renal and hepatic toxic effects, and inhibition of platelet aggregation.
  - Tell the patient that if the non-narcotic does not have a therapeutic effect initially, the dosage should be increased before another type of drug is tried.
- Discuss the use of narcotics, which are indicated for severe postoperative pain or intractable pain such as that associated with cancer:
  - Inform the patient that narcotics include morphine, hydromorphone, and methadone and that these may be administered by intravenous drip, intrathecally, or epidurally to enhance the analgesic effect.
  - Explain that fixed dosage schedules with adequate doses for pain relief provide more constant blood levels and predictable pain relief. Suggest that additional doses may be needed for breakthrough pain.
  - Discuss the side effects of narcotic analgesics: constipation, vomiting, and respiratory and central nervous system depression.
- Discuss and demonstrate the use of equipment for administering pain-relief medications:
  - External and implantable pumps for intravenous, epidural, and intrathecal administration of narcotic analgesics
  - Patient-controlled analgesia (PCA), particularly for the management of acute pain such as postoperative pain
  - Continuous subcutaneous infusion with an ambulatory infusion pump
- Discuss the treatment for side effects of narcotics. For example, constipation requires the use of laxatives and stool softeners (e.g., senna [Senokot]).

Modified from Canobbio MM: *Mosby's handbook of patient teaching,* ed 3, St Louis, 2006, Mosby.

RISK REDUCTION STRATEGIES

Deep Vein Thrombosis Prevention in Orthopedic Procedures

Prevention of venous thromboembolism is a major consideration for patients undergoing orthopedic surgery, especially total joint arthroplasty. The *American College of Chest Physicians Evidence-Based Clinical Guidelines* for use of antithrombic and thrombolytic agents and therapy contain review of the literature, expert opinions, and recent clinical trial evaluations. Approximately 40% to 60% of orthopedic hip and knee arthroplasty patients develop deep vein thrombosis postoperatively. Additional risk factors for orthopedic patients include age greater than 75, malignancy, immobilization, and the use of certain medications. Currently, surgeon preference influences which anticoagulation therapy is initiated after surgery (see Surgical Pharmacology, p. 742). The ACCP recommendations include that all hospitals have a formal, institutional-wide written policy addressing thromboprophylaxis. The policy would include dividing patients into categories of low, moderate, or high risk. Thromboprophylaxis would be provided when its benefit outweighs the risk. Regular reassessment is necessary.

From Geerts WH et al: Prevention of venous thromboembolism: American College of Chest Physicians evidence-based clinical practice guidelines, *Chest* 133:381S-453S, 2008; *Joint Commission National Patient Safety Goals, NPSG.03.05.01,* available at www.jointcommission.org/NR/rdonlyres/31666E86-E7F4-423E-9BE8-F05BD1CB0AA8/0/HAP_NPSG.pdf. Accessed June 16, 2009.

RAPID RESPONSE TEAM

Rapid response teams (RRTs) were developed and implemented as a challenge from the Institute for Healthcare Improvement. Evidence showed cardiac arrest or unplanned ICU visits were preceded by signs of physiologic instability. Development of RRTs led to patient intervention before cardiac or respiratory arrest, preventing further deterioration of the patient, and improved patient outcomes. Cardiac emergency teams and rapid response teams were clearly defined by the Consensus Conference of Medical Emergency Teams in 2005. RRTs are nurse-led with intermediate interventional capabilities, as compared to physician-led medical emergency teams.

McFarlan and Hensley reported that the University of Kentucky Hospital (UKH) implemented such a program. The UKH used Failure to Rescue criteria as defined by the Agency for Healthcare Research and Quality. Failure to Rescue includes the development of the following diagnoses during an inpatient admission that result in death: sepsis, acute renal failure, venous thromboembolism, gastrointestinal hemorrhage or acute ulcer, pneumonia, shock, and cardiac arrest. The goals of the UKH RRT included an interdisciplinary approach for early recognition and intervention of the signs of clinical decline in the acute adult care setting and to expedite a higher level of care as needed. Roles and responsibilities were defined and physician support was elicited. The RRT formulated an "early warning signs" list, created an algorithm for activation of the RRT, and used the situation, background, assessment, and recommendation (SBAR) format for communication among healthcare providers. Education of the staff was key. Initial evaluation after the implementation of the UKH program was encouraging. Patient tracking included cardiac arrests, which showed an 8% decline within the first 2 years after implementation. Continued data analysis has led to future goals of the RRT at UKH including preadmission assessment for prediction of admission to ICU and patient outreach.

From McFarlan SJ, Hensley S: Implementation and outcomes of a rapid response team, *J Nurs Care Qual* 22 (4):307-313, 2007.

Pain management may include insertion of an epidural catheter, use of a patient-controlled analgesia (PCA) pump, or local administration of pain medication through a pain pump. The advantages of using these techniques include rapid pain relief, increased patient satisfaction, and, often, less use of medication than with traditional intramuscular analgesics. These techniques can be used independently or in combination. In using the PCA pump, a predetermined intravenous dose of the prescribed pain medication is administered. It allows continuous infusion of analgesic as well as bolus administration when the patient feels it is necessary (Patient and Family Education).

Management of fluid and electrolyte balance may include use of intraoperative autologous transfusion or postoperative blood salvage. A potential problem with salvage of large amounts of blood is depletion of clotting factors; therefore coagulation problems should be identified (Risk Reduction Strategies). Postoperative blood salvage is accomplished with a closed-drainage system. It requires a complete understanding of the system for safe use (Rapid Response Team box).

Instruments and Accessory Items. Orthopedic surgical procedures require an extensive inventory of instruments and implants and specific instruments to implant and apply hardware. Revision surgery requires that the perioperative staff be prepared with the appropriate tools and extractors needed to remove an old implant and an understanding of equipment use.

IMPLANT INVENTORIES. Implant inventories include plates and screws, intramedullary nails and rods, total joint implants, and a host of accessory items. Surgeon preference, patient population, and equipment cost are considered when selecting stock items. The surgical team must ensure these items are stocked in a timely fashion to prepare for consecutive implant use.

Inventory should be organized by manufacturers, type of implants (e.g., total hip, knee), and comparative sizes. Some may be provided on a loaner or consignment basis. Staff must be familiar with the varied types and refer to manufacturer's information pertaining to each implant. Practices should ensure that the correct implant is opened on the operative field to prevent unnecessary expense or error in placement.

Many different alloys are used in the manufacturing of implants. However, all devices implanted in a patient must be of the same metallic composition to prevent galvanic corrosion; internal fixation implants used during an orthopedic procedure should be of the same metal. Screws, for example, should be of the same composition as the metal plate affixed to the bone. Alloys that are used most frequently include stainless steel, cobalt-chromium, and titanium-vanadium-aluminum.

Internal fixation devices should never be reused. Resulting imperfections, such as abrasions or scratches, increase the potential for corrosion and weakening of the implant. Bending implants to conform to the contour of the bone should be avoided whenever possible to prevent loss of strength. When bending is necessary, the proper bending press should be used. Once an implant is bent, it should not be reshaped or straightened; doing so may weaken the implant.

Orthopedic equipment and implants require special care, storage, and handling. When possible, implants should be individually wrapped and processed. Today's implants, excluding some plates and screws, are packaged separately by the manufacturer. During sterilization, implants should not be placed in a position in which knocking or bumping might occur. Appropriate sterilizing cases and trays should be used, and implants should be sterilized according to the manufacturer's instructions. An internal fixation device that has become damaged as a result of improper storage or handling must be discarded.

The perioperative nurse assigned to orthopedic patients should have a working knowledge of the general types and sizes of implants that might be selected. Templates of radiographs are often made preoperatively, providing a general idea of the size of the implants needed.

The U.S. Food and Drug Administration (FDA) requires strict guidelines in properly documenting and tracking implant devices. Documentation should include, but not be limited to, the patient's permanent record, the operative record, and an implant registry maintained by the OR. Many manufacturers

now include mailers to return information to the company for data collection. Information to be recorded includes the lot and serial numbers of those implants used and the manufacturer, size, type, and anatomic position of the implants.

ORTHOPEDIC INSTRUMENTATION. Orthopedic instrumentation varies from very small to large instruments. Some procedures require multiple instrument containers (sets). Organization of instrument sets for multiple uses prevents the need for duplication and requires thoughtful consideration of anatomic and physiologic needs. When preparing for a procedure, the perioperative nurse should open the minimum number of instruments yet be prepared for unexpected or untoward events. Careful planning and preparation of instrumentation ensure efficient use of time and equipment.

Instruments that do not function properly (as a result of dullness, poor adjustment, lack of lubrication, damage, improper fit, or incomplete cleaning) are primary sources of complaints and problems in the OR. Instrument maintenance is vital to ensure availability for the procedure and ease in completion of the procedure. Instruments should be used for the intended purpose during the procedure. Movable parts should be lubricated after each cleaning and checked for cracks or damage after each use. The perioperative nurse is responsible for instrument maintenance and familiarity with sterilization and packaging procedures.

The following basic bone instrument sets should be available in the orthopedic OR. Soft tissue instrument sets appropriate for the size of the anatomic site are used for procedures not requiring bone instruments or in addition to the sets. Additional instruments and special equipment are mentioned with the discussion of various surgical interventions.

- *Incision hip set:* total hip arthroplasty or fractures of the neck and proximal femur
- *Total knee set:* total knee arthroplasty or supracondylar and distal femoral fractures
- *Shoulder set:* shoulder arthroplasty and other shoulder procedures
- *Large bone set:* bone work on the large bones, including hip, knee, upper arm, and elbow
- *Extremity or small bone set:* bone work on the hand or foot
- *Fusion or bone graft instruments:* additional instruments necessary for an autograft

POWERED SURGICAL INSTRUMENTS. Powered surgical instruments (Figure 19-25) used in the OR have eliminated the need for many hand-operated tools, thereby reducing operative time and improving technical results. They are available as air-driven, battery-driven, or electrically driven equipment. Fingertip control provides the surgeon speed and power. Variable-speed saws, drills, and reamers offer wide flexibility. Power equipment has a safety control that prevents inadvertent activation; this should be engaged when passing the instrument to the surgeon or assistant. The perioperative nurse and surgical technologist should monitor the sterile field to make certain that powered instruments are not rested on the patient when they are not in use.

It is important to follow the manufacturer's recommended cleaning, sterilizing, and lubricating instructions. With proper care, powered surgical instruments have a long life span and many uses.

SUTURE MATERIAL. Suture material requires increased tensile strength and minimal degradability for the select type of tissue. Tendons and ligaments are fibrous, avascular tissues, resulting in a slower healing process than that occurring in tissues rich in blood supply. Absorbable suture may be used for sewing tendon or ligaments to bone. Nonabsorbable sutures, including polyester and surgical steel, are also used. For various ligament replacement grafts, a harvested tendon may be customized with multiple strands of suture material, increasing tensile strength and length of time until fibrous union occurs.

POLYMETHYLMETHACRYLATE. PMMA (bone cement) is an acrylic, cementlike substance composed of a liquid methylmethacrylate monomer and a powder methylmethacrylate-styrene co-polymer. The powder component is 10% barium sulfate, U.S. Pharmacopoeia (USP), which provides radiopacity

FIGURE 19-25 Pneumatic-powered surgical instruments for large bone procedures. **A**, Reciprocating saw. **B**, Oscillating saw. **C**, Single-trigger modular handpiece.

to the finished product. The liquid monomer is highly flammable, and the OR should be properly ventilated. Caution should be exercised during mixing of the two components to prevent excessive exposure of OR personnel to the vapors of the monomer. This exposure can cause irritation of the respiratory tract and eyes. Personnel in a room where methylmethacrylate is being mixed should not wear soft contact lenses. Many special hoods and mixing devices are available to minimize staff exposure to the fumes.

Adverse patient reactions with PMMA include transitory hypotension, cardiac arrest, cerebrovascular accident, pulmonary embolus, thrombophlebitis, and hypersensitivity reaction. Cardiac arrest and death, although uncommon, have resulted after insertion of bone cement. Adverse reactions have been attributed to a combination of factors, including a rise in intramedullary canal pressure causing embolic phenomena, a possible chemical and blood reaction causing sudden hypotension, and certain preexisting patient conditions. More research is needed to discover the exact cause of adverse reactions. Patient care should include collaborating with the anesthesia provider before insertion of PMMA and then monitoring for side effects after insertion.

Medications. Antibiotics, hemostatics, and antibacterial agents are used commonly. Antibiotics are delivered both intravenously and locally in irrigation solutions. Common antibiotics used in irrigation include polymyxin and bacitracin. Irrigation may also be delivered using pulsatile lavage, with antibiotics added to the solution. Hemostatic agents may include bone wax, gelatin foam, thrombin, microfibrillar collagen, and parecoxib sodium. Parecoxib sodium is a liquid, sprayable hemostatic agent consisting of collagen, thrombin, the patient's own platelets, and fibrinogen. Antibacterial ointments are preimpregnated in gauze dressings from the manufacturer or are applied before the application of the dressing. Other medications used during orthopedic procedures include steroids, local anesthetics, and normal saline. Local anesthetics are often injected near the end of the surgical procedure to minimize postoperative pain.

SURGICAL PHARMACOLOGY

Anticoagulation Therapy

Venous thromboembolism (VTE), including deep vein thrombosis (DVT) and pulmonary thromboembolism (PE), is one of the most common preventable causes of hospital death. More than 900,000 Americans experience DVT each year, and 500,000 of these persons develop PE, which causes approximately 300,000 deaths. Analysis of related data has suggested that fewer than 50% of patients diagnosed and hospitalized with DVT had received prophylaxis. In 2003, recognizing that the incidence of DVT/VTE was a significant patient safety issue, the National Quality Forum (NQF) endorsed Safe Practice 17: *Evaluate each patient upon admission, and regularly thereafter, for the risk of developing DVT/VTE. Utilize clinically appropriate methods to prevent DVT/VTE,* and Safe Practice 18: *Utilize dedicated anticoagulation services that facilitate coordinated care management.*

In addition, the Surgical Care Improvement Project (SCIP) targeted DVT as a key area for improvement in surgical patient care. SCIP is a national partnership of organizations committed to improving the safety of surgical care through the reduction of postoperative complications, with a goal of reducing the incidence of surgical complications nationally by 25% by the year 2010. SCIP identified two process measures in the reduction of VTE: (1) that surgery patients have the appropriate VTE prophylaxis ordered and (2) that it be administered within 24 hours before their surgery or within 24 hours after it.

More than 50% of major orthopedic procedures are complicated by DVT, and up to 30% by PE, if prophylactic treatment is not instituted. DVTs in the perioperative period involve several components, including venous stasis, acquired hypercoagulable state, endothelial injury, and the positioning of the limb intraoperatively. Despite the well-established efficacy and safety of preventive measures, studies show that prophylaxis is often underused or used inappropriately. Both low-dose unfractionated heparin (LDUH) and low-molecular-weight heparin (LMWH) have similar efficacy in DVT and PE prevention.

Some common drugs used to prevent DVT and their mechanisms of action are as follows:

- *Ardeparin*—LMWH; prevents conversion of fibrinogen to fibrin and prothrombin to thrombin by enhancing inhibitory effects of antithrombin III; used for preventing DVT after total knee arthroplasty (TKA)
- *Danaparoid*—glycosaminoglycan; prevents conversion of fibrinogen to fibrin and prothrombin to thrombin by enhancing inhibitory effects of antithrombin III; used for DVT prevention in total hip replacement or hip fracture surgery
- *Desirudin (Iprivask)*—thrombin inhibitor; prevents thrombin, resulting in prolongation of clotting time; used for DVT prophylaxis in hip replacement surgery
- *Enoxaparin (Lovenox)*—LMWH; prevents conversion of fibrinogen to fibrin and prothrombin to thrombin by enhancing inhibitory effects of antithrombin III and produces higher ratio of anti–factor Xa to anti–factor IIa; used for prevention of DVT and PE in hip and knee replacement surgery
- *Heparin (Calcilean, Calciparine, Hepalean, heparin sodium, Heparin LEO, heparin lock, Hep-Lock)*—anticoagulant and antithrombotic; prevents conversion of fibrinogen to fibrin and prothrombin to thrombin by enhancing inhibitory effects of antithrombin III; used for prevention of DVT and PE
- *Warfarin (Coumadin, Sofarin, warfarin sodium, Warfilone Sodium)*—anticoagulant; interferes with blood clotting by indirect means; depresses hepatic synthesis of vitamin K–dependent coagulation factors (II, VII, IX, X); DVT and PE prevention

Patient education should include the reason for DVT prophylaxis, the name (both generic and trade) of the drug, dosage, time of administration, and side effects. Because bleeding is a dangerous complication, signs and symptoms of both minor bleeding and major bleeding should be reviewed. Patients should receive both oral and written information along with the name of a physician or nurse to call if complications or questions arise.

Modified from Canobbio MM: *Mosby's handbook of patient teaching,* ed 3, St Louis, 2006, Mosby; SCIP: *A national quality partnership,* available at www.qipa.org/shared/content/pa_documents/Patient%20Safety%209SOW. Accessed June 23, 2009; Skidmore-Roth L: *Mosby's drug guide for nurses with 2010 update,* ed 8, St Louis, 2009, Mosby.

Protective Measures. Orthopedic procedures require caution as a result of the use of fluids for irrigation or bloody procedures. Personnel protective measures include handling items (blades, sharp instruments, bone) cautiously to prevent inadvertent punctures or cuts and wearing protective masks, eyewear, or a face shield as well as protective attire, including gowns and boots. Sharp bone edges are a hazard and can puncture gloves and skin. Double-gloving or use of protective gloves should be employed to protect the patient and personnel.

Bone Banking. The American Association of Tissue Banks (AATB) accredits and periodically inspects bone-banking programs to ensure that specific standards are followed in the retrieval, processing, storage, and distribution of bone allografts (AATB, 2008). Allografts are frozen until use. Vacuum-sealed freezers are monitored with an alarm. When requested for a procedure, the bone allograft is delivered to the field, slightly thawed, cultured, and washed with an antibiotic solution. Banked bone is available in many shapes of cortical and cancellous tissue.

Records are maintained on both donors and recipients. Donor records provide the donor identification, medical history (with circumstances of death if applicable), laboratory results, and graft description. Recipient records include recipient identification, surgeon and organization implanting the graft, surgical procedure, culture results, and any adverse reactions. Like other implants, the recipient's operative record should include the name of the bone bank from which the allograft was received, type of allograft, tissue number, and expiration date if applicable.

Evaluation

Evaluation is an ongoing process, occurring throughout the procedure. The perioperative nurse evaluates the patient, considering the nursing diagnosis and achievement of identified outcomes. This part of the nursing process provides feedback regarding the effectiveness of the plan, its implementation, and alterations needed for improving patient care. Was the patient protected from peripheral neurovascular injury? Was the patient free from perioperative positioning injury? Was adequate oxygenation maintained? Does the patient have more questions pertaining to recovery and rehabilitation? The answers will dictate whether there is a need to maintain or modify the plan. The evaluation information is shared with the nurse caring for this patient postoperatively to provide continuity of care.

The following sample outcome statements apply to evaluating care of the orthopedic patient when using the nursing diagnoses identified earlier in this chapter:

- The patient verbalized fears and feelings and indicated that anxiety and apprehension were lessened.
- The patient was free from peripheral neurovascular dysfunction on discharge to the postoperative area as evidenced by presence of pulses, warmth of the extremity, good capillary refill, and intact movement and sensation.
- The patient was free from injury related to perioperative positioning as evidenced by maintenance of skin integrity and absence of reddened areas.
- The patient maintained adequate ventilation and perfusion as evidenced by blood gases, arterial saturation, and vital signs within normal limits.
- The patient was free from surgical site infection as evidenced by temperature within normal limits and a clean and dry incision site.

Patient and Family Education and Discharge Planning

Discharge planning and patient education should be initiated when the healthcare provider evaluates the patient for surgery. It should continue when the patient comes into contact with the healthcare system and should involve a multidisciplinary approach. A method of planning the overall care from preadmission to discharge is to place a patient on a clinical guideline or care path based on "best practice"—a multidisciplinary case management tool. "Best practices" define the expected processes of care. Essentially they are strategies of care developed with the intent of encouraging physicians and other healthcare providers who care for the same surgical patient population to agree to a specific sequence of common interventions. Included with the clinical guideline on the patient's medical record is a set of orders that mirrors the guideline and allows the physician to make minor changes to the protocol. Receiving feedback from all disciplines involved in the patient's care and discharge planning is beneficial in reducing variance and improving efficiency, outcomes, and costs.

For the patient undergoing orthopedic surgery, patient and family education and discharge planning in the following areas are essential: wound care and dressing changes, pain control, wound assessment, physical and occupational therapy, personal care, housekeeping, mobility, nutrition, prescriptions other than pain medication, extended anticoagulant therapy (Surgical Pharmacology), application and removal of orthopedic appliances, and follow-up with a physician. Information concerning these content areas should be described, discussed, and reinforced with written instructions. Perioperative nurses should ensure that the patient and family understand the instructions, have the opportunity to demonstrate a requisite skill if that is part of home care and convalescence, and have time to ask questions and address concerns. A sample of written educational material that might be provided to the orthopedic surgical patient with a cast is presented in the Patient and Family Education box on p 736. Relevant content for devising patient and family educational material on pain management at home is presented in the Patient and Family Education box on pp. 738-739.

Surgical Interventions

ALLOGRAFTS/AUTOGRAFTS

Bone grafting using allografts or autografts may be used (1) to fill cavities after removal of large amounts of bone that might result in instability, (2) to fill bony defects, and (3) to promote union of fractures at the time of open reduction. The type of graft used depends on the location of the fracture or defect, the condition of the bone, and the amount of bone loss as a result of injury. Bone grafts may be used for procedures involving revision of joints if there is significant bone loss caused by resorption or mechanical destruction after removal of bone cement.

The bone graft may be the patient's own bone (autogenous in origin and referred to as *autograft*) or bone obtained from a tissue bank (homogeneous in origin and referred to as *allograft*). Autografts are often harvested from the iliac crest,

where there is cortical and cancellous bone. Various harvesting techniques are used. Struts of cortical bone from the iliac crest can be fashioned to the desired shape and used in areas needing structural strength. The amount of cancellous bone is plentiful. It is used to promote bone growth in areas of defect. Local bone graft material may be taken from the site of injury. Allografts are used when bone is not available from the patient because of the lack of sufficient quantity or because a secondary procedure is undesirable for the patient.

Procedural Considerations

Cancellous grafts may be taken from the ilium, olecranon, or distal radius; cortical grafts may be taken from the tibia, fibula, iliac crest, or ribs. When the recipient site of an autogenous graft is diseased, instruments used for the recipient site must be separated from donor graft site instruments. The operating team must change their gowns and gloves to take the bone graft and again follow the procedure to prevent cross-contamination. The patient is positioned to allow exposure to the surgical site. A sandbag may be placed beneath the area for easier access.

The instrumentation for taking a bone graft includes soft tissue instruments and a bone graft set. Grafts may be harvested with hand instruments, power tools such as an oscillating saw, or high-speed tools such as the Midas Rex. Power tools may be necessary if a uniformly shaped graft is needed to fill a defect. Because hemostasis is sometimes difficult to achieve as a result of the vascular nature of bone, wound drains may be desirable.

Operative Procedure

Harvest of Bone Graft. A cancellous bone graft consists of spongy bone usually taken from the anterior or posterior crest of the ilium. A cortical bone graft, consisting of hard, dense bone, is removed from the crest of the ilium or the tibia. The location of the crest of the ilium is subcutaneous, allowing exposure without difficulty.

1. The surgeon makes an incision along the border of the iliac crest, and strips, elevates, and retracts the muscles on the outer table of the ilium.
2. Strips of the iliac crest can be removed with an osteotome or oscillating saw.
3. A cortical window may also be made in the outer table, and the surgeon may use curettes or gouges to remove cancellous bone chips.
4. A drain may be inserted. The surgeon closes the wound in layers and applies a pressure dressing.

ELECTRICAL STIMULATION

The healing process in bone involves several stages (Figure 19-26). When a bone is damaged, such as during a surgical procedure or fracture, bleeding occurs. The amount of extravasated blood depends on the vascularity of the fracture site. The blood exudate infiltrates the surrounding area, where a clot is formed. Fibroblasts invade the hematoma and form a fibrin meshwork.

As osteoblasts invade the fibrin meshwork, blood vessels develop to build collagen. After several days, calcium deposits may form in the granulation tissue. These deposits eventually form new bone, known as *callus*. Within the callus, cartilage cells develop a temporary semirigid tissue that helps stabilize the bone fragments. The callus is immature bone that is remodeled by new connective tissue cells (osteoblasts) of the periosteum and the inner membrane of the bone cavity. Through this process, mature bone is formed, excess callus is resorbed, and trabecular bone is placed.

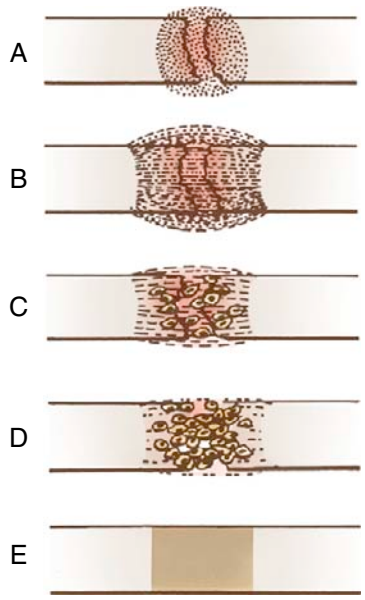


FIGURE 19-26 Bone-healing process. **A**, Hematoma formation. **B**, Fibrin network formation. **C**, Invasion of osteoblasts. **D**, Callus formation. **E**, Remodeling.

After several months, depending on the age and physical condition of the individual, the bone becomes firmly united, although the ossification process is not yet completed. Complete union of the fractured bone or joint is determined by means of clinical and radiologic examination.

Healing of bone is classified by degree. *Delayed union* signifies that healing has not occurred within the average time. The average time depends on many factors, and delayed unions must not be considered nonunion until the healing process has ceased without bony union. *Malunion* signifies that the fracture has united with deformity sufficient to cause impairment of the function or a significant angulation of the extremity. *Nonunion* signifies that the process of healing has ended without producing bony union; in this case, electrical stimulation may be used.

Electrical stimulation is artificially applied electrical current that induces or influences the formation of new bone. Various types of stimulators (Figure 19-27) are available for treatment of nonunion, including invasive (implantable), semi-invasive (percutaneous), and noninvasive (capacitance coupling). The bone stimulator of choice depends on the patient, pathologic condition, and the physician's comfort with the device.

The bone-growth stimulator is used in patients with high risk of nonunion. It can be used to provide electrical stimulation for treatment of nonunion, delayed union, congenital pseudarthrosis, and bone defects. It may be used with or without internal fixation devices, external fixation devices, or bone grafting. Patients who have undergone previous surgery, who have sustained significant tissue loss, or in whom bone grafting is contraindicated are candidates. Electrical stimulation requires long periods of immobilization of the site. This prolonged immobilization may impede rehabilitation.

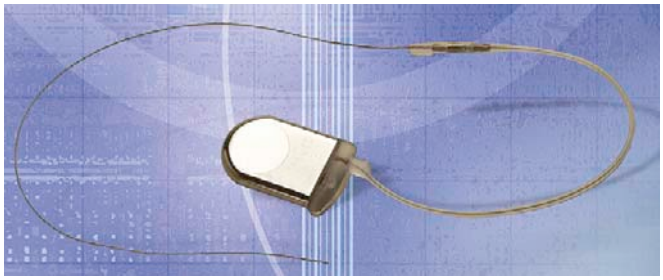


FIGURE 19-27 Bone-growth stimulator used after procedures to induce bone formation.

Procedural Considerations

Instructions for implanting and components selected vary according to the type. The position of the patient depends on the implant site.

In addition to the implant of the surgeon's choice and the implant-specific instrumentation, a soft tissue set is used. Curettes, osteotomes, or bone rasps are used for bony debridement and to scarify the donor bed. Power drills with drill bits may be necessary to create access through the bone for the electrical leads.

Operative Procedure

1. The surgeon exposes the site and debrides it as necessary. A stimulator may be implanted after the surgical procedure.
2. A bone slot is fashioned, spanning the nonunion site.
3. The surgeon makes a second incision about 8 to 10 cm from the first one and dissects the tissue. Before the generator is implanted, hemostasis must be achieved. The use of electrosurgical equipment may interfere with function of the bone-growth stimulator.
4. Using blunt or sharp dissection, the surgeon creates a subcutaneous channel for the cathode.
5. The surgeon guides the long cathode lead through the channel.
6. The generator is carefully implanted near the skin surface. The generator should be inserted into soft tissue—not against bone or metal fixation devices; it should not create a bulge beneath the skin.
7. The surgeon places the electrical coils in the prepared bone slot in equal lengths above and below the fracture site.
8. Cancellous bone grafts are placed between the coils if large bony defects are being treated.
9. Routine closure of the subcutaneous and skin tissue is carried out.

Once union has occurred (5 to 6 months), the surgeon removes the generator after a local anesthetic has been administered.

FRACTURES AND DISLOCATIONS

A fracture is a break in the continuity of a bone. The care of fractured bones or dislocation of a joint is complicated when there is trauma to the soft tissues, including muscles, nerves, ligaments, and blood vessels. Bone diseases, which can increase the risk of a fracture, can be metabolic, infectious, or degenerative. Metabolic diseases are disorders of bone remodeling. The most common are osteoporosis, osteomalacia, and Paget's disease, all of which may result in bone fractures. The most common infectious process is osteomyelitis. Degenerative musculoskeletal conditions are associated with aging. Osteoarthritis is the most common degenerative change.

Osteoporosis is one of the most common and serious of bone diseases and is responsible for more than 2 million fractures a year. Osteoporosis-related fractures most commonly occur in the hip, spine, and wrist, but any bone can be affected. The number of fractures caused by osteoporosis is expected to rise to more than 3 million by 2025 (National Osteoporosis Foundation [NOF], 2009).

Osteoporosis is characterized by excessive loss of calcified matrix, bone mineral, and collagenous fibers, causing a reduction of total bone mass. Decreasing levels of estrogen and testosterone in the older adult result in reduced new bone growth and maintenance of existing bone. Inadequate intake of calcium or vitamin D; lack of weight-bearing activities, exercise, and physical activity; smoking; and caffeine intake are other contributing factors. Osteoporotic bone is porous, brittle, and fragile, fracturing easily under stress. This results in susceptibility to spontaneous fractures and pathologic curvature of the spine (Barclay et al, 2008).

Osteomalacia is a metabolic bone disease characterized by inadequate mineralization of bone as a result of vitamin D deficiency, which leads to a reduced absorption of calcium and phosphorus. Risk factors for development of osteomalacia include malabsorption problems, vitamin D and calcium deficiencies, chronic renal failure, and inadequate exposure to sunlight. Medical treatment includes dietary supplements and exposure to sunlight.

Paget's disease is a disorder affecting older adults. It is characterized by proliferation of osteoclasts and compensatory increased osteoblastic activity, resulting in rapid, disorganized bone remodeling. The bones are weak and poorly constructed.

Types of Fractures

Fractures are classified into two main groups: closed fractures and open or compound fractures. *Closed fractures* are those in which there is no communication between the bone fragments and the skin surface. *Incomplete closed fractures* are those in which the whole thickness of the bone is not broken but is bent or buckled, such as in greenstick fractures, which commonly occur in prepubertal children. *Open fractures* exist when the break in the bone communicates with a wound in the skin. These fractures are usually considered contaminated, requiring measures to control potential infection.

The many varieties of fracture architecture (Figure 19-28) include (1) transverse fracture, in which the fracture line runs at a right angle to the longitudinal axis of the bone; (2) longitudinal fracture, which runs along the length of the bone; (3) oblique fracture and spiral fracture, in which bone is twisted apart (similar except that oblique is shorter than spiral); (4) comminuted fracture, in which the bone fragments splinter into more than two pieces; (5) compression fracture, in which one fragment is driven into the other end and is relatively fixed in that position; and (6) pathologic fracture, in which a bone will fracture easily because it is weakened by disease. A fracture in the shaft of a long bone is described as being in the proximal, middle, or distal third or at the junction of one of these two divisions. A fracture of one of the bony prominences of the end of a long bone is described as a fracture of that prominence by

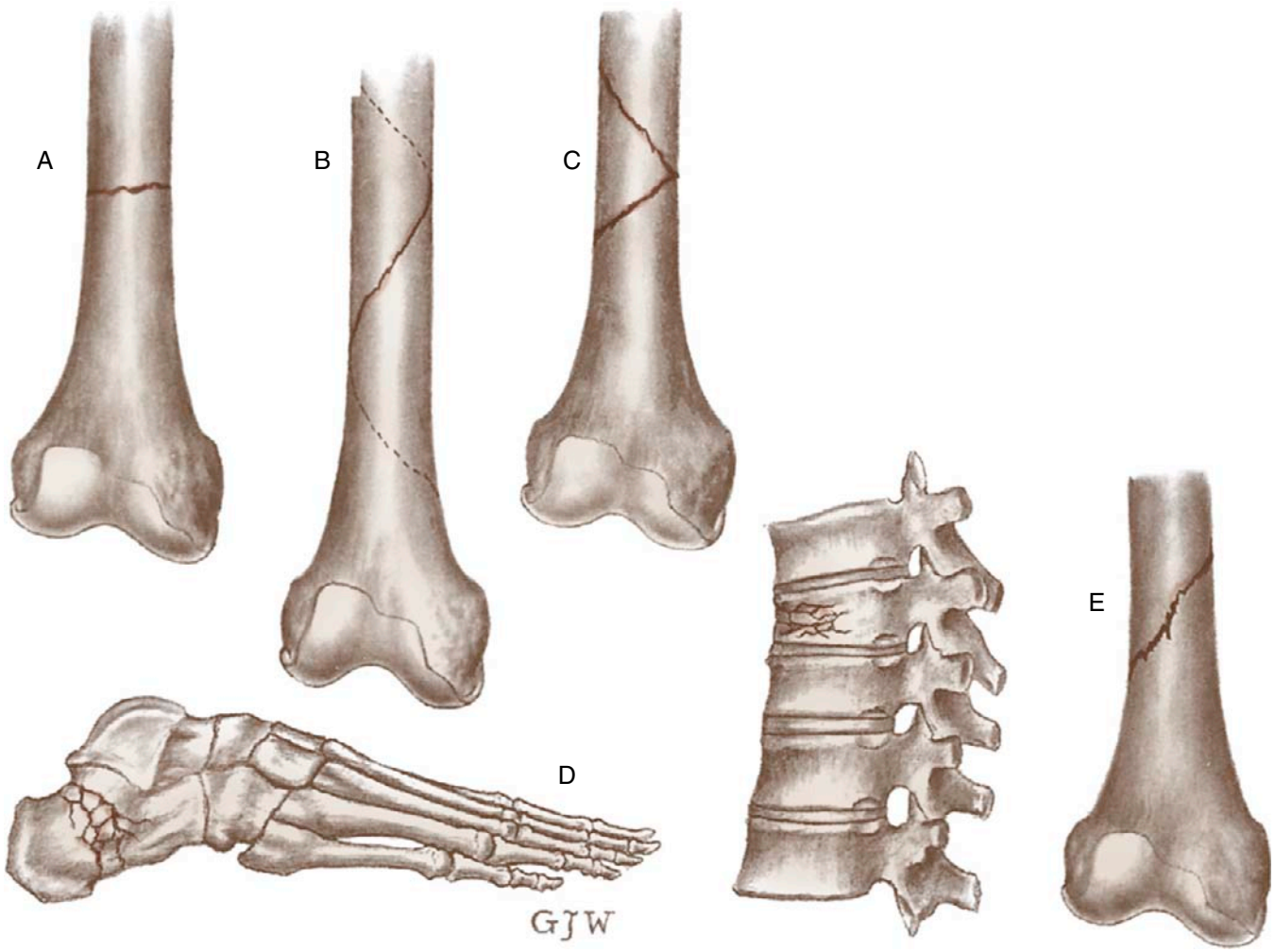


FIGURE 19-28 Fracture types, which may be open or closed. **A**, Transverse. **B**, Longitudinal or spiral. **C**, Comminuted. **D**, Compression. **E**, Oblique.

name. Examples include a fracture of the olecranon, medial malleolus, or lateral condyle of the femur.

An epiphyseal separation occurs when a fracture passes through or lies within the growth plate of a bone. When this occurs in a child with immature bone, retardation of limb length and growth may occur. These injuries require immediate and expert treatment.

An avulsion fracture results in a ligamentous attachment remaining intact on a separated bone fragment. This may occur after joint dislocation or rotational injury, such as the femoral condyle separating from the tibial plateau. A dislocation (luxation) is a complete displacement of one articular surface from another. This injury can disrupt neurovascular structures, requiring immediate attention. A subluxation is a partial dislocation, often indicated by ligamentous instability.

Principles of Treatment

The purpose of fracture treatment is to reestablish the length, shape, and alignment of the fractured bones or joints and restore anatomic function. Acute fracture treatment is necessary to alleviate neurovascular compromise. The surgical team should consider the following principles when providing care for the patient: (1) the patient's extremity or fracture site must be handled gently; (2) initial general medical treatment must be provided; (3) equipment and personnel must be readily available to treat impending or existing shock and to control hemorrhage; (4) aseptic technique must be maintained; (5) positioning must allow adequate circulatory and respiratory function with adequate exposure; and (6) patient comfort must be considered.

The primary goal in treatment of an upper extremity fracture is to preserve mobility and restore range of motion, enabling the individual to perform skilled and delicate work. In fractures of a lower extremity, the objectives of surgery are to restore alignment and length and provide stability of the extremity for weight bearing.

In the presence of open fractures involving soft tissues, several associated conditions may arise, including (1) secondary hemorrhage, (2) infection, (3) severe damage to soft tissues, (4) damage to blood vessels and nerves, and (5) Volkmann's contracture (ischemic paralysis).

Basic Treatment Techniques

Closed Reduction. The surgeon may treat fractures with closed reduction—manipulating the fragments into position without incising the skin. When possible this is the treatment of choice because it decreases the opportunity for infection,

improves results (including bone union of the fracture), and minimizes the recovery period. Significant bone comminution, periosteal damage, or soft tissue entrapped within the fracture site may result in complications.

PROCEDURAL CONSIDERATIONS. The choice of anesthesia depends on the site of fracture and the patient's condition. A closed reduction can be performed with (1) infiltration of local anesthetic agent into the fracture site (hematoma block), (2) intravenous regional anesthesia (Bier block), (3) regional or spinal nerve block, or (4) general anesthesia. Closed reduction may take place before an open procedure to reduce the fracture site. Skeletal traction may also be applied to the fracture site (Figure 19-29), requiring a surgical skin prep and application of drapes. The perioperative nurse consults with the surgeon to determine the appropriate casting or brace materials and makes certain they are readily available to prevent loss of fracture reduction. Instrumentation and supplies should be available in the event it is necessary to open the fracture site and apply fixation.

OPERATIVE PROCEDURE

1. The surgeon uses manual traction to manipulate the fragments into alignment.
2. Reduction is confirmed using radiography (x-ray or fluoroscopy).
3. After reducing the fracture the surgeon immobilizes it with casting material or bracing techniques.

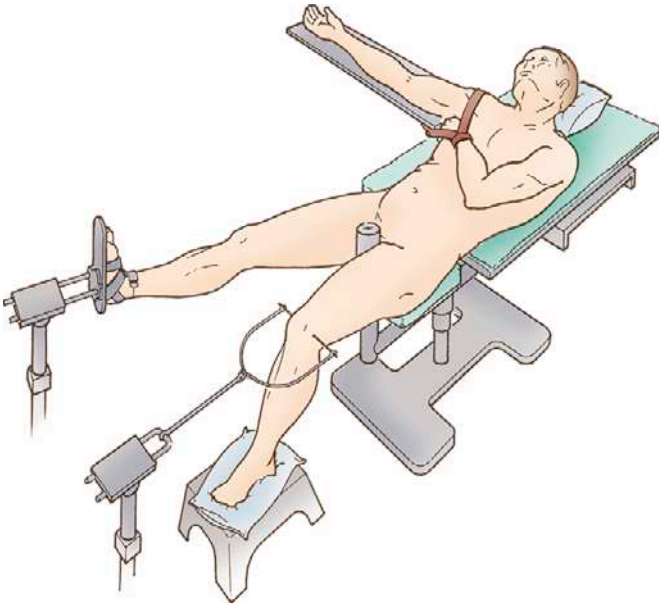


FIGURE 19-29 Application of skeletal traction with the patient positioned supine on the OR fracture bed.

External Fixation. External fixation of fractures provides rigid fixation and reduction with the ability to manage severe soft tissue wounds. Because of the increased chance of infection in patients with an open fracture, external fixation is often the preferred treatment. Advantages of external fixation include the absence of casting material, fracture stabilization at a distance from the injury site, ability to perform subsequent procedures such as skin grafts or vascularized grafts, minimal joint interference, early mobilization, and the ability to use internal fixation or other skeleton-fixation devices at the same time or sequentially.

Indications for external fixation include (1) severe open fractures, (2) highly comminuted closed fractures, (3) arthrodesis, (4) infected joints, (5) infected nonunion, (6) fracture stabilization to protect arterial or nerve anastomoses, (7) major alignment and length deficits, (8) congenital deformities, and (9) static contractures. External fixation provides a bridge between fracture reduction and insertion of an internal fixator such as an intramedullary nail, allowing time for vascular recovery. Internal fixation can take place at a later date.

Many improvements have been made in the design and articulations of external fixation devices. The fixators can be applied to most anatomic sites. The available external fixators vary greatly in design; however, all contain three main components: (1) bone-anchoring devices (threaded pins, Kirschner wires), (2) longitudinal supporting devices (threaded or smooth rods), and (3) connecting elements (clamps and partial or full rings). Improvements have resulted in the use of lightweight and stronger materials, which are radiopaque, for use as connecting rods. The radiopaque feature prevents postoperative radiographic interference when viewing the fracture site for progress in healing.

The Ilizarov device uses principles of tension-stress and distraction to correct bone defects and limb-length discrepancies. It is not routinely used for acute fracture fixation; however, the principles and technique are similar. Limb length may be adjusted with gradual bone distraction of bone ends, stimulating new bone formation.

PROCEDURAL CONSIDERATIONS. External fixators are applied using sterile technique after the patient has been administered a general or regional anesthetic. Radiographic imaging ensures fracture reduction after closed manipulation; it also ensures proper pin placement. Because the incision site is small to allow introduction of pins, a soft tissue set appropriate to the site will be necessary. Many different external fixators are available for use. Some examples are shown in Figures 19-30 to 19-33. Irrigation and debridement at the fracture site and surrounding soft tissue may be necessary if soft tissue is damaged, so pulsatile lavage with 3000 ml of normal saline solution should be available. The surgeon will use a power drill at the pin sites, and a periosteal elevator if necessary for blunt or sharp dissection. An appropriate-size pin cutter should also be available to shorten the pins if the need arises. The dressing consists of an antibacterial ointment, antibiotic-impregnated gauze, or nonadherent gauze with gauze overwrap.

OPERATIVE PROCEDURE

1. The fracture is reduced manually.
2. The surgeon incises the skin.
3. Using a periosteal elevator, the surgeon dissects the periosteum from the bone if necessary.
4. The surgeon predrills the cortex, using a drill sheath to protect surrounding soft tissue.
5. Hand drilling or low-speed power drilling is used to insert the half pins above and below the fracture.
6. Universal joints are slipped over the pins and joined with a connecting rod.
7. The surgeon tightens the frame using the appropriate wrenches.
8. Radiography or fluoroscopy is used to confirm reduction and alignment.
9. Dressings are applied to the pin sites.

FIGURE 19-30 Synthes external fixator.

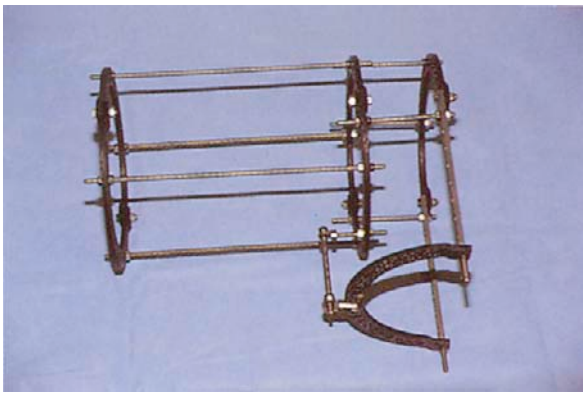


FIGURE 19-31 Ilizarov tibial external fixator.

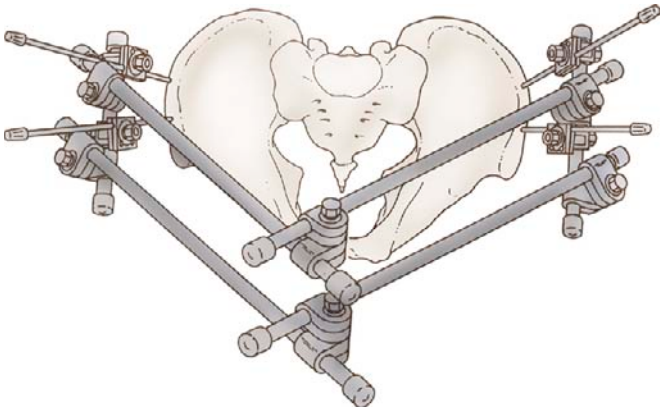


FIGURE 19-32 AO/ASIF pelvic external fixator, double frame using tube-to-tube clamps.

Internal Fixation. Internal fixation is often the treatment of choice for correction of fractures of long bones or those in the hip region. Application of compression plates and screws and insertion of pins, intramedullary rods, nails, or wiring are methods of internal fixation. Fractures of most anatomic parts in adults can be repaired using internal fixation.

Many principles and techniques apply when using internal fixation. Types of screws (Figure 19-34) include cortical, cancellous, lag, pretapped, and self-tapping. Cortical bone screws have threads that are closer together and narrower than other types of threads. These threads run along the entire length of the screw and transfix bone, gaining purchase (grab) of bone cortex.

Cancellous bone screws feature threads that are broader and farther apart than those of cortical screws. Cancellous screws are used in cancellous bone, which is less dense than cortical bone; the bone accumulates within the threads to provide the purchase for fixation. Like cortical screws, cancellous screws

FIGURE 19-33 Dynawrist dynamic wrist external fixator.

FIGURE 19-34 Types of screws used for fixation with or without plating systems.

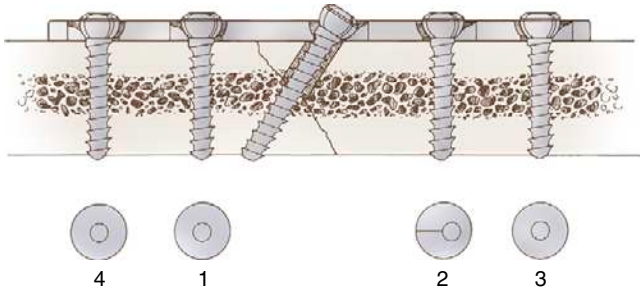


FIGURE 19-35 Plating a closed forearm fracture using dynamic compression showing final position of the screw insertion.

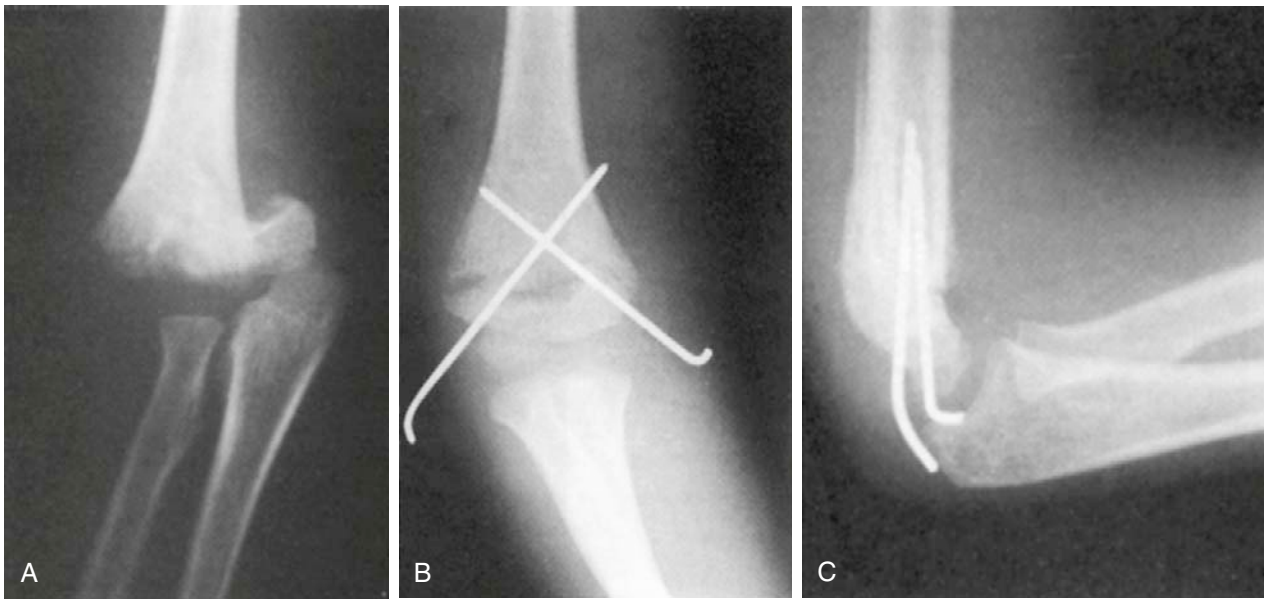


FIGURE 19-36 Percutaneous pinning of a supracondylar fracture. **A**, Severely displaced supracondylar fracture. **B** and **C**, Treated by closed reduction and percutaneous pinning.

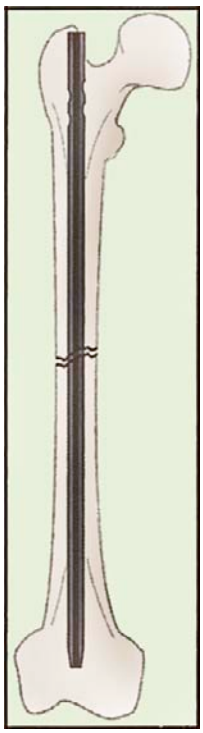


FIGURE 19-37 Rod placement for femoral fracture.

can traverse fracture sites and hold plates onto bone. The screw threads do not completely traverse the bone through the opposite cortex. Cancellous screws are commonly used when fractures occur at the condylar ends of the shaft.

Plating of a fracture may occur with or without dynamic compression (Figure 19-35). Dynamic compression uses screw and plate configurations to apply forces through the fracture site. Semitubular plates are less rigid and do not have the ability to produce dynamic compression. This type of plate is used in the forearm and fibula, where weight bearing, which could break the plate, is not a factor.

CLOSED REDUCTION METHOD. The surgeon may reduce fractures using closed reduction methods of manipulation and traction combined with percutaneous insertion of pins, intramedullary nails, or rods. Pins can be placed percutaneously (Figure 19-36) to fix fractures involving the digits, wrist, elbow, and foot. A rod or nail is placed percutaneously (Figure 19-37) in a large bone such as the humerus or femur. Closed reduction is, however, a misnomer, since small openings in the soft tissue and bone are made to facilitate introduction of the devices. These incisions are considerably smaller than those created when repairing the fracture using open reduction. The advantages of closed reduction over open reduction and internal fixation are (1) a lower incidence of infection and (2) absence of additional soft tissue or vascular damage.

OPEN REDUCTION AND INTERNAL FIXATION. Open reduction and internal fixation is a method of providing exposure of the fracture site and using pins, wire, screws, a plate and screw combination, rods, or nails to correct the fracture (Figure 19-38). Surgeons use open reduction and internal fixation when they are unable to reduce a fracture by closed methods and skeletal traction is not indicated. The advantage is that anatomic alignment of the fracture can usually be obtained and verified through direct observation. Fractures that are comminuted or difficult to reduce can be more effectively treated using this technique. The incidence of infection and nonunion, however, is increased when the wound is opened.

The procedure varies for each anatomic site, using the principles for specific fixation devices. Several procedures described in the text identify steps for completion of open reduction and internal fixation. Reference examples include the following:

- *Pin fixation:* application of a unilateral frame
- *Wire fixation:* reduction of patellar fracture, tension banding of the olecranon
- *Screw fixation:* correction of scaphoid fractures

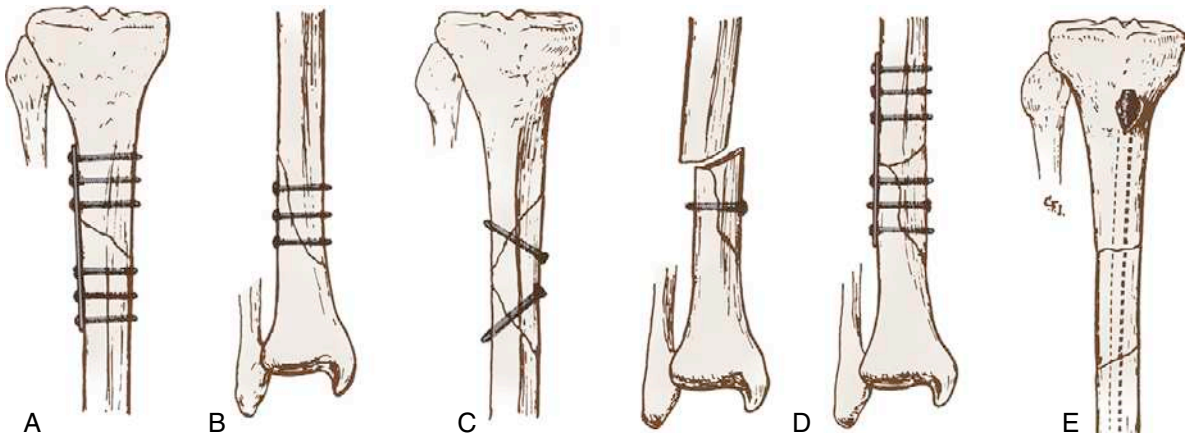


FIGURE 19-38 Types of internal fixation for fracture repair. **A**, Plate and screws for transverse or short oblique fracture. **B**, Transfixion screws for long oblique or spiral fractures. **C**, Transfixion screws for long butterfly fragment. **D**, Fixation for short butterfly fragment. **E**, Medullary fixation.

- *Plate and screw fixation:* repair of a comminuted distal humeral fracture
- *Rod or nail fixation:* correction of fractures of the shaft of the humerus, femoral shaft, or tibial shaft

SURGERY OF THE SHOULDER

Correction of Acromioclavicular Joint Separation

Acromioclavicular joint separation (Figure 19-39), a common occupational and athletic injury, results from a force applied downward, most commonly from a fall, directly to the top of the shoulder. The ligamentous support of the distal clavicle in the form of the coracoclavicular, coracoacromial, and acromioclavicular ligaments is disrupted. The result is either a posterior or a superior displacement of the lateral end of the clavicle.

The purpose of surgery in an acutely injured patient is to reestablish the proper relationship between the clavicle and the acromion, thereby reducing long-term shoulder pain and increasing function. This is accomplished by replacing the coracoclavicular ligaments with heavy suture or Mersilene tape or by inserting a screw through the clavicle and into the coracoid process. It may also be necessary to stabilize the acromioclavicular joint by placing a smooth Steinmann pin across the acromion and into the clavicle. Sometimes the distal end of the clavicle is also resected. If resection of the clavicle is the only treatment required, this may be completed arthroscopically. Shoulder arthroscopy is detailed in the Arthroscopy of the Shoulder section of Arthroscopy, p. 806.

Procedural Considerations. The perioperative nurse assists in placing the patient in the supine or semisitting position with a sandbag or folded sheet under the affected shoulder. The patient's shoulder is positioned slightly off the OR bed (Figure 19-40) to allow full range of motion, or if mobility of the arm is unnecessary, a shoulder positioner is used. The head is turned to the opposite side, taking care not to overstretch the nerves of the brachial plexus. The surgical technologist assists with draping the patient's arm with a stockinette to the midhumeral level.

A soft tissue set and bone instrumentation specific for the shoulder (Figure 19-41) are required. Depending on the technique used, bone screws and their instrumentation, free-cutting needles, bone-anchoring devices, and power instruments may be necessary.

Operative Procedure

CORACOCLAVICULAR SUTURE FIXATION

1. A curved incision is made to expose the acromioclavicular joint, the distal end of the clavicle, and the coracoid process.
2. The surgeon exposes the acromioclavicular joint and removes any loose fragments or debris.
3. Mattress sutures are placed in the ruptured coracoclavicular ligaments but not tied.
4. The surgeon places drill holes in the clavicle above the coracoid in the anteroposterior (AP) plane.
5. A #5 nonabsorbable suture is placed beneath the base of the coracoid and superiorly through the two holes in the clavicle. With the joint reduced, the sutures are tied.
6. If instability is still a concern, the surgeon places small Kirschner wires across the acromioclavicular joint, through the lateral border of the acromion. The ends of the wires are bent 90 degrees at the lateral border to prevent proximal migration.
7. The surgeon ties the sutures previously placed in the coracoclavicular ligaments.
8. The acromioclavicular joint capsule and the origins of the deltoid and trapezius muscles are repaired.
9. A sling-and-swathe bandage is then applied to the extremity.

Correction of Sternoclavicular Dislocation

Traumatic dislocation of the sternoclavicular joint usually occurs from an indirect blow on the anterior shoulder while the arm is abducted. The clavicle most frequently is displaced anteriorly, but posterior or retrosternal dislocations can occur. Posterior dislocation can be more severe because injury to the trachea, esophagus, thoracic duct, and large vessels of the mediastinum is possible. Except in severe cases, dislocation of the sternoclavicular joint is treated nonoperatively with manual traction and immobilization bandages.

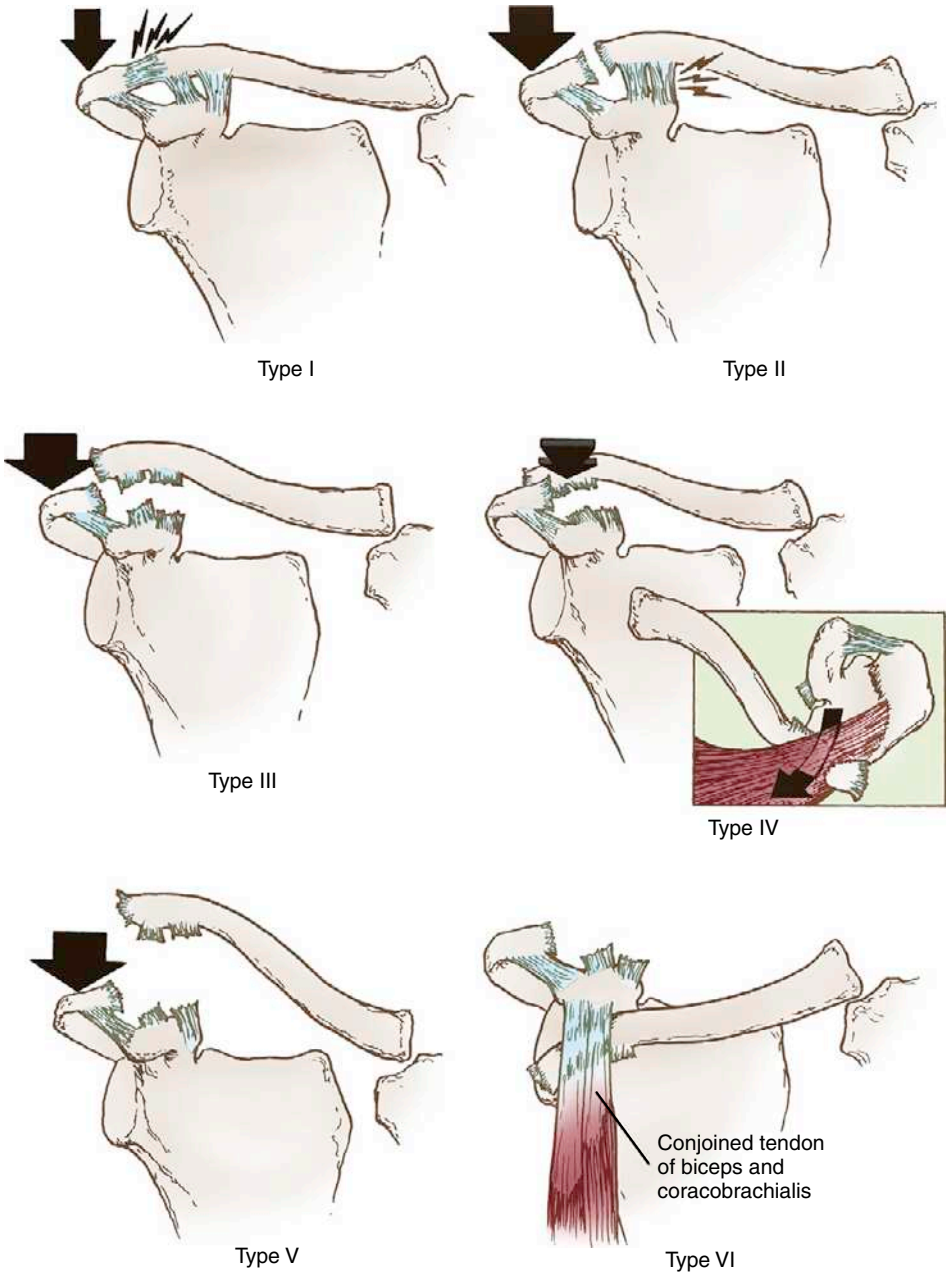


FIGURE 19-39 Classification of acromioclavicular injuries. *Type I,* Neither acromioclavicular nor coracoclavicular ligaments are disrupted. *Type II,* Acromioclavicular ligament is disrupted, and coracoclavicular ligament is intact. *Type III,* Both ligaments are disrupted. *Type IV,* Ligaments are disrupted, and distal end of clavicle is displaced posteriorly into or through trapezius muscle. *Type V,* Ligaments and muscle attachments are disrupted, and clavicle and acromion are widely separated. *Type VI,* Ligaments are disrupted, and distal clavicle is dislocated inferior to coracoid process and posterior to biceps and coracobrachialis tendons.

Clavicular Fracture

Fractures of the clavicle are some of the most common bony injuries. These injuries rarely require surgical intervention. The majority of clavicular fractures are the result of an indirect or direct blow on the clavicle or shoulder. The most common site of clavicular fractures is the middle-third portion of the bone, mainly at the middle- and outer-third junction.

Clavicular fractures are usually treated by immobilization in a figure-of-eight splint. The chances of nonunion are greatly increased when open reduction is used for a clavicular fracture. The outcome may result in a bony prominence, which may be disturbing to the patient; the overriding fragments are resorbed with time.

Clavicular fractures may require open reduction and internal fixation after nonunion, neurovascular compromise that cannot be resolved with reduction, distal clavicular fracture with torn coracoclavicular ligaments in the adult, or persistent wide separation of the fragments with soft tissue entrapment.

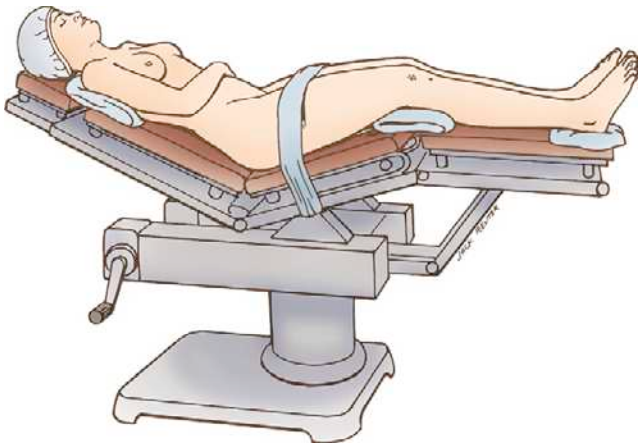


FIGURE 19-40 Positioning for a surgical procedure on the shoulder with the patient in a semisitting position and support beneath the affected shoulder.

FIGURE 19-41 Shoulder instrumentation set including humeral head retractors, glenoid neck retractor, modified Gelpi retractors, Goulet retractors, conjoined tendon retractor, subscapularis retractor, and glenoid awl.

Surgery is necessary when the fracture is displaced enough to cause underlying damage to the vessels and brachial plexus. Open reduction is accomplished with a tubular plate and screws or intramedullary pin fixation.

Procedural Considerations. The perioperative nurse assists with positioning the patient in the supine or semisitting position with a sandbag or folded sheet under the affected shoulder. The patient's head is turned to the opposite side, and care is taken to not stretch the nerves of the brachial plexus. The surgical technologist assists the surgeon with draping the entire extremity after it is prepped. Soft tissue instruments and bone instruments are used for dissection. Bone-reduction forceps and clamps will be used to obtain reduction, and Kirschner wires may be used to temporarily hold the reduction. Permanent reduction will be held with either Steinmann pins or plate and screws. A power drill will be necessary to apply these. In the case of a nonunion, bone grafting will be used.

Operative Procedure

1. The surgeon makes a 2.5-cm incision over the fracture site. The incision may need to be extended for comminuted fractures.
2. Dissection is carried down to the clavicle, taking care not to strip periosteum or disrupt vessels or nerves.
3. The surgeon exposes the fracture site and reduces the fracture with bone-holding forceps.
4. If pinning the clavicle is to be done, a Steinmann pin is passed into the medial fragment medullary canal and removed.
5. The pin is then passed in the same manner into the distal fragment.
6. The surgeon reduces the fracture again, and uses a threaded Steinmann pin across the fracture site through both fragments to transfix it.
7. If plating the clavicle is to be done, a small semitubular plate is used with at least two screw holes on each side of the fracture site.
8. The surgeon strips a small portion of the periosteum from the clavicle so that a plate can be applied to the anterior surface.
9. Extreme care must be taken when drilling screw holes to avoid damage to the subclavian vein and thoracic contents.
10. After closure, an immobilization sling is applied.

Correction of Rotator Cuff Tear

Most rotator cuff tears occur through the insertion of the tendinous fibers of the supraspinatus muscle that attaches onto the greater tuberosity of the proximal humerus. In severe tears, the remaining tendons of the cuff, the subscapularis, infraspinatus, and teres minor, may also be involved. Supraspinatus syndrome, also known as *impingement syndrome,* can involve multiple pathologic conditions, such as calcium deposits, bicipital tendonitis, subacromial bursitis, tenosynovitis, and other nonarticular lesions along with a cuff tear. The approach to diagnosis and treatment is similar for both partial and complete rotator cuff tears.

Partial rotator cuff tears and impingement usually affect people in the middle decades of life or later and are often attributable to a long-term degenerative process. Complete tears of the rotator cuff occur after accidental injury of younger patients, such as pitchers and football quarterbacks. Patients with rotator cuff tears may not be able to initiate abduction of the shoulder because the stabilizing forces of the ruptured tendons on the humeral head are lost. Many rotator cuff tears can be treated conservatively with physical therapy and nonsteroidal antiinflammatory drugs (NSAIDs).

A variety of procedures may be performed for these conditions when conservative treatment is unsuccessful. Methods of repair depend on the size and shape of the tear. The common goal is to restore joint stability, alleviate pain, and allow the patient to return to normal activities. In some instances a significant reduction in preinjury activity may be permanent.

Procedural Considerations. The perioperative nurse assists the surgeon in positioning the patient in the supine or semisitting position with a sandbag or folded towel under the affected

shoulder. The patient's head is gently turned to the opposite side, taking care to avoid undue stretch to the brachial plexus. A shoulder positioner can be used if intraoperative mobility of the arm is not a factor. In addition to a bone set and a soft tissue set, shoulder instruments will be required. The remaining equipment needs will depend on the severity of the tear. Minor tears may require no more than heavy nonabsorbable suture. Major tears will require a power drill and burr and possibly a microsagittal saw. Fixation may be gained with bone-anchoring devices. Free needles will be necessary if these are used.

Operative Procedure

1. The surgeon makes an anterosuperior deltoid incision and divides the coracoacromial ligament at the acromial attachment.
2. A subacromioplasty (resection of the undersurface of the acromion) is completed. This is also primary treatment for impingement syndrome.
3. Small, simple tears can be repaired by suturing the torn edges with heavy nonabsorbable sutures.
4. Massive tears may require attaching the torn edges to the greater tuberosity using bone-anchoring devices.
5. If the defect cannot be bridged, the surgeon may transpose a flap from the subscapularis tendon and suture it to the supraspinatus and infraspinatus muscles.
6. If impingement is involved or solely the cause of a rotator pathologic condition, other measures involving the same approach are taken.
7. The surgeon excises any calcium deposits encased in the tendon to alleviate mechanical obstruction or performs an acromioplasty.
8. After closure, a sling is applied.

Patients with small tears may begin motion on the third to fourth postoperative day. Larger tears may require immobilization for 2 to 8 weeks.

Correction of Recurrent Anterior Dislocation of the Shoulder

The anterior fibers of the shoulder capsule are stretched and weakened as a result of frequent dislocations of the shoulder joint. More than 150 operations or modifications have been devised to treat recurrent anterior dislocation. The goals are to (1) prevent recurrence, (2) prevent surgical complications, (3) prevent creation of arthritic changes, (4) maintain joint motion, and (5) correct the problem. The surgeon selects the procedure appropriate for the patient's condition that will satisfy the conditions necessary for correction of the problem. A stapling procedure was once common treatment of recurrent dislocation, but it has been replaced by other accepted procedures.

Procedural Considerations. The surgeon and perioperative nurse place the patient in the supine or semisitting position with a sandbag or folded sheet under the shoulder. The patient's arm is draped free so that the extremity can be manipulated. The surgeon will make an anterior curved incision or a longitudinal incision in the anterior axillary fold over the shoulder joint, depending on the location of the tear and procedure planned. A soft tissue set and a bone set will be required, as well as a set of instruments specific to shoulder surgery, power drill and burr, bone-anchoring devices, and free needles.

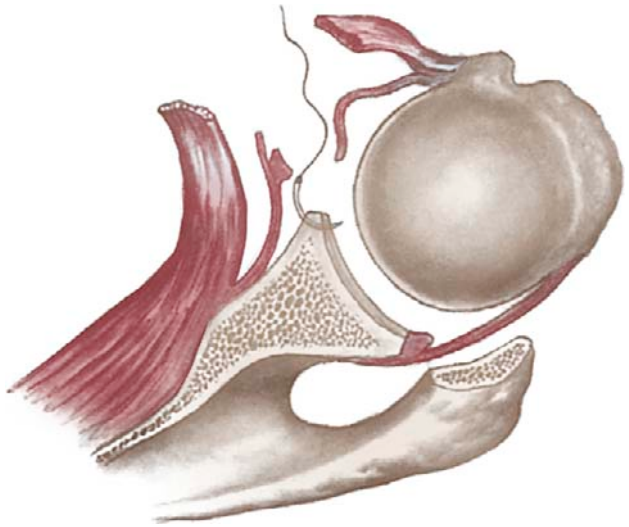


FIGURE 19-42 Bankart procedure for restoration of shoulder stability. Holes are made in the rim of the glenoid, and the free lateral margin of the capsule is sutured to the rim of the glenoid. The medial margin of the capsule is sutured to the lateral surface.

Operative Procedure

BANKART PROCEDURE. For the Bankart procedure (Figure 19-42), the scapula is not elevated with a sandbag or folded sheet. The surgeon reattaches the attenuated anterior capsule to the rim of the glenoid fossa with heavy sutures. The glenoid fossa rim is decorticated with a curette to provide a raw surface to which the capsule is attached. Special instruments designed for the Bankart procedure, such as the curved awl and humeral head retractor, facilitate the surgery, although the capsule may be attached with bone anchors, obviating the use of the awl. If the coracoid process is to be removed to obtain better operative exposure, a drill, bone screws, and washer should be available for reattachment. Postoperatively the extremity is immobilized in a sling or shoulder immobilizer. Shoulder motion is begun at 3 days postoperatively, and the patient may return to contact sports or heavy labor after approximately 6 months.

PUTTI-PLATT PROCEDURE. The steps of the Putti-Platt procedure are similar to those of the Bankart procedure in that the joint capsule is sutured to the glenoid rim. In addition, the Putti-Platt procedure requires the lateral advancement of the subscapularis. This produces a barrier against dislocation of the shoulder. This procedure is rarely useful when the anterior capsular mechanism is of poor quality.

The surgeon divides the subscapularis tendon 2.5 cm medially to its insertion. The glenoid and humeral head are inspected using palpation to assess osteochondral changes. The lateral portion of the subscapularis is sutured to the anterior glenoid rim. The medial portion of the subscapularis is sutured to the rotator cuff at the greater tuberosity. The layers of the shoulder joint are imbricated (overlapped), a technique used often in soft tissue reconstruction. The incision is closed, and a shoulder immobilizer is applied. The immobilizer is worn for approximately 3 weeks. External rotation of the arm should be avoided immediately after the repair.

BRISTOW PROCEDURE. In the Bristow procedure, the coracoid process, along with the attached muscles, is detached and inserted onto the neck of the glenoid cavity, where it is attached

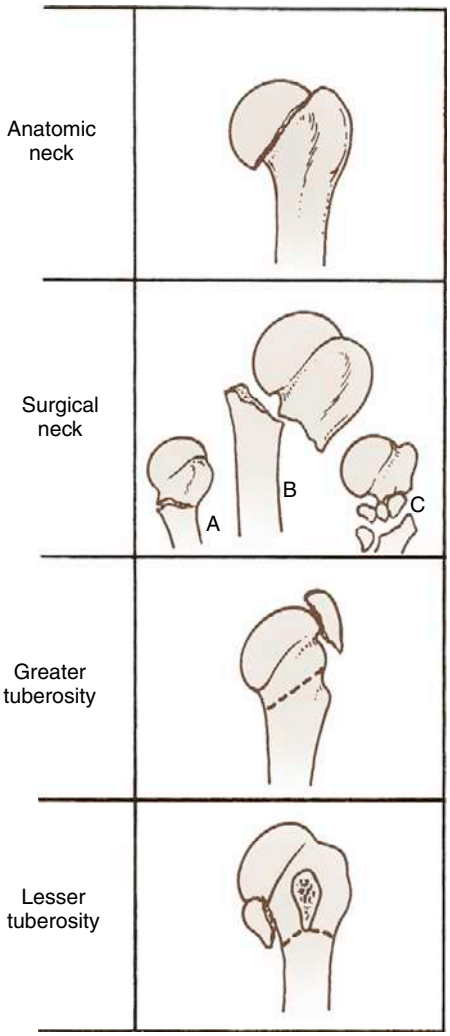


FIGURE 19-43 Fractures and fracture-dislocations relate to the pattern of displacement. Fractures can occur in two, three, or four parts.

with a screw through the subscapularis muscle. This stabilizes the anterior joint capsule and prevents recurrent dislocation. A Bristow procedure is considered an appropriate alternative when the anterior capsular mechanism is of poor quality. Disadvantages of this procedure are (1) internal rotation contracture, (2) inattention to labrum or capsule disorders, (3) potential for injury to the musculocutaneous nerve, (4) reduction of internal rotation power by shortening of the subscapularis muscle, (5) possible limitation of external rotation, (6) possible penetration of the screw into the articular surface of the glenoid, and (7) later development of early joint disease of the shoulder.

Correction of Humeral Head Fracture

Comminuted fractures of the humeral head (Figure 19-43) with displacement may require open reduction and internal fixation with screws or pins or closed reduction with a humeral nail or rod. However, if the fracture is badly comminuted, a prosthetic replacement is indicated. Traumatic or degenerative arthritic shoulder joints may be so painful or dysfunctional that a total shoulder joint replacement is necessary.

Extensive rehabilitation for the shoulder is required. Surgery should be performed as soon as possible as delay can allow time for increasing scar formation, contracture of the muscles, and increasing osteoporosis of the bone fragments. The shoulder is the most difficult joint in the body to rehabilitate because it has (1) the greatest range of motion, (2) a second space beneath the acromion that must be mobilized, and (3) many muscles that enter into complex movements.

SURGERY OF THE HUMERUS, RADIUS, AND ULNA

Fractures of the Humeral Shaft

Closed manipulation and immobilization usually reduce a fractured humerus as well as minimize the risk of nonunion and infection. When closed reduction is impossible or when nonunion of the fracture has occurred, surgery is indicated. The fracture is reduced and held with intramedullary fixation, a compression plate, a lag screw, or a rigid locking nail, with distal and proximal bone screws that will transfix the rod within the canal. This last device can control rotation of the fracture fragments and prevent distraction at the fracture site (Figure 19-44). Multiple flexible nails may be used if more rigid nails are not available. A bone graft may be used, depending on both the extent of the fracture and the length of time since injury. Compression plating of shaft fractures is usually reserved for supracondylar involvement or when other treatment has failed.

Procedural Considerations. Fluoroscopy and permanent radiographs are required to ensure proper alignment, reduction, and placement of implants. The perioperative nurse arranges for intraoperative radiology support and a radiolucent OR bed before the patient's arrival in the OR suite. The surgeon and nurse position the patient supine with the body near the edge of the bed to facilitate moving the arm. The extremity is prepped and draped from the middle of the chest to below the elbow.

A soft tissue set and a large bone set are required. In addition, the intramedullary fixation device of choice and the required instruments for its insertion will be needed. PMMA may be used in the case of pathologic fractures. Instruments that are required for harvesting bone graft might be needed as well. A traction tray could be used to gain reduction. A power drill will be necessary if screws are used to lock the device. Sterile x-ray cassette covers will be needed for permanent intraoperative films.

Operative Procedure

MEDULLARY FIXATION: ANTEGRADE TECHNIQUE

1. Proper length and alignment of the fracture must be attained with traction. Nail length should ensure proximal burying to avoid subacromial impingement and be 1 to 2 cm proximal to the olecranon fossa. The surgeon makes a skin incision from the lateral point of the acromion over the tip of the greater tuberosity. The fascia is incised, and the greater tuberosity is palpated.
2. Using a small awl, the surgeon enters the greater tuberosity and confirms placement with fluoroscopy in both anteroposterior (AP) and lateral views.
3. The surgeon removes the awl and inserts a ball-nosed reamer guidewire, advancing it down the medullary canal (periodically verified with fluoroscopy). Confirmation is made with each step to ensure that the wires, reamers, or implant has not fractured through the cortex along the shaft.

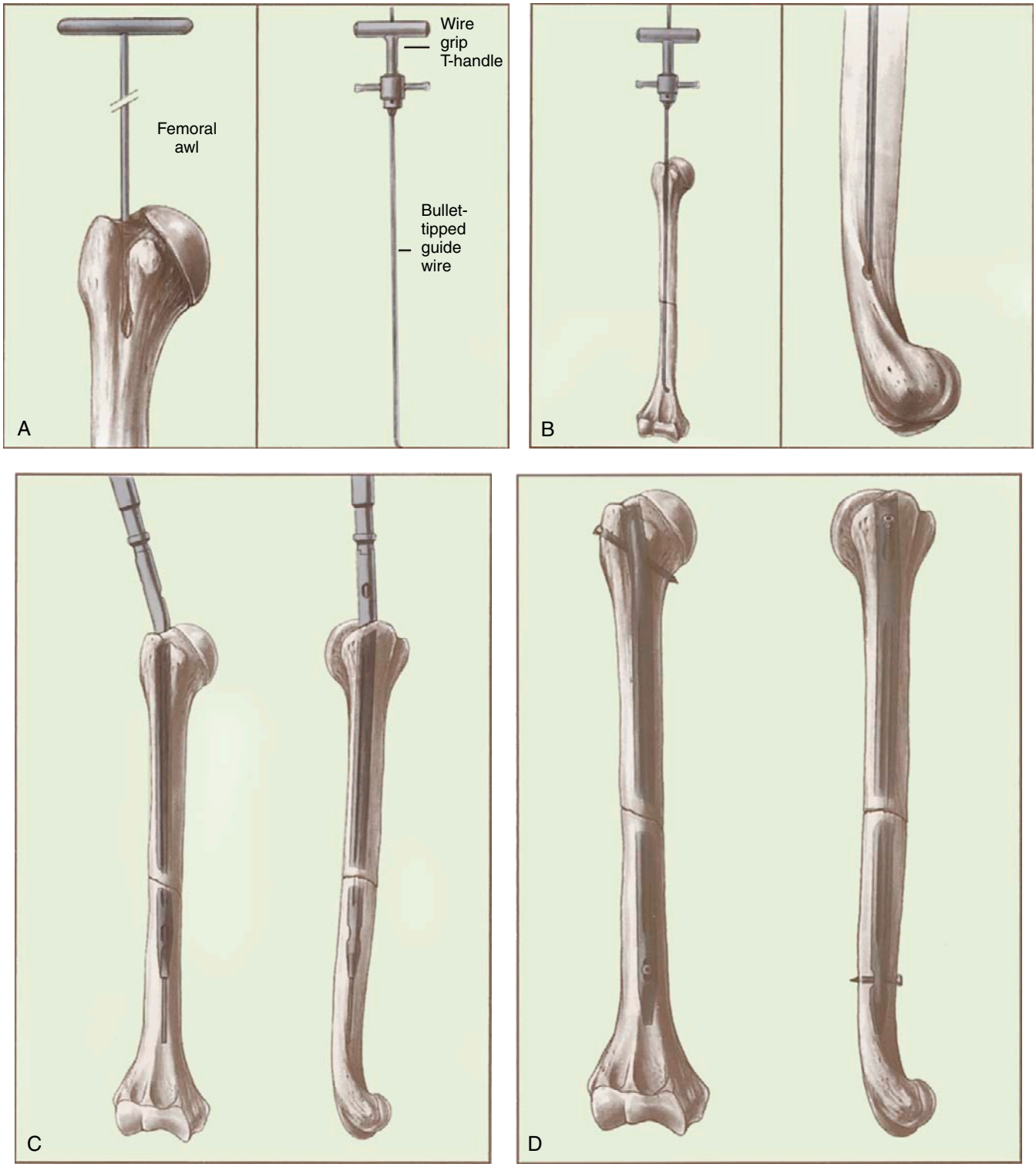


FIGURE 19-44 Placement of the humeral rigid locking nail with distal and proximal screws. **A**, After incision and exposure, a femoral awl is used to make an entry portal. **B**, Guidewire is advanced into the center of the epicondylar region. **C**, After reaming, the nail is advanced over the fracture site and seated. **D**, Proximal and distal locking takes place after the correct screw placement is determined.

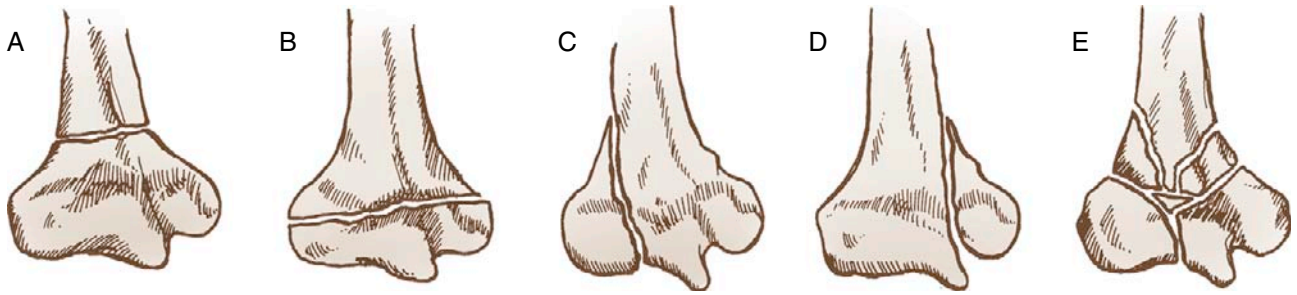


FIGURE 19-45 Classification of distal humeral fractures. **A**, Supracondylar. **B**, Transcondylar. **C**, Lateral condyle with trochlea. **D**, Medial condyle. **E**, Intercondylar with comminution.

4. The guidewire is advanced to within 1 to 2 cm of the olecranon fossa, avoiding distraction or shortening.
5. If Enders nails are being used, each one is advanced in the same fashion as the guidewire.
6. Nail length can be determined by using a second guidewire of the same length held against what remains extended from the humerus. The difference between the length protruding and the length remaining on the second rod is the approximate length requirement of the humeral nail. Another method uses a nail-length gauge that is held directly against the upper arm, viewed with fluoroscopy, and read directly on the gauge.
7. Enders nails may be held directly against the arm and viewed with fluoroscopy to determine proper length. If Enders nails are used, the surgeon drives two or three nails down the shaft, across the fracture site, and into the distal fragment. Fluoroscopy is used to confirm proper placement and reduction.
8. If intramedullary nailing is to be accomplished, the surgeon may use a cannulated reamer over the guidewire to ream the humerus. Reaming of the canal is completed in 0.5-mm increments. The humerus becomes smaller in diameter. Reaming is gentle to ensure that protrusion through the bone does not occur. The bone is reamed 0.5 to 1 mm larger than the selected nail diameter.
9. The surgeon uses a medullary exchange tube to maintain fracture reduction.
10. The ball-tipped guidewire is replaced with a non–ball-tipped guidewire.
11. The medullary nail is assembled for impaction with the appropriate outrigger and drill guides.
12. The nail is guided into the proximal end of the humerus, and the humeral nail driver is used to impact the nail within the canal. Care must be taken to avoid splitting the humerus or creating a supracondylar fracture by wedging the tip of the nail.
13. As the nail approaches and crosses the fracture site, manual reduction must be maintained.
14. The surgical technologist attaches the proximal drill guide to the nail impactor with the nail coupled; the surgeon makes a stab wound in the skin and pushes the nail to reach the bone.
15. An 8-mm drill sleeve is inserted through the drill guide, followed by a 2.7-mm drill guide into the first guide.
16. The surgeon scores the cortex with the 2.7-mm trocar, and transfixing of the hole is completed with a 2.7-mm drill from the lateral to distal areas of the cortex.
17. The humeral screw-depth gauge is inserted and read directly to determine the appropriate screw size.
18. A 4-mm fully threaded humeral screw is inserted to the selected length. The surgeon confirms the screw position by inserting a guidewire down the end of the nail, where it is impeded by the transfixing screw.
19. Fluoroscopy is used to target the distal humeral locking screw.
20. The surgeon creates a second percutaneous access from the anterior to posterior cortex of the bone to the bone surface of the humerus.
21. With the freehand technique, the cortex of the bone is scored followed by insertion of the 8-mm handheld drill sleeve and the 2.7-mm drill bit.
22. The selected size of humeral screw is gauged and inserted. Placement is confirmed with fluoroscopy, and the impactor assembly is removed from the nail.
23. Full-view radiographs are obtained in both dimensions, and the wound is irrigated and closed.

NOTE: Many variations of approach and technique are used, depending on the complexity of the fracture and any associated injury. Often the fracture site may have to be opened if it is comminuted or will not reduce properly through closed techniques. The radial nerve or other neurovascular structures may become entrapped or traumatized, requiring exploration and repair.

Although this type of antegrade fixation, using locked rods, is preferred for this type of fracture, it is not the only method. Often a retrograde technique is used, with the patient in the prone or lateral decubitus position. The retrograde technique, used more commonly in the care of femoral shaft fractures, is described on p. 767.

Distal Humeral Fractures (Supracondylar, Epicondylar, and Intercondylar)

Distal humeral fractures are classified into several types, depending on location and the presence or absence of articular involvement (Figure 19-45). Supracondylar fractures of the humerus do not involve the articular surface and can generally be treated with closed reduction and casting. Transcondylar fractures may or may not have articular involvement, and this will dictate treatment. Intercondylar fractures involve both condyles with a comminution of injury, are intraarticular, and present the greatest challenge for the surgical team. Fractures of the articular components—the capitulum and the trochlea—are usually the result of a fall on an outstretched arm. The force drives the radial head to shear off the capitulum, producing an intraarticular fragment. The lateral or medial condyles and epicondyles are also subject to fracture by various mechanisms.

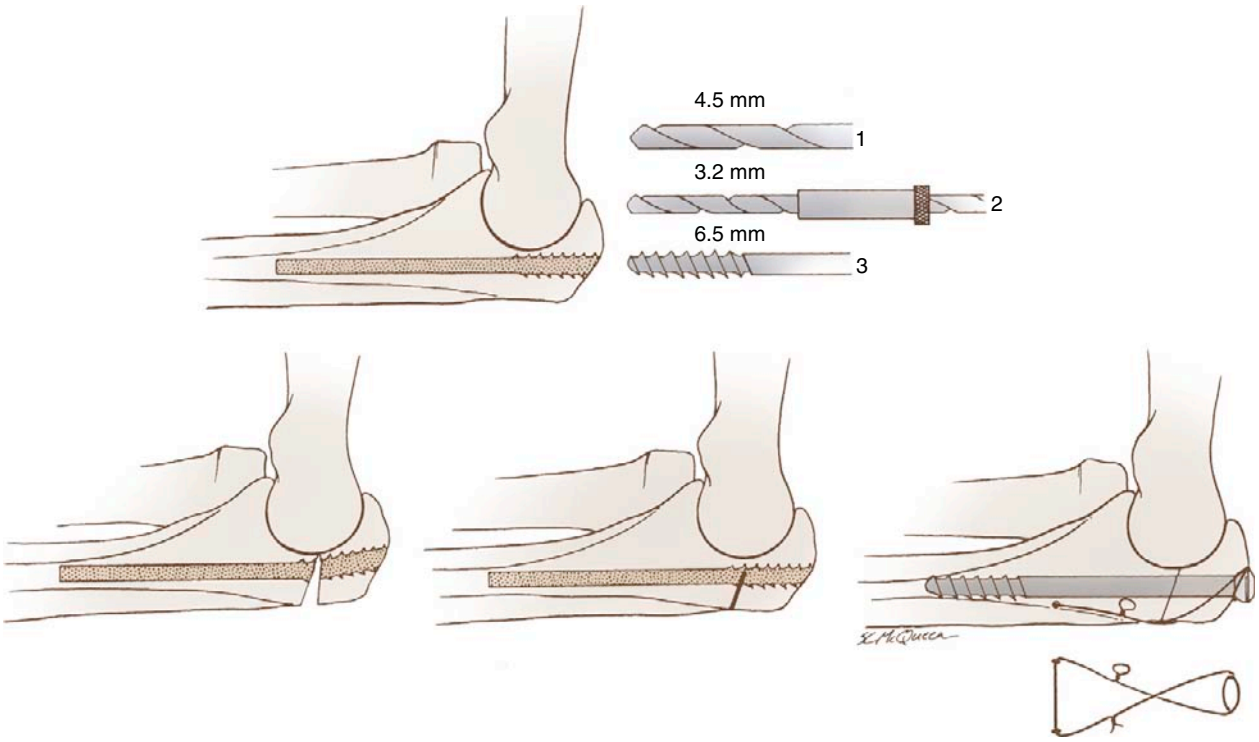


FIGURE 19-46 Osteotomy of the olecranon with placement of a lag screw and tension band wire fixation.

Patients may present with a single isolated fracture or any combination, as previously mentioned. Neurovascular and other soft tissue trauma is considered in selecting the type of reduction and fixation. Screws, pins, a variety of different plates, and dynamic compression technique can be used for internal fixation. Certain fixation techniques of the distal portion of the humerus may require an osteotomy of the olecranon (proximal ulna) to properly align and affix hardware (Figure 19-46). The general goals of treating these injuries are to (1) maintain neurovascular integrity, (2) restore normal joint articulation, (3) preserve motion of the joint, and (4) correct other soft tissue injuries.

Procedural Considerations. Regional anesthesia can be used for procedures on the distal end of the humerus. Bone graft harvesting may require use of general anesthesia. The patient may be prone with the elbow flexed over a small table, supine with the arm over the chest, supine with the arm on a hand table, or in the lateral position. A tourniquet is placed before the surgical prep and inflated during surgery as needed.

A soft tissue set, a large bone set, and a bone graft set are needed, in addition to a compression set, bone-holding clamps, reconstruction plates, and smooth Kirschner wires. A power drill and Kirschner wire driver will be needed to apply the hardware.

Operative Procedure

COMMINUTED DISTAL HUMERAL FRACTURE
(Figure 19-47)

1. The surgeon makes an incision over the distal humeral fracture site.
2. The fracture is exposed and reduced using bone-reduction clamps and temporary small, smooth Kirschner wires, driving them across the fracture site with the power drill.

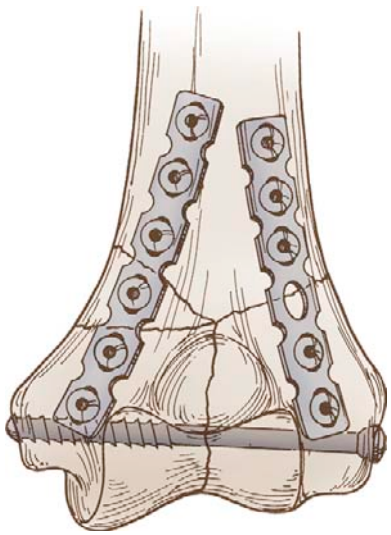


FIGURE 19-47 Repair of the distal comminuted humeral fracture with 3.5-mm reconstruction plates.

3. A cancellous bone screw is placed using drill and tap to transfix from one condyle to the other. The surgeon is careful not to violate the joint surface with the threads of the screw.
4. If the reduction is maintained, the surgeon removes the Kirschner wires.
5. A one-third tubular or reconstruction plate is contoured to the shape of the distal humeral fracture and applied to bridge the fracture fragments.

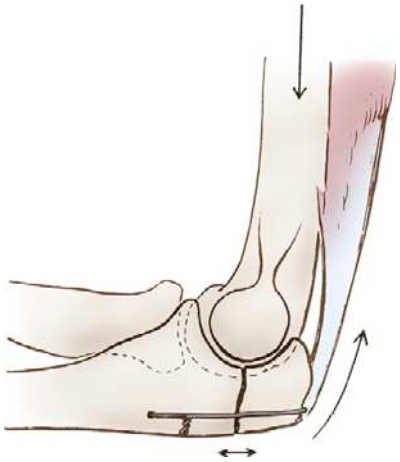


FIGURE 19-48 Tension band technique used for repair of the olecranon.

6. Throughout the entire procedure, the articular surface is periodically inspected to ensure integrity. The plates are held in place by hand while the patient's elbow is moved through its range of motion. The plates should not encroach on the olecranon or coronoid fossa (distal end of the ulna), since this will limit flexion and extension of the arm.
7. The bone is drilled and tapped from one cortex to the other with the appropriate drill and tap. The screw is inserted and seated to the bone surface on the plate. This is done for all subsequent screws, observing the fracture site and articular surface.
8. Interfragmentary screws may be used in addition to the cortical screws spanning the condyles. If osteotomy of the olecranon was previously done for exposure, it is reattached using the tension band technique with a cancellous bone screw and heavy-gauge (18 or 20 gauge) wire (Figure 19-48).
9. The surgeon irrigates the wound, places a drain (as needed), and closes the incision. A long arm posterior splint is applied.

Olecranon Fracture

If the olecranon fracture fragment is small, it may be excised and the triceps tendon reattached to the ulnar shaft. This does not result in loss of stability of the elbow joint. However, larger fragments must be reduced and held with internal fixation. Osteotomy of the olecranon is often done electively for surgical exposure (see previous section) and repaired in the same fashion as for a traumatic fracture.

Procedural Considerations. The patient is placed in the prone position with the arm on an armboard or hand table. A soft tissue set, a bone set, AO/ASIF instrumentation (AO/ASIF is the abbreviation for Swiss Association of Osteosynthesis/Association for the Study of Internal Fixation), heavy stainless-steel wire (16 and 18 gauge in long lengths), a wire tightener, Kirschner wires, bone-reduction clamps, a power drill, and Kirschner wire driver will be needed.

Operative Procedure

TENSION BANDING (Figure 19-49)

1. The surgeon makes an incision over the olecranon and exposes the fracture.
2. A drill hole is made in the distal fragment, traversing the bone.

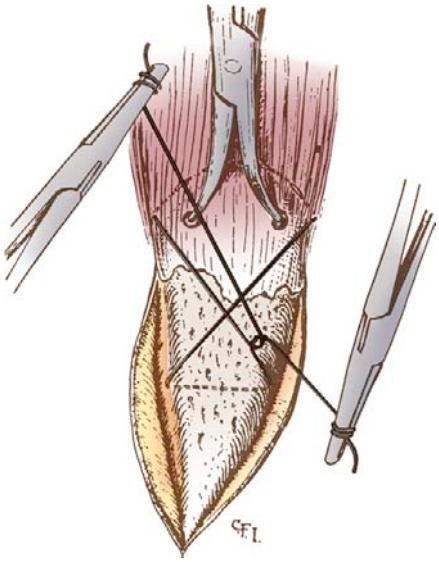


FIGURE 19-49 Operative procedure: tension banding with stainless-steel wire passed through drill holes; figure-of-eight adds stability to the fracture.

3. Stainless-steel wire is passed through the drilled holes, crossed over, and pulled toward the tip of the olecranon.
4. After using the drill and tap, the surgeon uses a cancellous bone screw to attach the proximal fragment to the distal, stopping short of totally seating the screw.
5. The surgeon pulls the wire and loops it around the exposed shaft of the screw while reduction is maintained manually or by using a reduction clamp. The wire can be tightened using the wire tightener. Two smooth Steinmann pins, bent over the exposed portion to hook the loop of wire, can substitute for the cancellous screws.
6. The remaining screw is threaded into the bone; the fracture site is observed for opposition.
7. The wound is irrigated and closed. Drains are generally not necessary. A long arm posterior splint is placed.

NOTE: Using this technique requires early active motion of the arm. Compression of the fracture site is achieved by moving the elbow through its range of motion and applying force by the hardware.

Transposition of the Ulnar Nerve

Transposition of the ulnar nerve involves freeing the nerve from a groove at the back of the medial epicondyle of the humerus and bringing it to the front of the condyle. The ulnar nerve is frequently divided or damaged after fracture or wounds to the elbow caused by trauma. Dislocation of the elbow may also cause ulnar nerve damage. Late traumatic neuritis may occur after an old injury, resulting in stretching of the ulnar nerve. The hand appears atrophied, and sensory loss is extensive. In severe cases, a clawhand deformity develops.

Procedural Considerations. The perioperative nurse assists with positioning the patient supine with the extremity slightly flexed on a hand table or over the chest. A tourniquet is applied to the upper arm, and the entire arm (fingers to tourniquet) is prepped and draped. A soft tissue set is required. Bone instruments may be required.

Operative Procedure

1. The surgeon makes an incision on the lateral aspect of the elbow near the epicondyle.
2. The fascia and the flexor carpi ulnaris muscle are divided.
3. The surgeon frees the ulnar nerve and dissects the medial intermuscular septum.
4. The nerve is then drawn anteriorly and placed deep into the brachialis flexor muscle origin.
5. The wound is irrigated and closed. A drain is not necessary. A short arm posterior splint is applied to the elbow postoperatively.

Excision of the Head of the Radius

Fractures of the radial head can be displaced or nondisplaced, segmental, or comminuted. Complications can arise when treatment is delayed, causing limitation of motion, pain, and posttraumatic arthritis. A congruous radial head is essential for proper rotation of the forearm at the elbow. Consequently, in an adult it is necessary to excise the radial head if a severely comminuted fracture with angulation interferes with rotation. The radial head should never be excised in children. The outcome for the patient undergoing radial head excision may result in some permanent loss of pronation and supination of the forearm. Noncomminuted fractures that are easily reduced can be treated using closed reduction and casting.

Procedural Considerations. The patient is supine with the arm over the chest or on a hand table. A tourniquet is applied. A soft tissue set, a small bone set, and an oscillating microsaw with blades are needed.

Operative Procedure

1. The surgeon makes an incision on the shaft of the radius from 5 cm distal to the radial head, extending proximally over the lateral humeral condyle.
2. Dissection is continued between the extensor carpi ulnaris and extensor digitorum muscles onto the joint capsule.
3. With the head and neck of the radius exposed through the joint capsule, the surgeon irrigates the joint to clear bone debris and blood clots.
4. The surgeon excises the radial head just proximal to the radial tuberosity, and removes all the periosteum to limit new bone formation. The remaining annular ligament is also excised. The fragments of the radial head should be saved and readily available so that they may be reassembled to ensure that all fragments have been retrieved.
5. The wound is closed, and a long arm posterior splint is applied with the elbow at 90 degrees.

Fractures of the Proximal Third of the Ulna with Radial Head Dislocation (Monteggia)

The Monteggia type of fracture presents with a proximal ulnar fracture and dislocation of the radial head. The fracture is rarely treated with open reduction in children. The open technique is often used to treat adults. A direct blow to the ulnar aspect or a fall while the arm is hyperextended produces this type of injury. If the open reduction approach is chosen, closed reduction of the radial dislocation is attempted and often is successful. At times the annular ligament may prevent reduction of the radial head dislocation, and open reduction becomes necessary. Deforming forces of the forearm vary, depending on the location of the fracture in relation to the insertion of muscles. These forces are often encountered when treating forearm injuries. The dynamic compression technique uses compression plates that are stockier and stronger than the semitubular plates mentioned earlier for distal humeral fractures. They are used to plate shaft fractures, where stress forces on the shaft are greater and stronger plates are required.

Procedural Considerations. The patient is placed in the supine position with or without a hand table. A tourniquet is applied and inflated as needed. A soft tissue set and a large bone set are required, as well as bone-reduction clamps and bone-grasping forceps, AO/ASIF instrumentation, plates and screws, and a power drill.

Operative Procedure

FIXATION WITH DYNAMIC COMPRESSION PLATE
(Figure 19-50)

1. The surgeon performs a closed reduction to reduce the radial head dislocation.
2. An incision is made; the ulnar fracture site is dissected.
3. The surgeon strips the periosteum and reapproximates the fragments using bone-reduction and bone-grasping forceps.
4. The bone is assessed for placement of a small- or large-fragment dynamic compression plate (DCP), with at least three screw holes proximal and three distal to the fracture site.
5. A concentric (neutral) hole is drilled into the ulna (through one of the screw holes on the plate) to the opposite cortex.
6. After the hole is gauged, the selected size of screw is inserted, with purchase of the opposite cortex ensured. A second screw is inserted on the opposite fragment in the neutral position.
7. On either side of the fracture site, an eccentric (loading) hole is drilled in the same fashion to the opposite cortex. The hole is gauged and tapped, and the screw is inserted.
8. The selected screw is entered eccentrically into the plate. As the screw seeks the center of the screw hole while riding the bevel of the screw hole, it compresses the fracture site. This screw should be tightened completely, and the other screws should be slightly loosened.
9. The fracture site is now visualized radiographically as the action of the screw in the plate compresses the fracture site.
10. The remaining bone screws are inserted following the same procedure.
11. The wound is irrigated and closed; a drain may or may not be inserted.
12. A long arm posterior splint is placed with the arm in 110 to 120 degrees of flexion.

Correction of Colles' Fracture with External Fixation

Colles' fracture is a dorsally angulated fracture of the distal end of the radius. Most of these fractures can be managed successfully with closed reduction and immobilization, but external fixation is especially useful in the case of a comminuted intraarticular fracture. Internal fixation is indicated when the distal end of the radius is severely comminuted and displaced. In these cases, Kirschner wires are used for internal fixation.

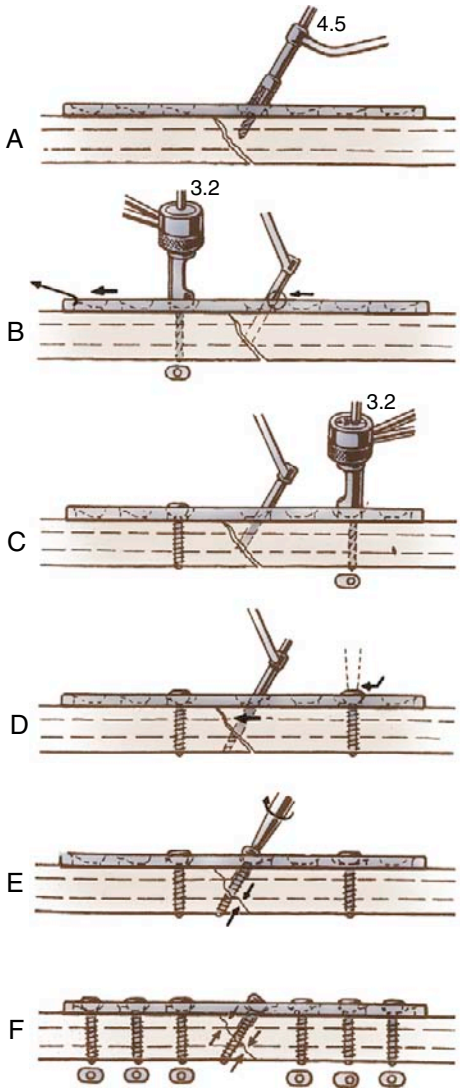


FIGURE 19-50 Fixation with dynamic compression plate. **A**, Gliding hole with drill bit. **B**, Fracture is reduced, drill sleeve is inserted, the fracture is drawn together, a hole is drilled, and a screw is inserted in the neutral position to correct the fracture. **C** and **D**, One screw is inserted in load position (eccentric) into the other fragment; as the screw is tightened, axial compression is generated. **E**, Lag screw inserted across the fracture site. **F**, Remaining screws inserted in the neutral position.

Procedural Considerations. The patient is in the supine position with the arm extended on a hand table and may require traction by means of finger traps. A soft tissue set and a small bone set are required, along with a power drill, small elevator, and the external fixation device of choice. Fluoroscopy is necessary.

Operative Procedure

1. Small incisions are made, and the surgeon places two pins through the second metacarpal—one at the base and the other distalward a distance equal to the span between the openings in the fixator.
2. Two pins are placed in the radius 8 cm from the styloid.
3. The surgeon confirms pin placement radiographically in both the AP and lateral views.
4. A frame is constructed to incorporate all four pins.
5. Reduction of the fracture is obtained, and the surgeon secures the frame.
6. Postreduction films are obtained to check alignment and pin position.

SURGERY OF THE HAND

Hand surgery has become highly specialized. The perioperative nurse encounters numerous procedures for treating bone, soft tissue, or both. Many of the techniques and principles used to treat large bone defects are used in the treatment of hand injuries. Hand procedures range from carpal tunnel release to complex digit reimplantation.

Tourniquets and regional anesthetics are often used for hand surgery. The OR team usually sits down at a hand table but may move to areas such as the iliac crest for bone grafting. The instruments for hand surgery are common to orthopedics but on a smaller scale. Many instruments and reconstruction systems have been developed primarily for hand surgery. Air- or battery-powered drills and saws are frequently used. The surgery often requires the use of eye loupes (glasses for magnification) or the microscope.

Carpal Tunnel Release

Carpal tunnel syndrome results from entrapment of the median nerve on the volar surface of the wrist; it is caused by thickened synovium, trauma, or aberrant muscles. Carpal tunnel syndrome is frequently seen in patients with rheumatoid synovitis or malaligned Colles' fracture and is associated with obesity, Raynaud's disease, pregnancy, and occupational injuries. The symptoms are pain, numbness, tingling of the fingers, and weakness of the intrinsic thumb muscles. These symptoms are usually reversible after the flexor retinaculum is incised so that the compressed median nerve is relieved. Carpal tunnel release may be completed endoscopically or by open incision.

Procedural Considerations. The patient is placed in the supine position with the arm extended on a hand table. A tourniquet is applied to the forearm or upper arm. A hand set is required. The endoscopic approach requires use of specialized equipment.

Operative Procedure—Open Approach

1. The surgeon makes a curvilinear, longitudinal volar incision from the proximal side of the palm, paralleling the thenar crease and extending to the crease of the wrist across the wrist joint.
2. The deep transverse carpal ligament is divided, taking care to avoid damage to the median nerve.
3. At this point the release is completed.
4. If indicated, the surgeon performs a tenosynovectomy.
5. The wound is closed, and a compression dressing and volar splint are applied.

Excision of Ganglions

A ganglion is a cystic lesion arising from a joint capsule or tendon sheath and containing glassy, clear fluid. Ganglions are most common on the dorsum of the wrist, palm of the hand, and dorsolateral aspect of the foot. Ganglions appear as firm masses that vary in size. They may resolve spontaneously but

occasionally require excision because of discomfort or for cosmetic reasons.

Procedural Considerations. The perioperative nurse assists with positioning the patient supine with the arm extended on a hand table, and applies the tourniquet as directed by the surgeon. A hand set is required.

Operative Procedure

1. The surgeon makes a transverse incision over the ganglion.
2. The ganglion is excised with a rim of normal joint capsule or tendon sheath at its base.
3. The wound is irrigated and closed, and a pressure dressing is applied. A plaster splint may also be applied to immobilize the affected joint.

Fractures of Carpal Bones

Most fractures of the carpal bones are treated by closed reduction and immobilization. However, it is occasionally necessary to operate on a fracture because of acute instability, delayed union, or nonunion. The scaphoid is the most commonly fractured carpal bone. Internal fixation is accomplished with Kirschner wires, small compression screws, or minifragment compression plates and screws. A bone graft from the distal end of the radius or olecranon may be taken.

For displaced or unstable scaphoid fractures, the Herbert bone screw (Figure 19-51) has several advantages: (1) strong internal fixation, (2) compression at the fracture site with reversed threads at each end of the screw, and (3) reduced time required for external immobilization.

Procedural Considerations. The patient is supine with the arm extended on a hand table. A tourniquet is applied and fluoroscopy should be available. A soft tissue set and a small bone or hand set are required in addition to the Herbert screw set. If a minifragment compression set is used, a power drill and smooth Kirschner wires will also be needed. A bone graft set should also be available.

Operative Procedure (Figure 19-52)

1. The surgeon makes a longitudinal skin incision over the palmar surface of the wrist.
2. The superficial palmar branch of the radial artery is ligated and divided.
3. The surgeon incises the flexor carpi radialis tendon sheath and retracts it to expose the capsule of the wrist.
4. The capsule is entered, and the scaphoid fracture is identified and inspected to determine the need for bone grafting.
5. The surgeon manipulates the fracture to reduce it and inserts small Kirschner wires to temporarily hold the reduction.
6. The scaphoid fracture is reduced and held with the Herbert jig.
7. A short drill bit and then a long drill bit are inserted to create a channel for the screw.
8. The surgeon inserts the Herbert screw and turns it until it is seated within the scaphoid.
9. Bone graft is placed around the fracture site if needed. (The loss of significant bone can often be corrected by fashioning a strut of bone from graft.)
10. The wound is irrigated and closed.
11. A splint is applied with a thumb spica or long arm cast incorporating the thumb.

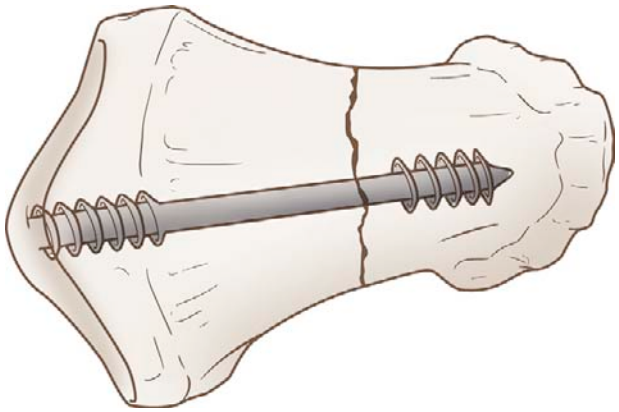


FIGURE 19-51 Herbert bone screw placement.

SURGERY OF THE HIP AND LOWER EXTREMITY

Fractures of the Acetabulum

Fractures of the acetabulum usually result from high-energy injuries such as motor vehicle accidents and falls with a landing on the extended extremities. The fracture is directly related to the force transmitted to the femoral head through the greater trochanter or lower leg. Management of these fractures can often present the surgical team with a complex and challenging task. Indications for internal fixation of acetabular fractures include (1) greater than 2 mm of displacement, (2) presence of intraarticular loose bodies, (3) inability to reduce under closed methods, (4) unstable fractures of the posterior acetabular wall, and (5) open fractures. Internal fixation is usually delayed 3 to 10 days to allow time for the patient to be evaluated and clinically stabilized. Until internal fixation is undertaken, the fracture is reduced by means of closed methods and the patient is maintained in skeletal traction. General anesthesia may be required for closed reduction and placement of skeletal traction when the acetabular fracture is severely displaced or dislocated. The fractures are divided into five basic groups: (1) fractures of the posterior wall, (2) posterior column, or (3) anterior wall; (4) anterior column and (5) transverse fractures (Figure 19-53). Internal fixation is accomplished with reconstruction plates and screws, total hip replacement with bone grafting (see Total Hip Arthroplasty, p. 782), or fusion if the fracture cannot be reduced.

Procedural Considerations. The surgical approach depends on the type and area of the fracture and the surgeon's preference. The perioperative nurse assists in placing the patient on a fracture or standard OR bed in the lateral or supine position. A general anesthetic is usually administered, but the procedure can be performed solely with a regional block or concurrent epidural infusion. Procedures of this magnitude can be lengthy and involve considerable blood loss. Appropriate measures should be taken to avoid complications attributable to these factors. The room should remain warm, the patient protected from pressure injury, and red blood cell salvaging techniques employed.

A soft tissue set, large bone and acetabular instruments, pelvic reduction clamps, reconstruction plates and screws (both 3.5 and 4.5 mm), plate-bending irons, and a femoral distractor will be necessary. A total hip set should be available. Also

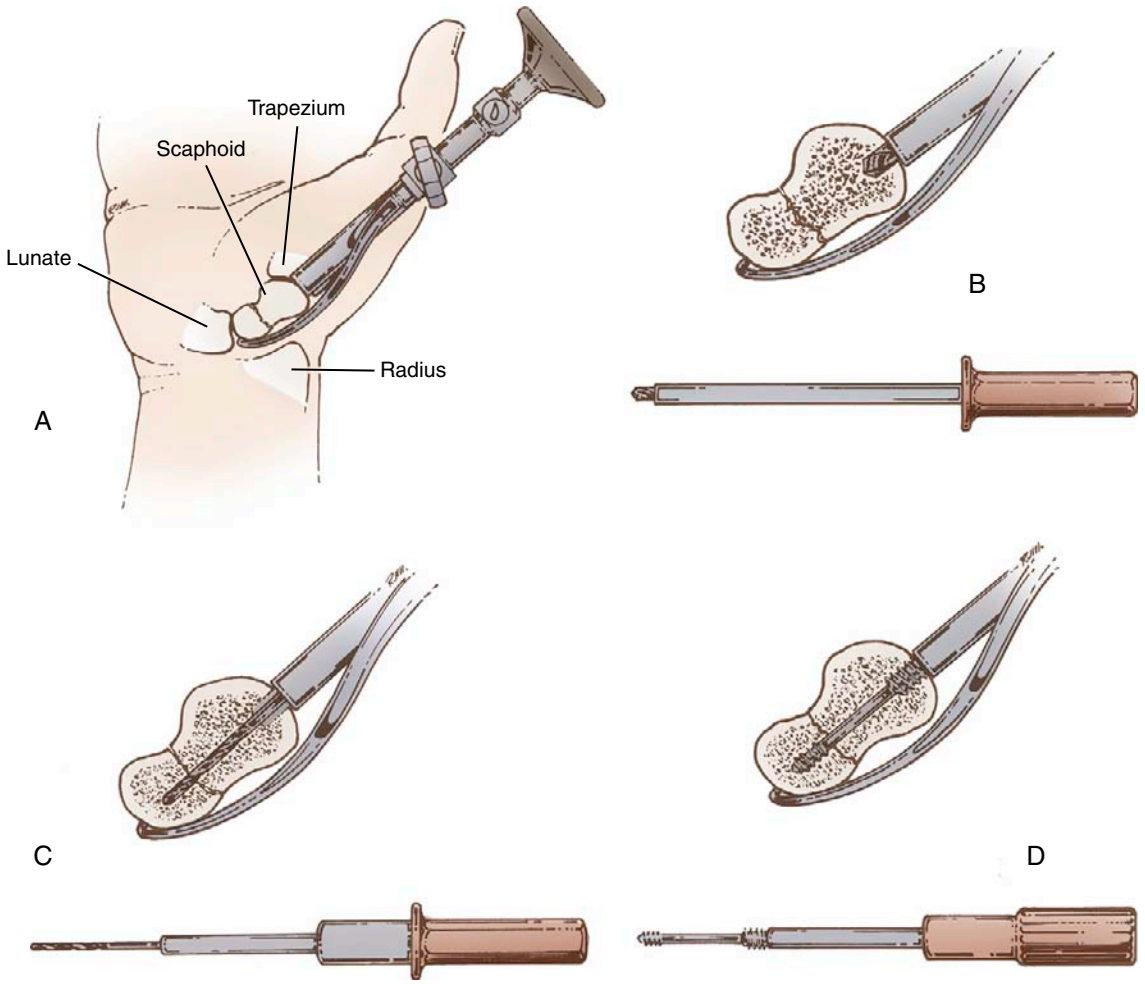


FIGURE 19-52 Repair of the scaphoid. **A**, Fracture site is exposed. **B**, Alignment guide reduces the fracture and guides all subsequent instrumentation. **C**, The screw hole is drilled by hand, and the tap is inserted. **D**, The Herbert bone screw is inserted through the drill guide.

needed are Kirschner wires and Steinmann pins, large-fragment bone screws, pulsatile lavage supplies, and power drill and reamer. Fluoroscopy may be used for this procedure.

Operative Procedure

POSTEROLATERAL APPROACH

1. The surgeon makes a lateral incision over the acetabular fracture site.
2. The joint is opened and the femur dislocated from the acetabulum.
3. The surgeon uses self-retaining or handheld hip retractors to maintain exposure of the acetabulum.
4. Femoral distraction or osteotomy of the trochanter may be used to improve visualization and access to the fracture.
5. The surgeon reduces the fracture using bone clamps, forceps, and a ball spike.
6. Reduction is accomplished in gradual steps using Kirschner wires to hold the fragments temporarily in place.
7. Reconstruction plates are fitted and contoured to the fracture site and secured with screws.
8. The surgeon may also use long cancellous lag screw fixation to provide interfragmentary compression, particularly in column fractures.
9. A bone graft may be needed for additional fixation. A femoral head allograft technique is sometimes used, in which the allograft is mushroomed to create a new acetabulum.
10. The surgeon uses pulsatile lavage to irrigate the wound with antibiotic solution to ensure the articular surfaces are free from loose bodies.
11. The wound is closed, drains are inserted, and pressure dressings are applied.

The leg is maintained in abduction and external rotation with traction. Once the fracture is stabilized, traction is no longer necessary.

NOTE: If there is associated traumatic dislocation of the hip with the acetabular fracture, the dislocation should be treated promptly. The dislocation should be reduced as soon as possible and skeletal traction inserted if needed to maintain reduction. Acetabular fractures often accompany femoral shaft fractures, which also need to be treated concurrently with the surgeon's desired method (see Femoral Shaft Fractures: Internal Fixation, p. 767).

Hip Fractures

Hip fractures are classified by anatomic location and can be categorized as femoral neck fractures, intertrochanteric fractures, and subtrochanteric fractures (Figure 19-54), and these can

each be subclassified. Fracture-dislocations also have a classification system and treatment protocol. Fractures of the greater or lesser trochanters alone are less common and can usually be treated nonoperatively.

Femoral neck fractures and intertrochanteric fractures commonly require open reduction and internal fixation. Neck fractures are more common in women because of several factors, including osteoporosis. Most elderly patients require a comprehensive preoperative medical evaluation to define and treat anesthetic risks. However, efforts should be made to correct the fracture as soon as possible to avoid complications related to immobility, skin pressure, pulmonary congestion, and thrombophlebitis. Avascular necrosis and degenerative changes can occur as a result of diminished blood supply to the femoral head, resulting in irreversible changes. Buck's traction may be placed preoperatively to reduce discomfort from muscle spasm caused by overriding of fracture fragments.

Manipulation, reduction, and internal fixation of these fractures are greatly facilitated by use of the OR fracture bed, which also permits adequate radiographic examination to determine placement of the internal fixation.

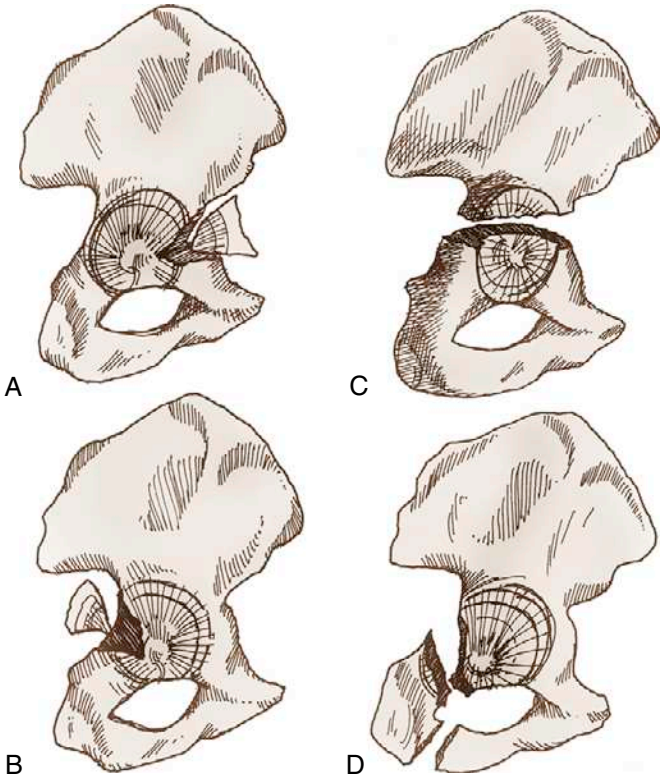


FIGURE 19-53 Acetabular fractures. **A**, Anterior wall. **B**, Posterior wall. **C**, Transverse. **D**, Posterior column.

Intertrochanteric Fractures. Intertrochanteric fractures occur most frequently in older patients. The fractures usually unite without difficulty. However, because the lower extremity is externally rotated at the fracture site, internal fixation is necessary to prevent malunion. Internal fixation allows patients to be mobilized earlier, thereby decreasing mortality and morbidity.

PROCEDURAL CONSIDERATIONS. The patient is placed in the supine position on the OR fracture bed, and the surgeon reduces the fracture by manipulating the extremity and then confirming with fluoroscopy. Various internal fixation devices, including Ambi, Free-Lock, dynamic hip screw (DHS), and medullary fixation, may be used. Success of the procedure is determined by bone quality, fragment configuration, adequate reduction, implant design, and implant-insertion technique. Intraoperative blood loss is minimized because the hip joint is not opened.

A soft tissue set and a large bone set are required in addition to the compression hip screw instrumentation and implants, bone-reduction and plate-holding clamps, and a power drill and reamer.

OPERATIVE PROCEDURE

Free-Lock Compression Plate and Lag Screw (Figure 19-55)

1. The surgeon reduces the fracture as previously described.
2. Reduction is checked in both the AP and lateral views with fluoroscopy.
3. The surgeon makes an incision from the greater trochanter distally to accommodate the length of the implant.
4. The dissection is completed through the fascia lata, and the vastus lateralis is exposed.

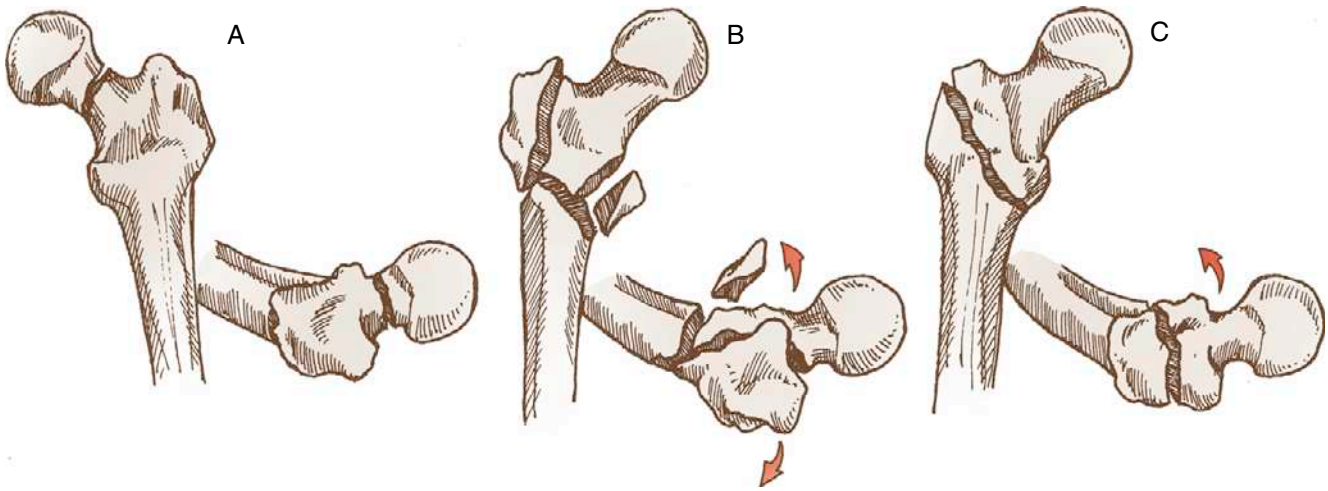


FIGURE 19-54 Proximal femur fractures. **A**, Midcervical. **B**, Comminuted subtrochanteric. **C**, Intertrochanteric.

5. The reduction is visually confirmed and the surgeon inserts the guide pin after determining the angle plate to be used. A 135-degree angle plate is commonly used.
6. The pin should be centralized in the femoral head approximately 1 cm short of the femoral articular surface. Care must be taken to not enter the joint space, since this might result in arthritic changes. Further penetration of the pin through the acetabulum and into the pelvis can potentially damage large vessels or bowel. A second pin can be used to control rotation in high neck or unstable fractures.
7. The surgeon uses a conical cannulated drill bit over the guide pin to open the lateral cortex.
8. The depth gauge is placed over the guide pin. The size of the required lag screw is determined from the guide.
9. A double-barrel reamer is adjusted to correspond to the depth of the guide pin. The cortex is reamed over the guide pin to create a channel for the lag screw and barrel of the compression plate.
10. The lag screw channel is tapped to the full distance of reaming to allow proper seating of the lag screw, particularly in young patients with firm bone. Reaming depth of osteoporotic bone is reduced 5 mm, and the tap depth is reduced approximately 1 to 2 cm to allow sufficient screw purchase.
11. The surgeon may confirm the plate angle with a trial. Once confirmed, the nurse opens the implants (plate and lag screw) to the back table.
12. The surgical technologist assembles the plate, lag screw, and insertion wrench with the centering sleeve. A screw stabilizer is passed through the center of the insertion wrench and threaded into the lag screw.
13. The surgeon places the entire assembly over the guide pin, and advances the lag screw to the desired depth with periodic verification with fluoroscopy. Penetration of the lag screw through the femoral articular surface must be avoided.
14. The insertion wrench is disassembled, and the barrel of the compression plate is placed over the lag screw. The barrel of the plate should fully cover the lag screw. The plate is seated on the lateral femoral shaft.
15. The surgeon secures the plate to the shaft of the femur with plate-holding forceps. The guide pin is removed. At this point, traction can be released to allow compression of the fracture site.
16. Screw holes are made using the drill guide and a 3.5-mm drill bit. The length is determined, and cortical screws are inserted through the screw hole on the plate with sufficient purchase on the opposite cortex of the shaft. The top screw hole on the plate can accept a 6.5-mm cancellous screw, which can be angled for better purchase in comminuted fractures.
17. Traction is released if not done previously. The surgeon inserts a compression screw into the barrel of the screw and threads it into the back of the lag screw, compressing the fracture site. The compression screw exerts a powerful

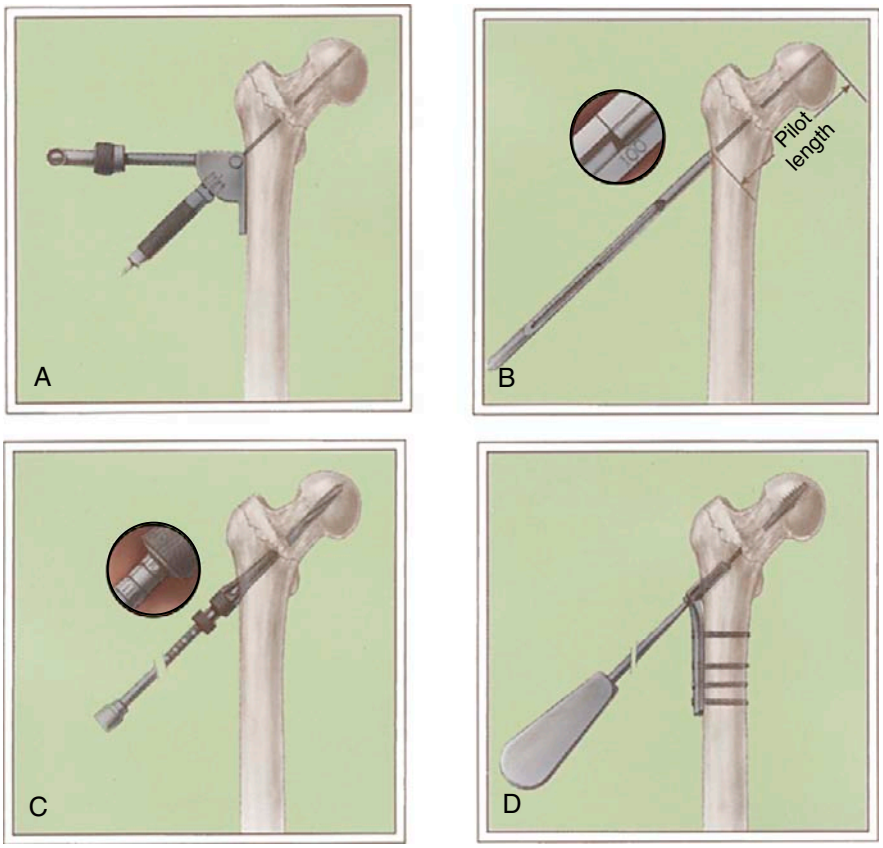


FIGURE 19-55 Intertrochanteric fracture repair with compression plate. **A**, Guide pin is inserted. **B**, Depth of guide is measured. **C**, Lag screw channel is reamed. **D**, Tube/plate is applied, and lag screw is inserted.

force. The amount of compression applied should correlate with the quality of the bone.

18. The wound is irrigated and closed. Two closed suction drains may be inserted during closure.

Weight bearing may begin as early as the first postoperative day, depending on reduction and quality of bone.

NOTE: Many of the same techniques and principles of long bone fracture fixation are used in treatment of various types of hip fractures. The different screw types, dynamic compression, and lag screw effect are described throughout the chapter.

Femoral Neck Fractures: Internal Fixation. Anatomic reduction is necessary before internal fixation of femoral neck fractures because of the high incidence of associated complications, such as nonunion and avascular necrosis of the femoral head. The degree of displacement, tamponade pressure from intracapsular bleeding, and delays in reduction and fixation can affect the blood supply to the femoral head. These factors contribute to death of the femoral head and failed fixation. Growing children may sustain fractures through the epiphyseal growth plate (slipped capital femoral epiphysis). These injuries are treated by reduction and internal fixation of the femoral head, similar to the procedures used in the adult. The Garden and AO nomenclatures are the most popular classifications for grading the fractures. Pins of various designs, such as Knowles and Hagie pins, and universal cannulated screws (Figure 19-56) are used for fixation (Figure 19-57). In cases of severe comminution or avascular necrosis of the femoral head, the patient may require a prosthetic replacement (see Total Joint Arthroplasty, p. 781).

PROCEDURAL CONSIDERATIONS. The perioperative nurse assists with positioning the patient on the OR fracture bed and a general or regional anesthetic (spinal or epidural) is administered. Slight traction and external rotation are adjusted on the affected side. A soft tissue set and a large bone set are required, as well as the fixation device of choice with instrumentation, Kirschner wires, Cobra retractors, a power drill, and fluoroscopy.

OPERATIVE PROCEDURE

Cannulated Screw Fixation for Nondisplaced Femoral Neck Fractures

1. The surgeon makes a 5-cm lateral incision over the greater trochanter and exposes the fracture.
2. The dissection is carried through the subcutaneous and fascial layers; the vastus lateralis is detached anteriorly and retracted, exposing the femoral neck.
3. Two guide pins are driven into the middle of the femoral head, one anterior and one posterior, within 5 mm of subchondral bone; a third pin is placed adjacent to the medial cortex at a 135-degree angle. The surgeon is careful to not violate the articular surface.
4. The guide pins are measured for correct screw length, and the cannulated screws are inserted over the guide pin without applying compression until all are seated.
5. Compression of the anterior screws is completed first and the posterior screws last to avoid collapse of the posterior aspect of the neck.
6. Traction is released, and the fracture site is visualized with fluoroscopy while the hip is rotated through a full range of motion.
7. Radiographs are taken to verify the position of the screws; the wound is irrigated and closed.

NOTE: Screw protrusion into the joint space can be disastrous to the articular surface. Radiopaque dye can be injected to rule out communication with the joint.

Femoral Head Prosthetic Replacement: Unipolar and Bipolar Implants. With the development of current cement fixation techniques and the evolution of the modular bipolar

FIGURE 19-56 Cannulated screw system.

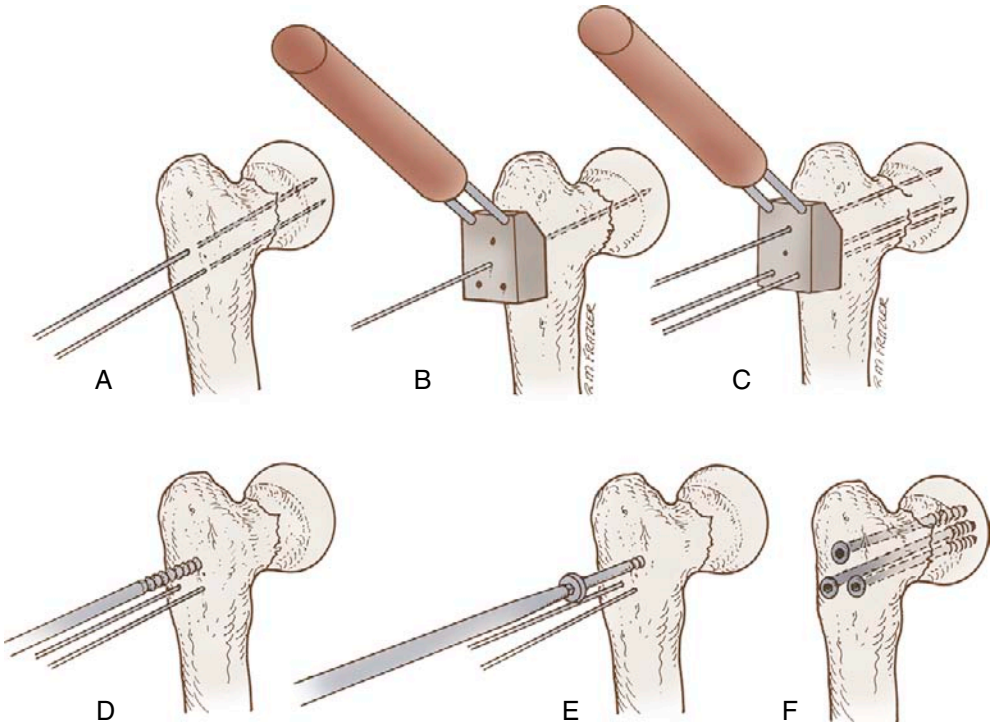


FIGURE 19-57 Internal fixation with cannulated screws (AO technique). **A,** Guidewire parallel to anteversion wire. **B,** Guidewire placed over positioning wire through diamond-patterned positioning holes. **C,** Guidewire placed through each outer triangle of holes. **D,** Cannulated tap passed over guidewire to tap near cortex. **E,** Large cannulated screw inserted over guidewire. **F,** Remaining screws inserted in same manner.

and monopolar design, the use of fixed endoprostheses such as the Austin-Moore and Thompson designs declined. During the early 1980s the bipolar system in conjunction with a cemented femoral stem became popular. Bipolar endoprostheses (Figure 19-58) were introduced to reduce the shear stresses affecting the acetabular surface, decreasing the motion and friction between the prosthetic head and the acetabulum that is seen with conventional (unipolar) endoprostheses. A femoral head prosthesis is snapped into a rotating polyethylene-lined cup that, when inserted, moves as one unit. Friction occurs between the ball and plastic instead of between the head and the acetabulum. This was a revolutionary design in the mechanics of hip motion and stresses. Current data, however, have some surgeons and engineers reevaluating the use of bipolar prostheses. It is believed that bipolar motion subsides after fibrous growth has taken place, allowing for only unipolar motion. There have also been reports of bone resorption and subsequent prosthetic loosening in cases in which bipolar prostheses were used. Researchers are evaluating evidence of metallic head wear of the polyethylene cup, creating microscopic debris with a subsequent chemical lysis of bone. Thus there has been resurgence in the use of unipolar heads for femoral head replacement.

Trends in healthcare toward cost reduction precipitated the development of the *diagnosis-related group (DRG) prosthesis*. The modular design was retained, allowing for different combinations of head size, neck length, and stem size. Instead of being bipolar, the head is solid, or unipolar, and the stem is the result of a less costly manufacturing process. The most cost-effective prosthesis is still the original Austin-Moore design, which may be selected for those patients whose life expectancy is short and who have a minimal level of activity. If major deficiencies in the acetabular side of the joint are present, a total joint arthroplasty may be performed. In deciding between the hemiarthroplasty and total hip reconstruction,

FIGURE 19-58 Modular bipolar endoprostheses.

the patient's medical condition, age, and level of activity must be considered.

Current biomaterials, methods of fixation (cemented versus uncemented), prosthetic life, and modular components allow conversion of a hemiarthroplasty (reconstruction of one side of the joint) to a total hip arthroplasty, provided that the femoral component is adequately fixed. Depending on the patient's condition, the acetabulum may eventually require arthroplasty as a result of degenerative changes. Improved technology and surgical technique have increased the life span of implanted components. The portion of the implant that articulates within the acetabulum can be removed and replaced with a smaller femoral head. The acetabulum is then prepared for prosthetic implantation by various means of fixation. The ability to convert from hemiarthroplasty to total arthroplasty reduces the amount of surgery required.

PROCEDURAL CONSIDERATIONS. The patient is placed in the lateral position after the administration of a general or regional anesthetic. The perioperative nurse preps the patient from the umbilicus down to and including the foot. Instrumentation for total hip replacement should be available but not opened until inspection of the resected joint is completed to determine if a total arthroplasty is required.

The soft tissue and the large bone sets are required, as well as the endoprosthesis instruments, trials, and implants. A power reciprocating or sagittal saw may be necessary. Templates or a caliper will be used to measure the size of the femoral head. Bone cement and the supplies for preparing and inserting it should also be available.

OPERATIVE PROCEDURE

Modular Austin-Moore Endoprosthesis

Both posterior and anterior approaches can be made to the hip to place an endoprosthesis. The posterior approach is quicker and generally involves less blood loss, but detractors suggest that there is a higher dislocation rate and a greater chance of infection because of the proximity of the incision to the anus. Although both approaches are widely used, the posterior approach is described as follows:

1. The surgeon makes a linear incision from 5 cm below the posteroinferior iliac spine toward the posterior aspect of the greater trochanter and distally along the posterior aspect of the proximal femur for 7 mm.
2. The capsule is entered, and the femoral head is removed and gauged with the template. Fragments that may be loose in the acetabulum or attached to the ligamentum teres are removed.
3. The surgeon inserts a trial cup into the acetabulum, and applies axial compression while checking clearance of the extremity's lateral motion.
4. The femoral neck is fashioned to achieve an accurate prosthetic fit.
5. Using a punch, the surgeon opens the medullary canal from the femoral neck. The intramedullary canal is reamed and rasped to accommodate the prosthesis.
6. Once the canal is prepared, the surgeon inserts the prosthesis of choice with or without bone cement.
7. A unipolar or bipolar assembly is snapped onto the neck of the femoral stem. The height of the head determines the neck length and is selected after trial reduction.
8. The hip is reduced, and closure is accomplished in layers over suction drains.

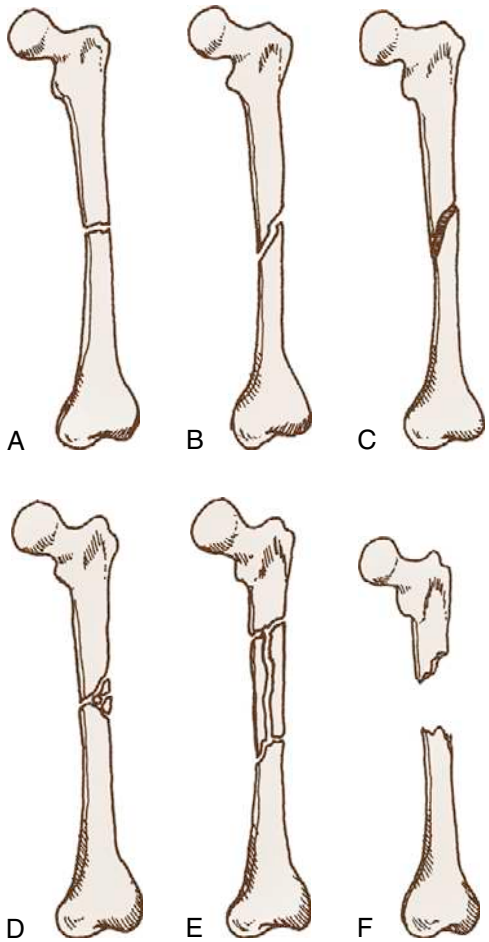


FIGURE 19-59 Femoral shaft fractures. **A**, Transverse. **B**, Oblique. **C**, Spiral. **D**, Comminuted. **E**, Longitudinal split. **F**, Complete bone loss.

Femoral Shaft Fractures: Internal Fixation. Fractures involving the femoral shaft are very common in today's orthopedic OR. Prolonged immobility, with its attendant complications, and disability can result if femoral shaft fractures are not managed appropriately. The femur is the largest principal load-bearing bone in the body. Fractures of the femoral shaft can be surgically treated with several available techniques. Considerations for treatment are type and location of fracture (location on shaft), the number of segments involved, the degree of comminution (Figure 19-59), and the activity level of the patient. Femoral shaft fractures are often associated with ipsilateral (same-side) trochanteric or condylar fractures. Pathologic fractures often occur in this region.

Possible treatment methods for femoral shaft fractures are closed reduction, skeletal traction, and femoral cast bracing. External fixation has limited utility when fractures associated with surgical site infection or neurovascular compromise are treated, but it may serve temporarily until internal fixation can be performed. Although plates and screws are used for femoral shaft fractures, their use has been widely disputed because of complications such as bent or broken plates, refractures, and deep surgical site infections. Intramedullary (IM) fixation devices have become the preferred method of treatment. IM nails and rods increase the load sharing of the bone, making the implant less likely to fracture. Bone healing requires a load

across the fracture site to promote osteosynthesis and prevent refracture. The open or closed method of intramedullary nailing can be used with locked and nonlocked nails. Closed methods of intramedullary fixation often minimize exposure of the surgical site and decrease surgical time, resulting in less opportunity for infection.

Intramedullary nail and rod designs vary: (1) flexible nails such as the Rusch or Enders type, (2) standard rods such as the Sampson and AO rods, and (3) interlocking nails (see Fractures of the Humeral Shaft, p. 754) such as the Grosse-Kempf and Russell-Taylor varieties. Closed reduction and intramedullary nailing with or without locking screws have become the method against which other methods are measured. Incidences of scarring, blood loss, and infection are all favorable. Fracture hematoma remains intact at the fracture site, which is important in bone healing, and the rate of bone union is increased.

PROCEDURAL CONSIDERATIONS. General or epidural anesthetics are used. The patient is placed on the OR fracture bed in the supine position, traction applied, and the fracture manually reduced and confirmed with fluoroscopy. If the fracture is profoundly unstable, the surgeon must take care during manipulation to prevent neurovascular complications. For open IM fixation, extra retractors and bone instruments may be required. For a percutaneous reduction, a soft tissue set and a large bone set are required in addition to the IM nail implants and associated instruments, a power reamer and drill, and long guidewires for reamers. This procedure requires the use of fluoroscopy. A skeletal traction tray with Steinmann pins may be necessary.

OPERATIVE PROCEDURE

Russell-Taylor Rod With or Without Locking Screws

1. The surgeon makes an incision over the tip of the greater trochanter and continues it proximally and medially for 6 to 8 cm. The fascia of the gluteus is incised, and the piriformis fossa is palpated.
2. With a threaded guide pin followed by cannulated reamers or by use of an awl, the surgeon identifies the trochanteric fossa and penetrates the cortex. A 3.2-mm guide rod is inserted to the level of the fracture. A curved guide pin is available for more severely displaced fractures.
3. Under fluoroscopy, the surgeon advances the guidewire across the fracture site and into the distal fragment until the ball tip of the guidewire reaches the level of the epiphyseal scar. A second guidewire is held against the portion of the guidewire extending out of the proximal femur, and the length is measured. That measurement is subtracted from 90 mm (total guidewire length) to determine the length of the intramedullary nail required.
4. The cannulated reamers are placed sequentially over the guidewire. The entire femur is reamed at 0.5-mm increments. The entire shaft, and especially the fracture site, should be visualized with fluoroscopy as the reamers pass.
5. The final reamer size should be verified with the reamer gauge. The femur is reamed 1 mm over the selected nail diameter. Inserting a nail in an inadequately reamed femur or inserting a nail that is too large can cause severe bone splitting and comminution.
6. The proximal screw guide/slap hammer is assembled onto the nail. The nail is oriented to match the curve of the femur.
7. Using the handle of the inserter, the rotation of the nail is controlled and the nail is driven into the femur. The nail is fully seated when the proximal screw guide is flush with the greater trochanter. The surgeon disengages the inserter from the slap hammer.
8. Using the power drill and correct drill sleeves, the surgeon drills a 4.8-mm hole through both cortexes and measures the depth directly off the bit.
9. Through the appropriate drill sleeve, a 6.4-mm self-tapping locking screw is inserted and the drill sleeve is removed.
10. By fluoroscopy, the distal screw holes are confirmed as perfect circles on the screen. The distal targeting device is mounted on the nail, followed by the left or right adapter block. The adapter block is adjusted until the calibration reads the length of the nail. The cross hairs are aligned in the adapter to the holes in the distal nail, with confirmation by fluoroscopy.
11. The surgeon makes an incision through the adapter block over the distal femur to the lateral cortex. Following the same steps as those for placing the proximal screw, one or two distal locking screws are inserted. There are various freehand techniques for inserting distal locking screws.

SURGERY OF THE LOWER LEG (DISTAL FEMUR, TIBIA, AND FIBULA)

Many procedures on the lower leg use the same principles of fracture fixation already mentioned. Meticulous detail is required to ensure proper alignment and optimal surgical results for the patient. As in the hip, fractures around the knee require secure fixation to allow bone healing, preserve motion, and provide joint mobility as early as possible. Fracture treatment for the various described injuries is based on location and the pattern of fracture. Methods of fixation for the distal end of the femur and proximal end of the tibia include pins, wire, compression plates, intramedullary nails, supracondylar plates, and cannulated screws. Multiple-trauma patients with one or a combination of fractures may require more than one method of fixation. Open reduction and internal fixation must ensure anatomic restoration of the joint surface and rigid fixation, and allow early motion of the knee joint.

Most operations on the knee are performed with the patient in the supine position and the leg prepped and draped from the groin to the middle of the calf or including the entire foot. It is occasionally necessary for the surgeon to operate with the foot of the OR bed dropped and the patient's knee flexed to 90 degrees. Consequently, it is important for the nurse to position, the patient so that the knee is at a break in the bed; if it is necessary, the lower leg can then be flexed at the knee during the operation. A tourniquet is often used.

Femoral Condyle and Tibial Plateau Fractures

The joint surfaces are often involved with fractures of the distal end of the femur and proximal end of the tibia. Anatomic alignment of the articular surfaces is necessary to provide joint stability and decrease the chance of posttraumatic arthritis. Nonunion is the most common complication in supracondylar fractures, leading to failure of surgery. As with humeral head and hip fractures, it is important that the articular surfaces are reopposed as close as possible to avoid future degenerative changes. Unfortunately, these often cannot be avoided, and

patients with this type of injury often face future joint arthroplasty and replacement (see Total Joint Arthroplasty, p. 781).

Distal femoral fractures result in varying degrees of comminution. Condylar fractures can be unicondylar or bicondylar, with separation of both condyles (Figure 19-60). Type A fractures are extraarticular. Type B are single condyle fractures in the sagittal or coronal planes, whereas type C fractures are T and Y configurations. Type C fractures have varying degrees of shaft and condylar comminution, presenting the greatest treatment challenge.

Simple, nondisplaced distal femoral fractures can be treated with closed reduction and immobilization by casting if anatomic

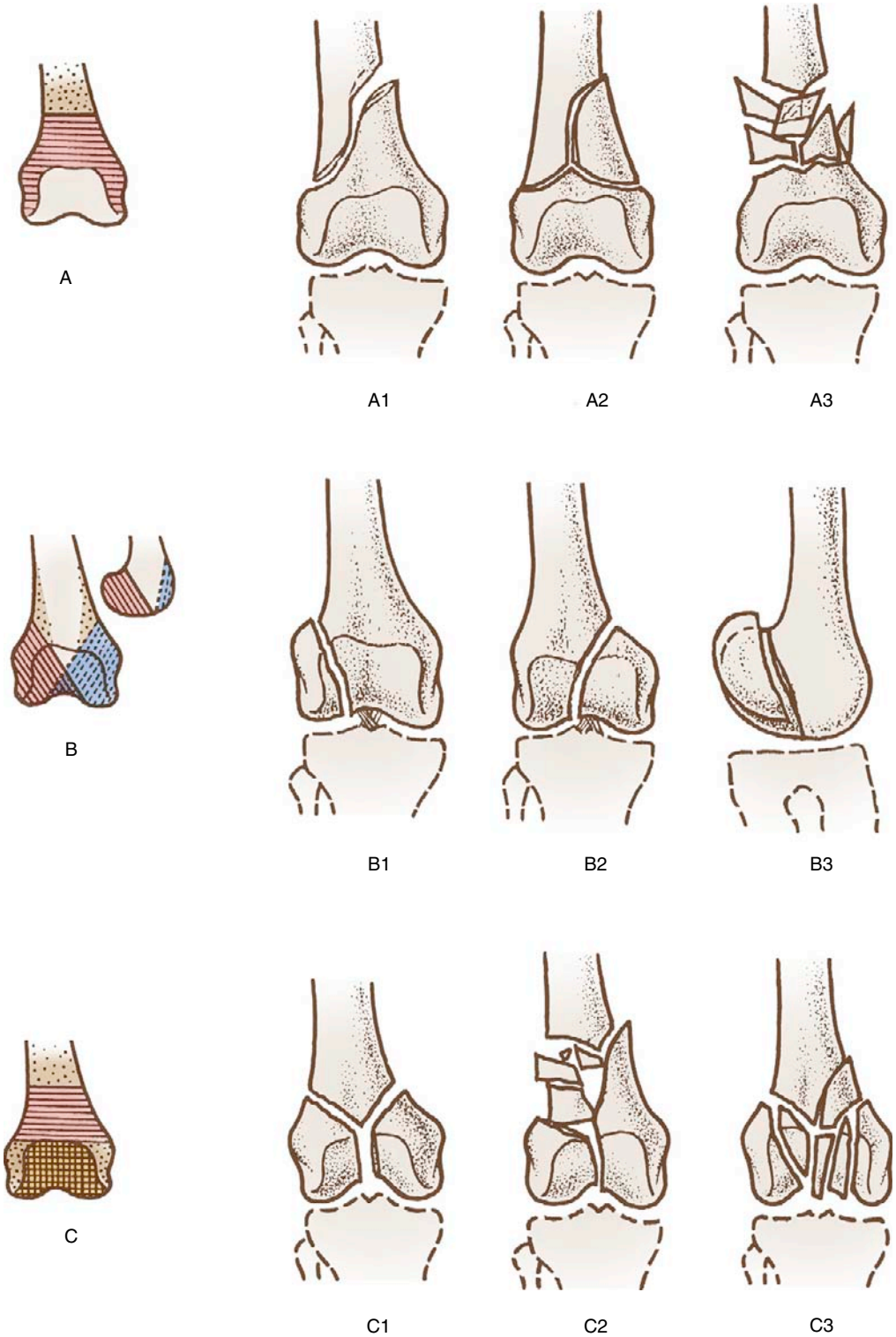


FIGURE 19-60 Classification of fractures of distal femur described by Müller and associates.

reduction is achieved. Nondisplaced, extraarticular fractures can be treated with a hinged cast brace. Comminuted fractures in this region can also be treated in this manner if shortening and angulation are minimal. Traction can be used initially to augment this type of treatment. Distal femoral fractures are treated with open reduction if distal tibial traction and manipulation attempts fail. Flexible nails, locking intramedullary nails, blade plates, condylar compression screws, and condylar buttress plates are accepted methods of treating condylar fractures. Attention must be given to the attachment of the cruciate ligaments, which originate in the condylar notch and may require fixation of a partial or full disruption as a result of the injury to the knee (see "Arthroscopic Anterior Cruciate Ligament Repair," p. 804).

Tibial plateau fractures historically have been attributed to bumper or fender injuries, but a variety of falls or other traumas frequently are the cause. Compression force of the distal end of the femur on the tibia produces the various types of plateau fractures. Commonly this occurs from abduction of the tibia while the foot is planted, driving the lateral femoral condyle into the lateral tibial plateau (also called the *condyle*). There are several classification systems based on fracture and dislocation patterns. The general theme of these fracture classifications and examples of their treatment can be summarized by the following types (Figure 19-61): (1) pure cleavage, unicondylar fracture, (2) cleavage fracture combined with local depression, (3) pure central depression, (4) medial condylar wedge with depression or comminution, (5) bicondylar but with continuity of diaphysis and metaphysis, and (6) comminution with dissociation of metaphysis from diaphysis. Fractures of the tibial plateau are often associated with dislocation, which may spontaneously reduce at the time of trauma.

Special attention must be given to the possibility of neurovascular insult, which must be addressed immediately. Elevation and fixation of the depressed fracture are the focus for treatment of plateau fractures. As with distal femoral fractures, the articular surfaces and cruciate insertion require reapproximation and fixation. Repair to the menisci and ligaments should occur simultaneously to prevent knee instability.

Blade plates, buttress plates, and cannulated screws are all methods by which fractures of the tibial plateau are fixed. Severe fractures are treated using multiple buttress plates and screws (Figure 19-62). Bone graft from the iliac crest and fibular head autograft are often used when there is a significant amount of bone lost to comminution with proximal tibial fractures.

Supracondylar Fractures of the Femur

Fractures of the distal femur in the multiple-trauma patient are treated early to promote rapid ambulation, which decreases complications caused by immobility. In an effort to deliver quick fracture reduction and stabilization, many orthopedic trauma systems have been developed. Often these are the same systems used in daily orthopedic procedures with modifications to expedite implantation and fixation. Some of the intramedullary devices do not require reaming.

Procedural Considerations. Initial stabilization of the patient may immediately precede the nailing procedure. Often other team members are attending to treatment of other systems. The perioperative nurse is challenged to control traffic, coordinate team efforts, and protect the patient from increased risk of infection by the inadvertent contamination of instruments and implants. The patient is placed in the supine position after induction of general or regional anesthesia. If possible, the patient is positioned on the OR fracture bed; if not, a radiolucent OR bed is used. A pneumatic tourniquet may be applied as high up on the femur as possible, taking care to protect the genitals during placement. The nail can be inserted using the closed or open technique.

The soft tissue set and large bone set are required, as well as the intramedullary supracondylar nail implant (Figure 19-63) and the instruments necessary for its insertion. A power drill, guidewires, intramedullary rod set, and fluoroscopy will also be needed. In addition, Steinmann pins, Kirschner wires, bone-reduction clamps, and a bone graft set should be available. Occasionally a primary total knee arthroplasty will be performed, and the appropriate instruments should be available should that possibility exist.

Operative Procedure

INTERCONDYLAR FRACTURE OF THE FEMUR, T TYPE (AIM SUPRACONDYLAR INTRAMEDULLARY NAIL)

1. The surgeon makes a standard midline skin incision with parapatellar arthrotomy. Depending on the degree of intraarticular extension, the incision may be as small as 2.5 cm or involve lateral eversion of the patella to gain visualization of the entire joint.
2. Articular fractures should be anatomically reduced and secured with 6.5-mm or 8.0-mm cannulated screws placed in the anterior and posterior aspects of the condyles to allow adequate space for the placement of the nail.
3. Using an awl, the surgeon makes an entry hole into the femoral canal just anterior to the femoral insertion of the posterior cruciate ligament. Care is taken to ensure anatomic alignment of the condyles to avoid varus or valgus femoral alignment.
4. The hole is enlarged with the nonadjustable step reamer to accept the largest diameter of the chosen nail. Further reaming of the canal is necessary only in the case of nonunion, when the canal is reamed 0.5 to 1 mm larger than the size of the selected nail.
5. The selected nail is attached to the screw-targeting jig, which is then locked into place by the jig adapter. Before the nail is inserted, the alignment of the jig and nail holes is carefully checked by manually inserting the sheath and trocar through the selected holes.
6. The surgeon places the nail in the prepared canal and advances it retrograde either by hand or with gentle blows of a mallet on the jig adapter. The nail should be countersunk approximately 3 to 5 mm below the articular surface.
7. The screws may then be placed using the targeting jig, and sheath and trocar assembly. The surgeon makes a small lateral incision and advances the sheath and trocar to the femoral cortex. A 5.3-mm drill bit is advanced through the medial cortex, and the length is measured from the calibrated drill bit or by use of a depth gauge. The appropriate 6.5-mm cortical screw is inserted, and the process is repeated for placement of the second screw.
8. Proximal locking of the nail is then performed in a similar fashion, taking care to use the appropriate holes in the targeting jig for the length of nail inserted. The 3.8-mm drill bit and 4.5-mm self-tapping screws are used to fill these holes after femoral rotation and alignment are confirmed with fluoroscopy.

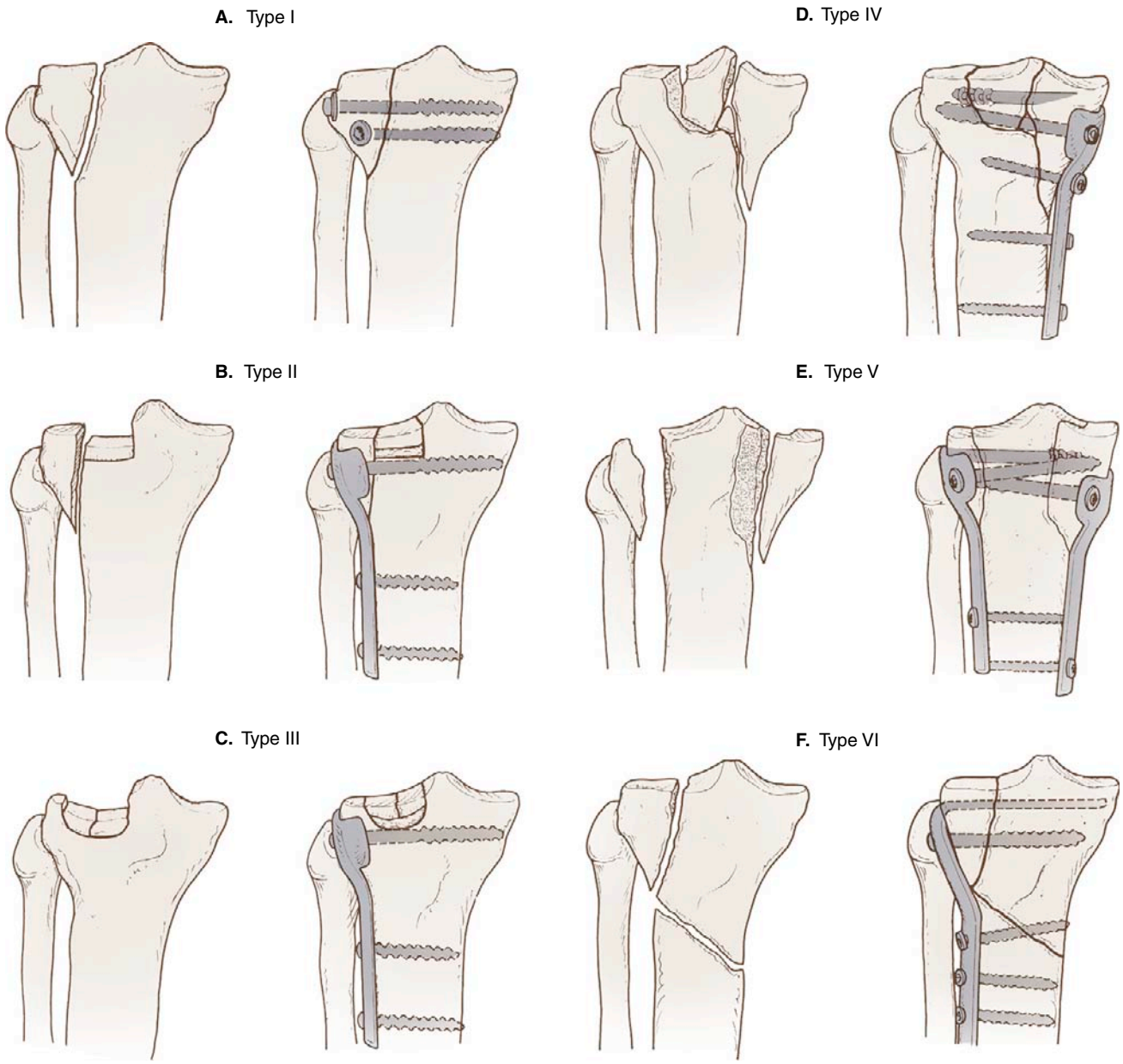


FIGURE 19-61 Classification of fractures of the tibial plateau. **A**, *Type I:* Pure cleavage fracture. **B**, *Type II:* Cleavage combined with depression. Reduction requires elevation of fragments with bone grafting of resultant hole in metaphysis. Wedge is lagged on lateral aspect of cortex protected with buttress plate. **C**, *Type III:* Pure central depression. There is no lateral wedge. Depression may also be anterior or posterior or involve whole plateau. After elevation of depression and bone grafting, lateral aspect of cortex is best protected with buttress plate. **D**, *Type IV:* Medial condyle either is split off as wedge or may be crumbled and depressed, which is characteristic of older patients with osteoporosis (not illustrated). **E**, *Type V:* Note continuity of metaphysis and diaphysis. In internal fixation, both sides must be protected with buttress plates. **F**, *Type VI:* Essence of this fracture is fracture line that dissociates metaphysis from diaphysis. Fracture pattern of condyles is variable, and all types can occur. If both condyles are involved, proximal tibia should be buttressed on both sides.

9. The jig adapter and screw-targeting jig are removed, and an end cap is placed into the distal end of the nail. The surgeon irrigates the wounds and closes them in layers. A compression dressing is applied.

Range-of-motion and muscle-strengthening exercises are begun on the first postoperative day. Care is taken to protect against varus and valgus stresses. The patient is discouraged from bearing weight on the extremity until there is radiographic evidence of healing.

SUPRACONDYLAR FRACTURE (COMPRESSION PLATE)

1. The lateral area of the distal end of the femur is exposed above and below the knee joint.
2. The surgeon reduces the fracture site and inserts multiple Kirschner wires for fixation.

FIGURE 19-62 Severe fractures are treated by use of multiple buttress plates and screws.

FIGURE 19-63 Supracondylar nail.

3. A calibrated Steinmann pin is placed transversely across the condyles parallel to the joint line. The pin must stop 8 to 10 mm short of the medial cortex.
4. The length of the lag screw is gauged when it is read directly on the calibrated Steinmann pin, and adjustable double reamers are used to ream to this depth.
5. A lag screw is inserted across the condyles, followed by the compression screw.
6. The surgeon secures the plate to the femoral shaft with cortical bone screws and confirms the repair by fluoroscopy.
7. The incision site is irrigated and closed. A knee immobilizer is placed.

MEDIAL AND LATERAL Y-TYPE TIBIAL PLATEAU FRACTURES

1. The surgeon makes a long anterolateral incision, starting 2.5 cm above the superolateral aspect of the patella and tendon and proceeding distally around the patella to the anterior aspect of the tibia just below the tibial tuberosity. The distal end of the tibial shaft should be exposed.
2. The level of the prepatellar bursa is identified. The surgeon uses blunt dissection beneath the skin and retracts the proximal end of the tibia to expose it from midline medially to midline laterally.
3. Using a tibial bone plug, the surgeon detaches the patellar tendon and exposes both the medial and lateral articular surfaces. The articular surface is reconstructed using temporary Kirschner wires. A contoured T-plate is attached to the medial aspect of the tibia using cancellous screws in the proximal portion and cortical screws in the distal portion. A smaller T-plate is inserted on the lateral side and secured in the same manner. The Kirschner wires are removed. Care should be taken to ensure that the screws do not interfere with each other as they traverse from opposite sides of the tibia.
4. The surgeon reattaches the patellar tendon using a 6.5-mm cancellous screw through the bone plug.
5. The wound is closed and immobilized at 30 degrees with a posterior splint.

Patellectomy and Reduction of Fractures of the Patella

Patellectomy was a frequently performed procedure until the early 1970s. It is possible to excise a portion of the patella (for comminuted fracture) or the entire patella (for painful degenerative arthritis) without significantly affecting ordinary activities. However, patellectomy has been shown to significantly reduce power of extension as the joint extends, which is the most important function of the knee. Other complications associated with patellectomy are (1) slow return of quadriceps mechanism strength, (2) quadriceps muscle atrophy, and (3) loss of knee protection from the patella. Removal of the entire patella may result in relative lengthening of the knee extensor mechanism, which necessitates overlapping of the quadriceps tendon at the time of operation to prevent a lag in knee extension. Patellectomy should be performed only when comminution is extensive and reconstruction of the articular surface of the patella is not possible.

If the fracture consists of two large fragments that can be anatomically reduced, fixation is accomplished with a tension band, a circumferential loop technique, or bone screws. Tension band wiring produces compression forces across the fracture site and results in earlier union and immediate mobility of the knee.

Procedural Considerations. The patient is supine. The tourniquet is applied, and the leg is prepped and draped. A soft tissue set and a bone set are required, along with a power drill and bits, bone-reduction clamps, 18-gauge wire, heavy needle holders, and a wire tightener.

Operative Procedure

1. The surgeon makes a transverse curved incision over the patella.
2. Using sharp and blunt dissection the surgeon exposes the surface of the patella, the quadriceps, and the patellar tendons.
3. The joint is irrigated, and the fracture is reduced with bone-reduction clamps.
4. One length of wire is passed around the insertion of the patellar tendon and then around the quadriceps tendon. A second wire is passed more superficially through the bone fragments.
5. The fracture is overcorrected, and the wire is tightened with the wire tightener. In flexing the knee or contracting the quadriceps, the condyles press against the patellar fragments, producing compression at the fracture site.

Correction of Recurrent Dislocation of the Patella

Recurrent dislocation of the patella can be the result of violent initial dislocation or more commonly from underlying anatomic abnormalities. The underlying condition causes an abnormal excursion of the extensor mechanism over the femoral condyles. Dynamic forces, such as the vastus lateralis, and static forces, such as those arising from the shape of the patella, tend to displace the patella laterally. Dislocations occur when there are extreme displacing forces combined with internal rotation of the femur and flexion of the knee. If untreated, patellar dislocations will deteriorate the knee by causing abnormal patellofemoral articulation, chondromalacia, and meniscal tears.

Conservative treatment aimed at quadriceps strengthening may be indicated in some patients. Numerous procedures have been designed to realign the knee extensor mechanism. All the procedures include incising the lateral quadriceps tendon and shifting the insertion of the patellar tendon medially or distally to the original insertion of the tibia.

Procedural Considerations. The patient is supine. The tourniquet is applied, and the leg is prepped and draped. A soft tissue set and a bone set are required, along with a large-fragment screw set, a power drill, a microsagittal saw (Figure 19-64), and osteotomes.

Operative Procedure

PATELLAR REALIGNMENT (ELMSLIE-TRILLAT)
(Figure 19-65)

1. The surgeon makes a lateral parapatellar incision beginning proximally to the patellar pole, laterally around the patella, and extending to 2 cm distally and just laterally to the tibial tuberosity.
2. A skin flap is developed and retracted medially to expose the capsule. A medial arthrotomy is completed, the joint is inspected, and any pathologic condition present is repaired.
3. The lateral retinaculum is released from the vastus lateralis proximally and the patellar tendon distally.
4. Using a ½-inch osteotome, the surgeon scores the tibial tuberosity medially and laterally, just below the fat pad and under the patella.
5. The surgeon continues the osteotomy using a microsagittal saw distally for 4 to 6 cm, and leaves the periosteum hinged at the distal-most part of the osteotomy.

FIGURE 19-64 Microsagittal saw.

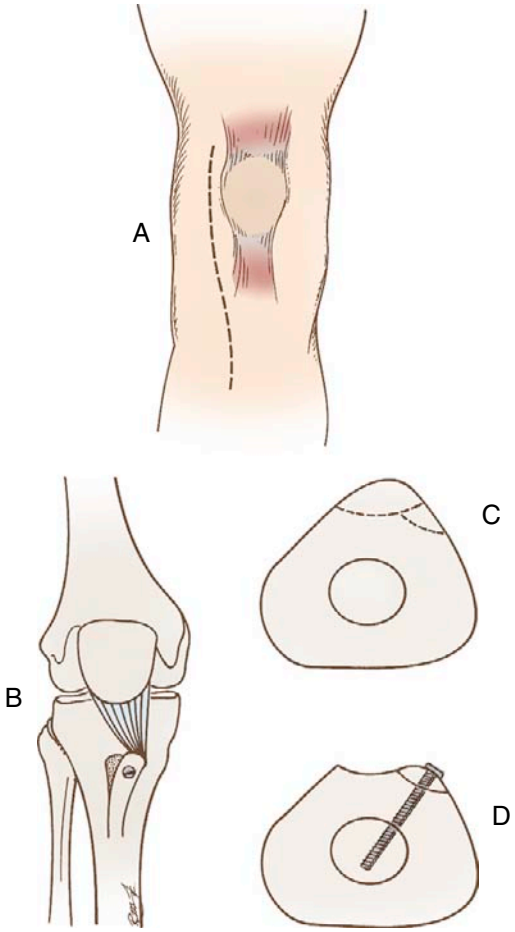


FIGURE 19-65 Elmslie-Trillat procedure as modified by Cox. **A**, Skin incision. **B**, Completed procedure. **C**, Cross section of tibia at level of tibial tuberosity to show bone cuts made to free tuberosity in center and to create new bed for transposed tuberosity to right. **D**, Cross section of tuberosity fixed with screw in new location anteromedially. Screw should not penetrate posterior aspect of cortex.

6. The entire segment, with patellar tendon attached, is displaced medially and manually held in place while moving the knee through a range of motion. Tracking of the patella on the femoral groove is completed by systematically moving the knee medially in increments.
7. A cancellous bone bed is prepared at the point of reattachment of the tibial tuberosity.
8. The surgeon displaces the tuberosity medially and places a 6.5-mm cancellous bone screw.
9. The wound is irrigated and closed, and a long leg cylinder cast is applied. The cast is bivalved immediately.

Repair of Collateral or Cruciate Ligament Tears

The stability of the knee depends on the integrity of the cruciate and collateral ligaments. If any of these supporting structures is damaged, an unstable knee is likely unless properly

repaired. Injuries to these supporting structures are usually not isolated. More frequently, several of the ligaments are injured at the same time. For example, the injury commonly referred to as the "terrible triad" includes a torn anterior cruciate ligament (ACL), torn medial meniscus, and torn medial collateral ligament.

The knee demonstrates grave disability with major ligamentous disruption. The *collateral ligaments* reinforce the knee capsule medially and laterally. They resist varus and valgus stresses on the knee. The *cruciate ligaments* control anterior-posterior stability. Along with the ligaments, the muscle groups stabilize the joint and control movement. Because muscle strength is the first line of defense for the knee, damage is repaired to protect the ligaments. For optimum function of the joint, damaged structures should be reconstructed as close as possible to the original anatomic structures. If the knee is left untreated, osteoarthritis will develop.

Injury to a single cruciate ligament may not significantly compromise knee function. When the injury is combined with other injuries, surgery may be warranted. Surgeons may use various types of ligament grafts to replace or augment the cruciate ligaments. Autografts, allografts, and artificial substitutes are available. Ligament substitutes act as a scaffold, stent, or augmentation of the torn cruciate ligaments. Scaffolds support the soft tissue initially to allow ingrowth of the host tissue. Stents protect the joint from excessive stress while the permanent ligament substitute is healing. Augmentation, as by the patient's own iliotibial band, protects the graft initially after repair of a partial tear. Synthetic ligaments, which are less popular, include carbon-fiber grafts, polyglycolic acid material, Dacron, polyester, and polytetrafluoroethylene.

All synthetic grafts are subject to mechanical failure from weakening with fragmentation and synovitis. These are recommended for salvage procedures only when conventional reconstruction has failed and when other autogenous tissue is unavailable for substitution. Biologic materials from animals, such as bovine xenografts, are also available for ligament substitution, although they are subject to increased risk of infection, synovitis, and rejection. Homogeneous allografts are the substitute of choice for knee reconstruction when no autogenous graft is available from the patient. Disadvantages of homogeneous allografts include long-term weakening, possible rejection, and the possibility of infectious disease transfer.

Autogenous tissues are currently the substitute of choice, with the middle third of the patellar tendon and a block of patella being the most reliable. To minimize necrosis and maintain graft strength, the fat pad with its blood supply may be preserved along with the patellar tendon. Using this graft and other soft tissue autografts, the cruciate-deficient knee can be reconstructed arthroscopically (see Operative Arthroscopy, p. 802). A combination of a torn ACL, medial meniscus, and medial collateral ligament in the past often indicated the need for an open procedure (arthrotomy). With developing technology, many of these procedures can now be done arthroscopically. When reconstructing the cruciate ligament, the surgeon must have the graft biomechanically correct to maintain proper function. Many devices and systems are used to provide placement assistance and gauge appropriate graft tension. These devices are used either separately or in some combination. Though the variations are many, the principles are the same.

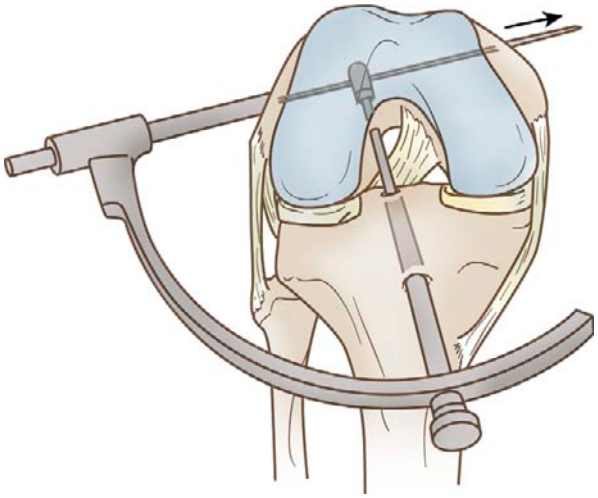


FIGURE 19-66 Reconstruction guide used for ligament repair.

Procedural Considerations. The patient is positioned supine with a tourniquet applied to the upper area of the thigh. The perioperative nurse preps the patient from the upper area of the thigh down to and including the foot. Soft tissue instruments, arthroscopy instruments, ACL reconstruction instruments, Steinmann pins, reconstruction guides (Figure 19-66), and a tension isometer are required. A power drill, microsagittal saw, and burrs are essential. The fixation device of choice should also be available. Meniscal repair instruments should be in the room.

Operative Procedure

ANTERIOR CRUCIATE REPAIR. An examination under anesthesia (EUA) is performed immediately after induction of anesthesia, when the ligaments are completely lax, to evaluate the severity of the injury.

1. The surgeon makes a straight midline or slightly medial incision across the knee.
2. Meniscus tears in the vascular zone (peripheral) are repaired with arthroscopic meniscal repair instruments or cutting needles with a heavy absorbable suture to repair the meniscofemoral and meniscotibial ligaments. If the meniscus is not repairable, the surgeon will perform a partial meniscectomy.
3. Using a power saw and osteotome, the surgeon harvests patellar and tibial bone plugs from the middle third of the patellar tendon.
4. A notchplasty is then performed, debriding and smoothing the lateral intercondylar wall with a burr and curette.
5. The surgeon uses the ligament guide to develop the femoral and tibial osseous tunnels and passes guidewires from the lateral area of the femoral condyle and tibial tubercle into the intercondylar notch at isometric points near the anatomic attachment site of the ACL.
6. The pins are then overdrilled with cannulated drills as close to the size of the patellar tendon graft as possible. The tunnels are smoothed with a curette.
7. Sutures are placed through drill holes at both ends of the graft to pass the graft through the tunnels.
8. The surgeon passes the graft through the femoral and tibial osseous tunnels and fixes it at both ends with interference screws, staples, or polyethylene buttons.

9. The medial collateral ligament and posterior oblique ligament are then individually repaired at their insertion sites with bone screws and spiked washers.
10. Additional extraarticular repair is done if necessary.
11. The surgeon closes the wound over intraarticular and subcutaneous drains, and a locking knee brace or knee immobilizer is applied.

Popliteal (Baker) Cyst Excision

Baker cysts occur in joints, frequently affecting the popliteal fossa. Baker cysts are often painful and can become very large, especially when associated with rheumatoid arthritis. Cysts in the popliteal fossa occur without a precipitating cause in children; in adults they often indicate an intraarticular disease process, such as rheumatoid arthritis, or a torn meniscus.

Procedural Considerations. In contrast to many other operative procedures on the knee, the patient is placed in the prone position. A soft tissue set and a bone set are required.

Operative Procedure

1. The surgeon makes an oblique incision in the popliteal area over the mass and divides the fascia to expose the mass.
2. Using blunt dissection, the surgeon frees the cyst and clamps it at the base of its attachment to the joint capsule.
3. The cyst is divided, and the pedicle is inverted and closed.
4. After the mass has been removed, the surgeon irrigates and closes the wound.

Postoperatively, the knee may be immobilized in extension with a posterior splint.

Fractures of the Tibial Shaft

The location of the tibia results in frequent exposure to injury. Open fractures are more common in the tibia than in other major bones because one third of its surface is subcutaneous. Tibial shaft fractures are difficult to treat. The blood supply to the tibia is more precarious than that of other long bones because of its lack of enclosure by heavy muscle. The presence of hinge joints at the knee and ankle allows no adjustment for rotational deformity after fracture, so special care is required to correct for rotation during reduction and fixation. Rotational deformities are often seen. Delayed union, nonunion, and infection are fairly common complications. Closed reduction and casting provide excellent healing without significant complications, but this treatment can require casting for 6 months or more. Surgical reduction and internal fixation generally allows for earlier weight bearing and a shortened period of casting; however, the rate of complications is higher.

In general, torsional fractures seem to heal better and are more amenable to treatment than transverse fractures. It is theorized that twisting injuries cause less damage to endosteal vessels than that caused by transverse fractures, in which periosteum and endosteal vessels are torn circumferentially. The important prognostic indicators for tibial fractures are as follows: (1) the amount of initial displacement, (2) the degree of comminution, (3) the presence or absence of infection, and (4) the severity of soft tissue injury, excluding infection. As a rule, high-energy fractures, such as those caused by motor vehicle accidents or crushing injury, have a much worse prognosis than low-energy fractures, such as those caused by falls on ice or skiing accidents.

Because intramedullary tibial nailings do not cause a significant increase in infections, external fixation of open tibial shaft fractures is less commonly performed. However, in the presence of gross contamination, severe soft tissue and vascular injury, bone infection, and delayed treatment, external fixation is the treatment of choice. The Ilizarov external fixation device is indicated when bone loss is significant and limb lengthening is required. Plate and screw fixation is another method in which tibial shaft fractures can be treated, although infection and nonunion of tibial shaft fractures are twice as likely with this method. Plate and screw fixation is indicated when intraarticular fragments of the knee and ankle are associated with the injury. Closed intramedullary nailing is the treatment of choice in tibial shaft fractures because infection is less likely to occur and the periosteal blood supply is preserved. Static locking nails (locking both proximal and distal ends of the nail) are indicated for fractures with comminution, bone loss, and lengthening osteotomies. Dynamic locking nails (locking the end closest to the fracture site) are indicated for proximal or distal tibial fractures, nonunions, and malunions. Locking tibial nails include the Russell-Taylor and the Grosse-Kempf tibial nail.

The key to successful treatment of open tibial fractures, as in all open fractures, is meticulous and systematic debridement of all foreign matter and devitalized tissue. The surgeon is careful to minimize devascularization when reducing and fixing the fracture. Systemic antibiotics and those delivered by pulsatile lavage help reduce the chance of infection.

Procedural Considerations. The patient is usually administered a general or regional anesthetic while still on the hospital bed or in the transport vehicle and then transferred to the OR fracture bed. The perioperative nurse assists with positioning the patient supine with the affected hip flexed approximately 45 degrees and the knee at 90 degrees. This positioning provides a horizontal orientation of the tibia. Using a calcaneal traction pin or table foot holder, traction is applied and rotational alignment obtained. After rotational alignment is obtained, a tourniquet is applied and the leg is prepped and draped. Some surgeons prefer to use a standard OR bed, breaking it at the knee. This obviates the need to insert the calcaneal traction pin and allows for easier maneuvering of the tibia during insertion of the locking screws.

A soft tissue set and a large bone set are required, in addition to the intramedullary nail and insertion instruments of choice. A power drill and reamer-driver will be needed to use the necessary intramedullary reamers (Figure 19-67). Fluoroscopy will be needed as well. If open plating is being considered, the plates of choice and the large-fragment screws need to be available as well as bone-reduction clamps.

Operative Procedure

CLOSED OR OPEN TIBIAL INTRAMEDULLARY NAILING (Figure 19-68)

1. If the open technique is required, the fracture site is exposed, reduced, and irrigated as necessary. Focus is then turned toward the nailing procedure.
2. The surgeon makes a 5-cm incision medial to the patellar tendon to just below the tibial tuberosity.
3. Using a curved awl, the surgeon opens the medullary canal just proximal to the tibial tuberosity.
4. A guide rod (3.2 mm) is inserted into the shaft of the tibia down to the fracture site. The proximal fragment is reduced distally and the guide rod advanced into the distal fragment. Rod types include the straight guide rod for simple

FIGURE 19-67 Intramedullary flexible reamer system.

fractures, a curved guide rod for displaced fractures, and a cutting tip for an obstructed canal.

5. The length of the required nail is determined by the guide rod method (see Operative Procedure under Femoral Shaft Fractures: Internal Fixation, pp. 767-768) or by using the nail-length gauge and confirming with fluoroscopy.
6. With cannulated reamers over the guide rods, the surgeon reams the entire tibia 1 mm larger than the nail to be inserted. Inserting a nail too large for the canal can have a detrimental effect.
7. The driver, proximal drill, guide, and hexagonal bolt are assembled onto the tibial nail.
8. The surgeon inserts the nail over the guide rod and, with a mallet, drives it down the proximal fragment to enter the distal fragment, crossing the fracture site. The nail is not fully seated.
9. The guide rod is removed to prevent incarceration, and the surgeon completes the seating of the nail. The proximal tip of the nail should be flush with the tibial entry site.
10. Proximal locking is accomplished with the corresponding drill and tap through the proximal drill guide for 5-mm cortical bone screws.
11. Using the distal targeting device or a freehand technique, the surgeon inserts the distal screws. The 5-mm cortical bone screws are inserted, traversing the tibia through the tibial nail.
12. The surgeon irrigates the wounds. If bone graft is to be used, the surgeon places it around the fracture site and then closes the wound. Dressings are applied, and a cast or splint for immobilization may be applied.

Dynamization, or removal of either the proximal or the distal screws, may take place after 3 months for fractures that are stable but lack callus. Dynamization produces compressive forces at the fracture, thereby promoting osteogenesis.

TIBIAL DYNAMIC COMPRESSION PLATING

1. The surgeon makes a longitudinal incision large enough to accommodate the selected plate lateral to the tibial crest and exposes the fracture site.
2. The periosteum is stripped only enough for application of the plate. Circumferential stripping can diminish blood supply.
3. The surgeon reduces the fracture, places a plate across the fracture site, and secures the plate with bone-holding and plate-holding forceps. The plate may have to be contoured with a handheld or plate-bending press.
4. Using the neutral drill guide, the surgeon drills a 3.2-mm bicortical hole into the plate screw hole close to the fracture site, gauges it, and taps to 4.5 mm. The first bone screw is inserted, ensuring purchase of the screw on the opposite cortex.
5. Using the load drill guide (eccentric), the surgeon drills a second hole next to the fracture line in the opposite fragment. Drill and tap are accomplished as in the previous step. As the screw enters the bone, it will seek the center of the screw hole (the screw is eccentric, and the screw hole is beveled). The fracture site is brought under compression as the screw seats into the hole.
6. The wounds are irrigated. If bone graft is to be used, the surgeon places it around the fracture site and then closes the wound. Dressings are applied, and a cast or splint for immobilization may be applied.

SURGERY OF THE ANKLE AND FOOT

Ankle Fractures

Ankle fractures include fractures of the medial malleolus (tibia), lateral malleolus (fibula), and posterior malleolus (posterior aspect of the articular surface of the distal end of the tibia). They may or may not be associated with ligamentous injury. Ankle fractures can be classified in anatomic lines as unimalleolar, bimalleolar, and trimalleolar. Because medial malleolar and posterior malleolar fractures involve the distal weight-bearing articular surface of the tibia, open reduction and anatomic alignment are necessary. Fixation of the lateral malleolus is also important because it forms the ankle mortise—the socket formed by the distal tibia and fibula into which the body of the talus fits.

Anatomic reduction prevents the occurrence of degenerative joint disease. Displaced fractures are treated with pins, malleolar or bone screws, or plates and screws (Figure 19-69). Bimalleolar fractures can be treated with closed reduction and casting, but approximately 10% of these eventually develop a nonunion. The lateral malleolus (distal end of the fibula) is important for lateral and rotational stability of the joint. Open reduction and internal fixation using Steinmann pins or screws placed obliquely into the tibia is a common technique. Lateral malleolar fractures can be fixed with the cancellous lag technique—overdrilling the first fragment and allowing compression of the fragments. Fracture of the lateral malleolus can also be treated with a Rush rod, inserted through the fragment and into the fibular canal. Compared to the other varieties of fractures, trimalleolar fractures require surgery more frequently. The posterior lip of the articulating surface of the tibia is usually involved and needs to be anatomically reduced to minimize degenerative changes. Cannulated screws can provide efficient reduction of a posterior fragment.

Procedural Considerations. The patient is in the supine position. The affected leg is prepped and draped after application of a pneumatic tourniquet. If the lateral ankle is involved,

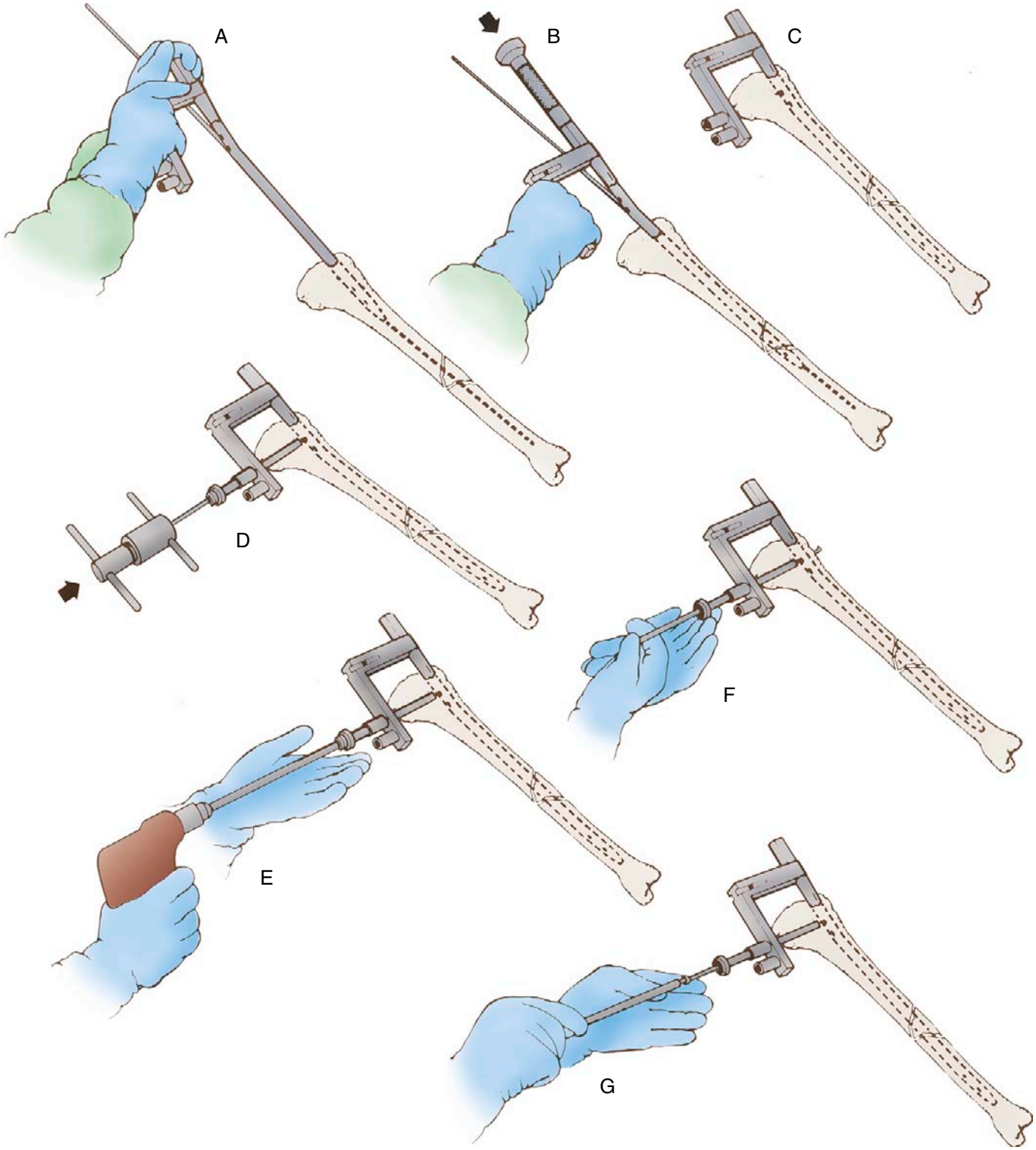


FIGURE 19-68 Tibial intramedullary nailing. **A**, Attachment of nail to proximal drill guide. **B**, Driving nail over guide rod. **C**, Final seating of nail with its tip flush with tibial entry portal. **D**, For proximal interlocking, cortex is dimpled. **E**, Depth measurements are made. **F**, Locking screw length is confirmed. **G**, Self-tapping screw is inserted through drill sleeve.

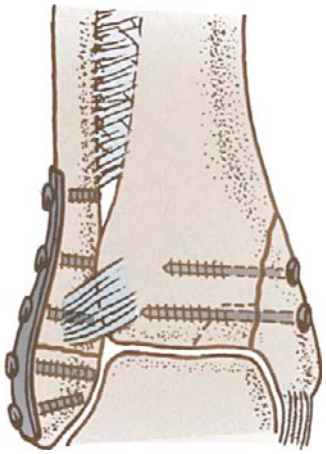


FIGURE 19-69 Plate-screw placement for lateral malleolar fragment repair using one-third tubular plate.

a padded sandbag is placed beneath the hip to internally rotate it. A soft tissue set; a small bone set; a small-fragment set with plates, screws, and pins; a power drill; and bone-reduction clamps are required.

Operative Procedure

TRIMALLEOLAR FRACTURE

1. The surgeon makes medial and lateral incisions across the ankle.
2. The posterior malleolar fracture is exposed and reduced with bone-holding clamps and manipulation.
3. The surgeon inserts two Kirschner wires above the anterior tibial lip to temporarily reduce the fracture. The wires are directed anteriorly to posteriorly, to engage both fragments.
4. A drill hole is made anteriorly to posteriorly through both fragments. After measuring with a depth gauge, a malleolar, small cancellous, or other preferred screw is inserted through the fracture. The wires are removed.
5. The surgeon manipulates the lateral malleolar fracture into reduction.
6. If the fracture is oblique and not comminuted, the surgeon reduces it with one or two lag screws placed anteriorly to posteriorly. If the fracture is transverse, the surgeon inserts a long screw or medullary pin across the fracture line into the canal of the proximal fragment. A small semitubular or one-third tubular plate is applied if the fracture occurs above the syndesmosis.
7. Once the posterior and lateral malleolar fractures have been fixed, the medial malleolar fracture is finally reduced using bone clamps.
8. The reduction is held with two Kirschner wires while a hole is drilled through the medial malleolus into the metaphysis of the tibia.
9. Using a depth gauge, the surgeon determines the screw length. The malleolar screw is inserted across the fracture site and the Kirschner wires are removed.
10. If rotational stability is needed, the surgeon may add an additional smaller screw or compression wiring.
11. Intraoperative radiographs are taken in AP, lateral, and mortise views.
12. The wounds are irrigated and closed, and a short or long leg cast or splint is applied.

Triple Arthrodesis

The talocalcaneal (subtalar), talonavicular, and calcaneocuboid joints must be fused in patients with pronounced inversion or eversion deformities of the foot. Such deformities occur in clubfoot, poliomyelitis, and rheumatoid arthritis. Occasionally this operation is necessary for patients who have pain resulting from degenerative or traumatic arthritis, such as that occurring after intraarticular fractures of the calcaneus. Triple arthrodesis limits motion of the foot and ankle to plantar flexion and dorsiflexion.

Procedural Considerations. The perioperative nurse assists with positioning the patient in the supine position and preps the patient from the midcalf down to and including the foot. The perioperative nurse should consult with the surgeon before the procedure to determine if bone grafting is anticipated so the patient's iliac crest area can be prepped.

A soft tissue set; a small bone set; a power saw, drill, or rasp; a bone graft set; and the AO compression plates and screws or bone staples to hold the fusion are required. Kirschner wires can be used to provide temporary fixation. A small lamina spreader is helpful in providing exposure.

Operative Procedure

1. An anterior or anterolateral approach is used.
2. The surgeon exposes the subtalar and calcaneocuboid joints and the lateral portion of the talonavicular joint.
3. The surgeon incises the capsules of the talonavicular, calcaneocuboid, and subtalar joints circumferentially to obtain as much mobility as possible. If this release allows the foot to be placed into a normal position, removal of large bony wedges is not required.
4. Using an osteotome, power saw, or power rasp, the surgeon removes the articular surfaces of the calcaneocuboid joint, the subtalar joint, and the talonavicular joint. The small lamina spreader is used to expose these surfaces. Care is taken to save all bone removed for later use in the fusion.
5. The removed bone is cut into small pieces to be used for bone grafting. If the quantity is insufficient, the surgeon will harvest additional bone from the anterior ilium. Most of the bone is placed around the talonavicular joint and in the depth of the sinus tarsi.
6. Smooth Steinmann pins, staples, or screws are used for internal fixation.
7. The wound is closed over a suction drain. A short leg cast or splint is applied.

Bunionectomy

A bunion (hallux valgus) is a soft tissue or bony mass at the medial side of the first metatarsal head. It is associated with a valgus deformity of the great toe (Figure 19-70). A bunion is caused by a basic structural defect of the foot, which predisposes to the development of this deformity. Ill-fitting shoes accentuate the situation and speed the development of bunions. Bunions are more common in women because of shoe styles, including high heels and pointed toes. Other factors that may contribute to this deformity are heredity, flatfeet, foot pronation, longer first toe, muscle imbalance, and inflammatory disturbances of the feet.

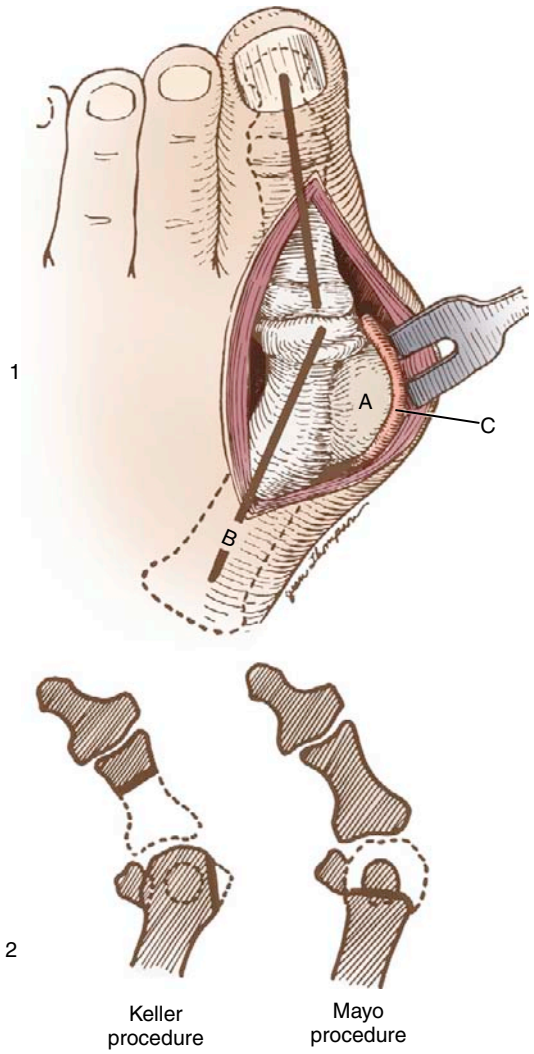


FIGURE 19-70 Bunionectomy. *1,* Bunion. *A,* Exostosis of metatarsal head; *B,* hallux valgus deformity; *C,* overlying bursa. *2,* Operations for hallux valgus.

Symptoms include pain on the dorsomedial aspect of the first metatarsal head or directly over the medial exostosis, swelling of the big toe, painful plantar callus, and plantar keratosis. Discomfort to the entire foot occurs as the forefoot becomes more fatigued and symptomatic, with pain radiating to the leg and knee.

Hallux valgus is treated with a variety of surgical procedures (Figure 19-71). All these procedures remove the exostosis and attempt to realign the great toe by removal of bone, transfer of tendons, osteotomy of the first metatarsal shaft, or appropriate imbrication of soft tissue.

The goals of surgery are correction of the deformity (cosmesis), resection of the abnormal bony components (reconstruction), and restoration of normal or near-normal range of motion (function).

Procedural Considerations. The anesthesia provider administers a general or regional anesthetic, and a tourniquet is applied. The foot and leg are prepped and then draped using a sterile stockinette.

A soft tissue set, a small bone set, Kirschner wires, a power wire driver, and a microsagittal saw are required.

Operative Procedure

KELLER PROCEDURE

1. The surgeon makes a midline, straight, medial incision beginning at the neck of the proximal phalanx and extended proximally.
2. Using blunt and sharp dissection, the surgeon exposes the joint capsule. A flap incision is made to expose the underlying hypertrophic bone found at the dorsomedial aspect of the first metatarsal head.
3. All soft tissue attachments are removed from the base of the proximal phalanx.
4. The surgeon uses a power-oscillating saw to resect the proximal third of the proximal phalanx.
5. Proper alignment of the toe is maintained as one or two 0.062-inch Kirschner wires are placed in the center of the medullary canal of the phalanx and then driven into the metatarsal head, neck, and shaft.
6. The surgeon irrigates and closes the wound. A bandage is applied to maintain the toe in the correct position.
7. Postoperative convalescence requires a minimum of 6 weeks.

Correction of Hammer Toe Deformity

The term *hammer toe* is most often used to describe an abnormal flexion posture of the proximal interphalangeal joint of one of the four lesser toes. This deformity causes painful calluses to develop on the dorsal joints of the four lesser toes, since the cocked-up digits rub against the shoes. Incising the long extensor tendon to the toes and fusing the proximal interphalangeal joint treat the deformities. A smooth Kirschner wire is frequently used to stabilize the fusion and position the toe properly during the postoperative period.

Procedural Considerations. The patient is positioned supine. An ankle tourniquet is applied. The foot is prepped and draped. A soft tissue set, a small bone set, Kirschner wires, and a power wire driver are required.

Operative Procedure

1. The surgeon makes an elliptic incision over the proximal interphalangeal joint measuring 5 to 6 mm wide with a 2-mm or 3-mm lateral extension on either side.
2. The capsular tissue of the distal third of the proximal phalanx and proximal interphalangeal joint is entered to expose the defect completely.
3. Using a small rongeur or microsaw, the surgeon resects the distal third portion of the proximal phalanx. Once the capital fragment is excised, the surgeon debrides the remaining portion of the distal proximal phalanx with a rongeur or rasp.
4. Digital alignment can be maintained with small Kirschner wires.
5. The surgeon irrigates and closes the wounds. A sterile dressing and orthopedic shoe are applied for postoperative recovery.

Metatarsal Fractures

Metatarsal fractures occur in various sites. These fractures have a reduced healing potential because metatarsals consist mainly of cortical bone, which lacks vascularity. Treatment is

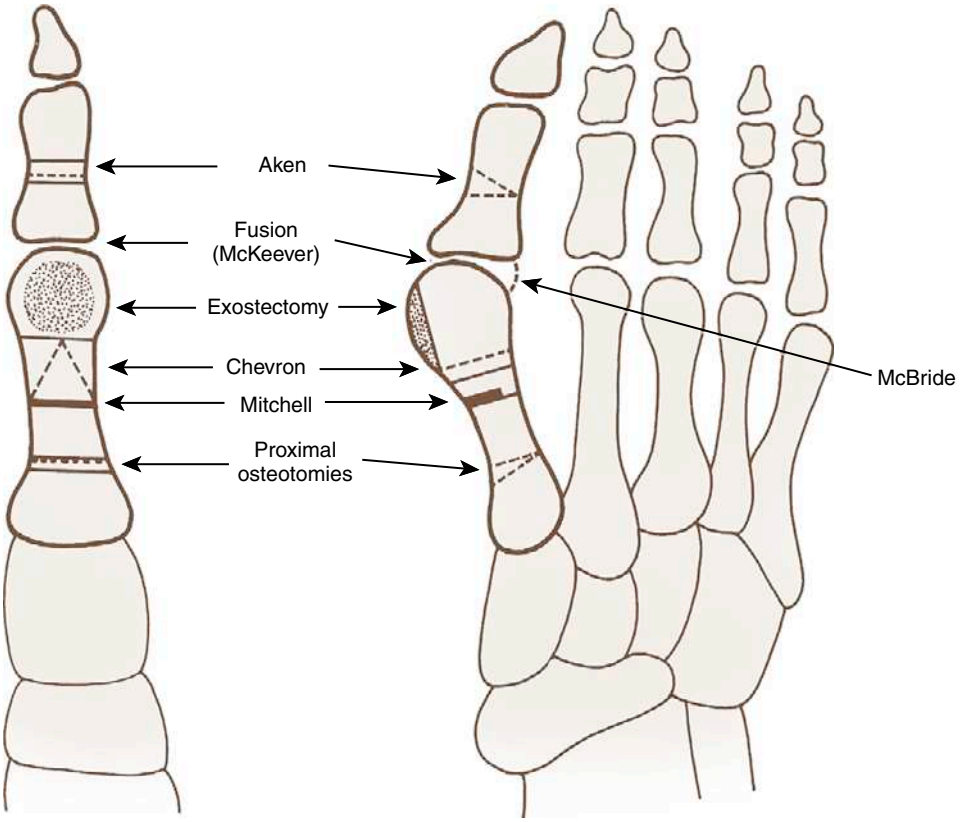


FIGURE 19-71 Types of bunionectomies.

determined by the extent of the fracture—the greater the displacement, the greater the need for reduction. In general, transverse and short, oblique, midshaft fractures of the metatarsals are internally fixed because of their instability and displacement. Pins, wires, screws, and plates are used for internal fixation of metatarsal fractures. The simplest method is Kirschner wire fixation.

Procedural Considerations. The patient is placed in the supine position, a tourniquet is applied, and the foot is prepped and draped. A soft tissue set, a small bone set, Kirschner wires, and a power wire driver are required.

Operative Procedure

1. The surgeon makes a small incision over the fracture and identifies and retracts the distal fragment.
2. A smooth Kirschner wire is driven distally, exiting the skin.
3. The surgeon uses a wire driver to drive the wire proximally into the canal of the proximal fragment.
4. If the fracture is more complex or comminuted, the surgeon may cross two Kirschner wires through the fracture to transfix the fracture site.
5. The incision is closed, and a postoperative shoe is applied.

Metatarsal Head Resection

Patients with rheumatoid arthritis frequently have dorsally dislocated toes and prominent and painful metatarsal heads on the plantar surfaces of their feet. Excision of all the metatarsal heads commonly relieves the pain and corrects an associated bunion deformity.

Procedural Considerations. The patient is placed in the supine position, a tourniquet is applied, and the foot is prepped and draped. A soft tissue set, a small bone set, Kirschner wires, a power wire driver, and a power microsagittal saw are required.

Operative Procedure

CLAYTON TECHNIQUE

1. A transverse plantar incision is made, and tissue is dissected to the metatarsal heads.
2. Using a microsagittal saw the surgeon removes the metatarsal heads and half the proximal phalanges.
3. The surgeon transects the extensor tendons; they are not repaired.
4. The skin is closed, and a dressing and postoperative shoe are applied.

PELVIC FRACTURE AND DISRUPTION

Patients with multiple trauma often present with multiple fractures that can be life-threatening. Complications of pelvic fractures include injury not only to major vessels and nerves but also to major visceral organs, such as the intestines, bladder, and urethra. Factors influencing mortality include associated visceral injury, hemorrhage, and head injury.

Pelvic fracture classification is divided into three main groups (Table 19-1). *Type A fractures* are stable, without ring involvement (A1) or minimally displaced fractures of the ring (A2). *Type B fractures* are rotationally unstable and vertically stable and are also subclassified: B1 is an open book fracture, B2 has ipsilateral compression, and B3 has contralateral compression.

TABLE 19-1

Classification of Pelvic Injuries

Type A	Stable
	A1—Fractures of pelvis not involving ring
	A2—Stable, minimally displaced fractures of ring
Type B	Rotationally unstable, vertically stable
	B1—Open book
	B2—Lateral compression: ipsilateral
	B3—Lateral compression: contralateral (bucket handle)
Type C	Rotationally and vertically unstable
	C1—Unilateral
	C2—Bilateral
	C3—Associated with an acetabular fracture

Type C fractures are both rotationally and vertically unstable: C1 is unilateral, C2 is bilateral, and C3 is associated with the acetabulum. Radiographic films, computed tomography (CT) scan, and magnetic resonance imaging (MRI) all prove useful in determining the type and appropriate treatment for pelvic trauma.

Treatment is based on classification and may include closed manipulation and reduction or internal and external fixation. Internal and external fixation can be used concurrently in the treatment of some pelvic fractures.

Type A fractures are stable and can be treated nonoperatively. Type B1 fractures may be treated with external fixation or anterior plate fixation. Type C fractures usually require open procedures to fix the fractures with plates and screws, and reduction of sacral disruptions with transiliac rods or screws. Type C fractures may be treated with external fixation when the patient is hemodynamically unstable and a quicker, simpler procedure is prudent.

External fixation is the most widely recommended treatment for type B fractures of the pelvis. A technique similar to that of external fixation of extremity fractures is done in the OR with anesthesia and sterile conditions. If external fixation is to be used, the earlier it is attempted the greater the chance of success.

Procedural Considerations

This procedure is often done during other emergent and trauma resuscitative efforts. The patient's entire pelvic area is prepped and draped. A pelvic skeleton in the room may help the team visualize maneuvers and pin placement to be attempted to complete the reduction. A soft tissue set is needed in addition to the external fixator of choice and the instruments for its insertion, including a power drill.

Operative Procedure

AO External Fixation

1. The surgeon reduces the pelvic disruption manually and confirms it radiographically. It may be impossible to completely reduce the disruption without skeletal traction using a distal femoral pin.
2. Kirschner wires are inserted percutaneously to determine the position of the pin placement, taking into consideration the inward and downward crest slope.
3. The surgeon places parallel rows of pins into the anterior iliac crest area by drilling the outer cortex and placing 5-mm half-pins medially and distally. The pins should enter cancellous bone between the outer and inner tables of ilium.
4. Three universal frames are placed over the pins as close to the skin as possible for maximum rigidity.
5. Optimal reduction of the fracture is visualized using radiography. The surgeon applies the crossbar, and compression and distraction maneuvers are used to maintain the reduction.
6. The surgeon removes the crossbar and applies the connecting rods with couplers.
7. After the couplers are in place, the surgeon reattaches the crossbar and tightens the joints of the frame.
8. The pin sites of tented skin are released. The wounds are dressed with iodine ointment and gauze.
9. The frames are left in place generally for 8 to 12 weeks.

TOTAL JOINT ARTHROPLASTY

Arthroplasty of the joints is performed to restore motion of the joint and function to the muscles and ligaments. It is indicated in individuals with a painful, disabling arthritic joint that is no longer responsive to conservative therapy. In the past, the procedure was reserved for those with a less active lifestyle, and surgeons treated patients with reconstructive procedures such as arthrodesis or osteotomy because of the unknown life expectancy of the materials used in the manufacturing of the prostheses. Technological advances in the prostheses used today allow the younger patient, or the very active older person, to undergo joint replacement. Many total hip and knee replacements are done each year. Improvements in implant design, materials, and fixation techniques are ongoing, as is research on enhancing soft and hard tissue healing (Kolisek et al, 2007).

The classic combination of metal on polyethylene is the mainstay of joint implants. Metals used in hip and knee implants include *cobalt-chromium* (weight-bearing femoral head) and *titanium* (stems of hips and tibial components). The acetabulum and tibial articulating surfaces continue to be substituted with *ultra-high-molecular-weight polyethylene* (UHMWPE), which provides superior wear characteristics. Other designs have emerged in total hip arthroplasty, including metal on metal and the use of ceramic femoral heads.

At one time it was thought that bone cement was the weak link in the longevity of a joint implant because of a relatively high rate of loosening of cement-fixed implants, especially in younger, more active patients. In response to this belief, alternative methods of fixation have been developed. One method involves the application of a precoat of PMMA to the femoral stem to enhance bonding of the prosthesis to the cement mantle. Another method involves the attachment of a porous metal surface to parts of the femoral stem and the entire outer surface of the acetabular component. Most of the porous surfaces are composed of multiple layers sintered in place, creating interconnecting, open pores among the various particles. This allows for the ingrowth of bone to occur, ultimately anchoring the prosthesis in place. "Porous coating" was an attempt to eradicate what was termed *cement disease*—a lysis of bone around the prosthesis causing early loosening. It is now believed that this condition is caused by "wear debris"—particulate matter being shed from metal-to-polyethylene interfaces—and not necessarily from the effects of PMMA.

Bone cement, or PMMA, is an area that has received considerable attention in the search for optimal bone-to-implant fixation. Cement seems to exhibit various degrees of porosity depending on mixing methods and cement pressurization

within the canal. Bone cement must prevent motion at the implant interface. Porosity can lead to fatigue and fracture, which ultimately can lead to implant loosening. Local tissue effects of PMMA may include (1) tissue protein coagulation caused by polymerization, (2) bone necrosis caused by occlusion of nutrient metaphyseal arteries, and (3) cytotoxic and lipotoxic effects of nonpolymerized monomer.

Despite the high rate of success of total joint implantation over the years, there are numerous potential complications. They are generally divided into medical complications, mechanical complications, and infections. Medical complications include, but are not limited to, cardiac dysrhythmias, myocardial infarction, hemorrhage, and pulmonary emboli. Mechanical complications are implant breakage, loosening, and wear. Infection in the patient with a total joint implant is a catastrophic complication that usually requires additional surgery and prolonged hospitalization.

Most surgeons recommend the routine use of antibiotics in primary and revision joint arthroplasty. Antibiotic coverage is initiated preoperatively, continued during lengthy procedures, and administered for 24 to 48 hours postoperatively. Pulsatile lavage systems are used to keep tissues moist, remove debris, and dilute bacteria that may be present. Additional antibiotics are often added to the physiologic saline solutions used for irrigation and to PMMA; however, data do not conclusively support or dispute this practice.

Total Hip Arthroplasty

Total hip arthroplasty is a common orthopedic procedure performed on patients with hip pain caused by degenerative joint disease, rheumatoid arthritis, or avascular necrosis. A total hip replacement can be cemented, noncemented, or hybrid. Hybrids involve cementing one component, usually the femoral stem, and then inserting a metal-backed, porous-coated acetabular component in a press-fit state. Hybrid arthroplasty is a controversial procedure for two reasons. The first relates to research that demonstrates that wear debris is increased with the larger metal-to-polyethylene interface present in the metal-backed, porous-coated acetabular component. The second relates to cost. The metal-backed, porous-coated acetabular component is significantly more expensive than the all-polyethylene component. Consequently, patient selection is very important in determining which type of component is best.

The primary function of the femoral component is the replacement of the femoral head and femoral neck after resection. The femoral head should ultimately sit where it reproduces the center of rotation of the hip. The neck length is variable and is built into several different heights of femoral heads that are eventually seated onto the Morse taper of the femoral stem. The version (implant rotation within the canal) is very important; too much anteversion or retroversion leaves the hip prone to dislocation. The normal position of the proximal femur is in 10 to 15 degrees of anteversion.

Femoral stems can be collarless or have collars that sit down on the resected femur. Collars will produce forces on the bone and may be desired in cases of osteoporotic bone, where bone genesis may be diminished because of the disease process.

Acetabular cups have also presented challenges in trying to maintain fixation within the socket. When cement techniques of the 1970s were used, femoral loosening plateaued about 5 years after surgery. Wear properties of the UHMWPE are also a concern. For this and other reasons associated with component failure, the idea of modularity was developed. Modular components, such as a polyethylene cup that snaps into a metal acetabular shell, greatly decrease the amount of surgery needed in the case of some revisions. In the case of excessive cup wear or a short femoral neck, surgery is minimized with the ability to exchange the modular components without removing the implants fixed to the bone.

Acetabular cups come with a textured back for cement fixation and may have standoff pegs to allow an appropriate cement mantle. Noncemented cups usually are porous-coated and may have screw holes present to aid in anchoring the less-than-stable cup. The presence of screw holes in an acetabular component is another controversial issue. Some believe that more wear debris is created with micromotion between the screw head and the cup as well as between the uneven surface of the screw and the polyethylene liner.

Prostheses are available for every patient's needs. Modular hip systems allow the orthopedic surgeon to choose from an array of interchangeable components that have been developed. Various femoral head sizes (22, 26, 28, and 32 mm) are available to maintain proper center of rotation. Acetabular cups may be snap fit, low profile, or deep profile, which adds additional thickness to the medial wall, where bone loss may be significant.

With modular systems, unipolar or bipolar cups are also an option when the acetabular articular surface is relatively normal. The unipolar and bipolar cups with appropriate head sizes are designed to fit on various modular system stems.

Custom prostheses or revision and extralong stems are available when bone loss is significant. These implants are employed in cases of revision where fixation is needed farther down the femoral canal or in oncologic cases where tumor and corresponding bone have been resected.

Young, active individuals with strong, healthy bones are ideal candidates for noncemented total hip replacement arthroplasties. Elderly patients with osteoporosis and poor-quality bone are usually candidates for cemented components because their bones may lack the compressive strength to support weight-bearing forces (Boughton, 2009a) (Research Highlight).

Hip Reconstruction (Cemented). Numerous implants are available for total hip implantation. Many of the implants can be used for the same surgical indications, and one implant may not function any better than another, provided that all other conditions and techniques are the same. The instruments required to implant any one device cannot be used for another. During the preoperative verification process and time-out the perioperative nurse and surgical technologist collaborate to ensure that all the instrumentation is available.

PMMA adheres to the polyethylene and metal but not to the bone. It fills the cavity and interstices of the bone and forms a mechanical bond. PMMA is manufactured as a liquid monomer and a powder, and is mixed under sterile conditions by the surgical technologist in the OR at the time of implantation. It usually takes 10 to 12 minutes to harden. Because of the potentially harmful effects of PMMA fumes to the nasal epithelium, an exhaust system should be used during the mixing process.

PROCEDURAL CONSIDERATIONS. The patient is positioned in the lateral decubitus position and secured in place with anterior and posterior bolsters. This position is essential

RESEARCH HIGHLIGHT

Increased Risk Factor for Death After Total Hip Arthroplasty (THA)

Patients undergoing a total hip arthroplasty for an acute hip fracture experience an increase in mortality. Other factors, including patient co-morbidities, general health, and delays in surgery, also impact mortality in the 30-day postoperative period. This retrospective study examined 3232 primary THAs, performed from May 1993 through May 2006. Of those surgeries, 75% were elective; the remaining 25% occurred after sustaining a hip fracture. Groups were matched for patient characteristics, at a ratio of four living patients to one deceased patient. The overall mortality for the 13-year period was 0.34%. Those patients who underwent THA after fracture had a higher mortality (1.15%) compared to patients who had an elective THA (0.08%). An anesthesia score of III to IV (ASA classification; see Chapter 4) increased mortality 13 times and cardiovascular disease elevated the risk of dying 8 times. A delay in surgery of 3 or more days also increased the risk for mortality. The use of aggressive thromboprophylaxis did not influence mortality. The most important reasons for death were cardiac events and pulmonary embolism.

Modified from Comba FM: *Certain factors increase risk for death after total hip arthroplasty, AAOS,* 2009, available at www.medscape.com/viewarticle/588980. Accessed April 22, 2009.

FIGURE 19-72 Pulse lavage used for pressurized irrigation when one is irrigating surgical wounds, debriding bone during a joint replacement, debriding open fractures or physically induced wounds, irrigating soft tissue injuries, or irrigating contaminated wounds.

to ensure correct anatomic placement of the acetabular cup. The perioperative nurse verifies that the patient's bony prominences are adequately padded. The skin prep is completed from the level of the umbilicus down to and including the foot; then the patient is draped. The radiographs are overlaid with the implant templates.

A soft tissue set and a large bone set are required. In addition, the total hip implants and corresponding instrumentation, acetabular reamers, hip retractor set, power reamer-driver and saw, and pulse lavage with a 3-L bag of normal saline solution (Figure 19-72) will be needed. If PMMA is used, femoral canal suction wicks, a cement restrictor and its inserter, and PMMA including its mixing supplies will be needed (Figure 19-73). If a trochanteric osteotomy is

FIGURE 19-73 Polymethylmethacrylate (PMMA) and supplies for mixing and delivery in the canal.

performed, the equipment of choice for its reattachment will be required.

Revision of total hip arthroplasties requires the same instrumentation as for cemented total hip reconstruction in addition to cement removal instrumentation, fluoroscopy, and the revision implants and their corresponding instrumentation.

OPERATIVE PROCEDURE

Cemented Modular Hip System, Posterior Approach

1. The surgeon makes an incision 2.5 cm distal and lateral to the anterosuperior iliac spine and curves the incision distally and posteriorly over the lateral aspect of the greater trochanter and lateral surface of the femoral shaft to 5 cm distal to the base of the trochanter.
2. The surgeon divides the tensor fasciae latae over the greater trochanter, and carries this distally to the extent of the incision. Dissection is carried proximally between the interval of the gluteus medius and the tensor fasciae latae muscles.
3. The anterior fibers of the gluteus medius tendon are tagged and detached from the trochanter. The surgeon incises the capsule longitudinally along the anterosuperior surface of the femoral neck. In the distal part of the incision, the origin of the vastus lateralis may be either reflected distally or split longitudinally to expose the base of the trochanter and proximal part of the femoral shaft.
4. After completing the capsulotomy, the surgeon dislocates the hip. Adduction and external rotation will present the femoral head anteriorly into the surgical site.
5. The surgeon places the femoral osteotomy guide over the lateral femur to identify the point on the femoral neck where the osteotomy should be made. Some femoral osteotomy guides also gauge the neck length required. The surgeon marks the level and uses an oscillating or a reciprocating saw to complete the femoral osteotomy.
6. The femur is retracted to expose the acetabulum, allow completion of the capsulotomy, and expose the bony rim of the entire acetabulum.

7. The surgeon inspects the acetabulum, removes any osteophytes, and reams the articular cartilage with bone-conserving reamers in a circumferential manner. The smallest reamer is progressed in a graduated method 1 or 2 mm at a time until the cartilage is reamed down to expose osteochondral bone. A hemispheric shape and bleeding bone should result.
8. Remaining soft tissue is curetted from the floor of the acetabulum, and cystic areas are filled with cancellous bone from the femoral canal and packed with a bone tamp. Any other bone grafting of major bony defects is accomplished using the fixation method of choice (bone screws).
9. Several 6-mm holes are drilled into the floor of the acetabulum, aimed into the ilium, ischium, and pubis. Holes are undercut using curettes. These prepared holes act as anchoring areas for the bone cement.
10. Trial acetabular components are placed on the positioning device and positioned in the socket. The surgeon assesses the cup for size, position within the socket, and the relationship of the component compared with the bony margins of the acetabulum.
11. The prepared acetabular socket is lavaged, dried with wicks, and filled with cement that has been injected and pressurized with an injection gun. The surgeon positions the acetabular shell component and holds it motionless until the cement polymerizes. Extruded cement is trimmed from around the edge of the component. A polyethylene insert is later snapped into the shell.
12. A sponge is placed in the acetabulum to protect the component from bone debris and subsequent cement as attention is turned to the femur.
13. Dropping the patient's foot toward the floor and internally rotating and pushing the leg proximally expose the proximal femur. The surgeon accesses the femoral canal using a box osteotome or trochanteric reamer followed by the T-handle canal reamer.
14. Beginning with the smallest broach, the surgeon alternately impacts and extracts the proximal femoral canal. Progressively larger broaches are used to crush and remove cancellous bone until cortical bone is reached. A broach that is not advancing should not be used as this could result in shattering the femur.
15. With the final broach seated to the desired depth in the canal, the neck is prepared with a calcar reamer. The broach remains while the surgeon places the femoral trial component along with the various-size head, neck, and offset trial components.
16. The trial component is removed, and the canal is lavaged and brushed to accommodate the PMMA.
17. A cement restrictor is inserted into the femoral canal. The femoral components are passed and assembled on the back table.
18. The cement is injected and pressurized within the femoral canal.
19. The femoral component, with the proximal and distal centralizers, is inserted into the canal with or without the femoral head.
20. The surgeon positions the appropriate size of femoral head onto the stem, and reduction is carried out. The joint is taken through a range of motion to check for positioning, stability, and the limit to which dislocation occurs.
21. Depending on the surgeon and the surgical approach, the greater trochanter may or may not have been removed for exposure of the hip joint. If removed, it is reattached with 18-gauge wire or a cable grip system.
22. The surgeon closes the wound in layers over suction drains. The skin is closed with staples, and a sterile dressing is applied to provide compression to the wound.
23. An abduction pillow or splint is placed between the patient's legs postoperatively if stability of the joint is of concern.

Hip Reconstruction (Noncemented). Fixation with a noncemented prosthesis is initially accomplished by a tight fit and intimate contact of the implants within bone of substantial strength. As with all prosthetic designs, it is essential to fill the medullary canal and wedge the prosthesis in as tightly as possible to provide temporary press-fit fixation. These prostheses closely follow normal anatomic shape. Only the instrumentation corresponding to the implant should be used. Precise machining of the femoral canal must be ensured. Acetabular components are usually press-fitted, but many systems provide holes for screw fixation if stability of the prosthesis is in doubt. Sufficient time is then allowed for the cancellous bone to heal by growing into the porous portions of the prosthesis.

The healing process requires the same amount of time as a long bone cortical fracture (approximately 3 months). The patient must be cautious after the procedure and protect the operative hip from excessive compression, rotation, and shear stresses.

PROCEDURAL CONSIDERATIONS. The position and incision are the same as those used for the cemented total hip replacement. The radiographs and implant templates are placed on the view box.

OPERATIVE PROCEDURE

Noncemented Anatomic Medullary Locking (AML) Hip System (Figure 19-74)

1. After the incision is made, the surgeon enters the capsule and dislocates the femoral head.
2. A pilot hole is established in the trochanteric fossa as an intramedullary reference point.
3. The surgeon uses progressively sized fully fluted rigid reamers to ream the intramedullary canal.
4. A femoral neck osteotomy is achieved by positioning an osteotomy template along the axis of the femur and cutting at the level of the collar.
5. The surgeon clears the soft tissue from the acetabulum and reams it with hemispheric reamers.
6. Trial acetabular sizers are placed to determine the correct position and size of the prosthetic component.
7. A hollow osteotome is used in the femoral canal to connect the pilot hole to the osteotomy site.
8. Femoral broaches are then inserted to enlarge the intramedullary space for trial insertion.
9. The surgeon may use a power calcar planer placed over the trunnion of the broach to contour the femoral neck.
10. A trial head and neck component is positioned onto the fitted broach, and a trial reduction is carried out.
11. If trial reduction is satisfactory, the surgeon removes all the trial components.
12. The appropriate size of acetabular component is inserted into the acetabulum, and a polyethylene insert is locked into place.

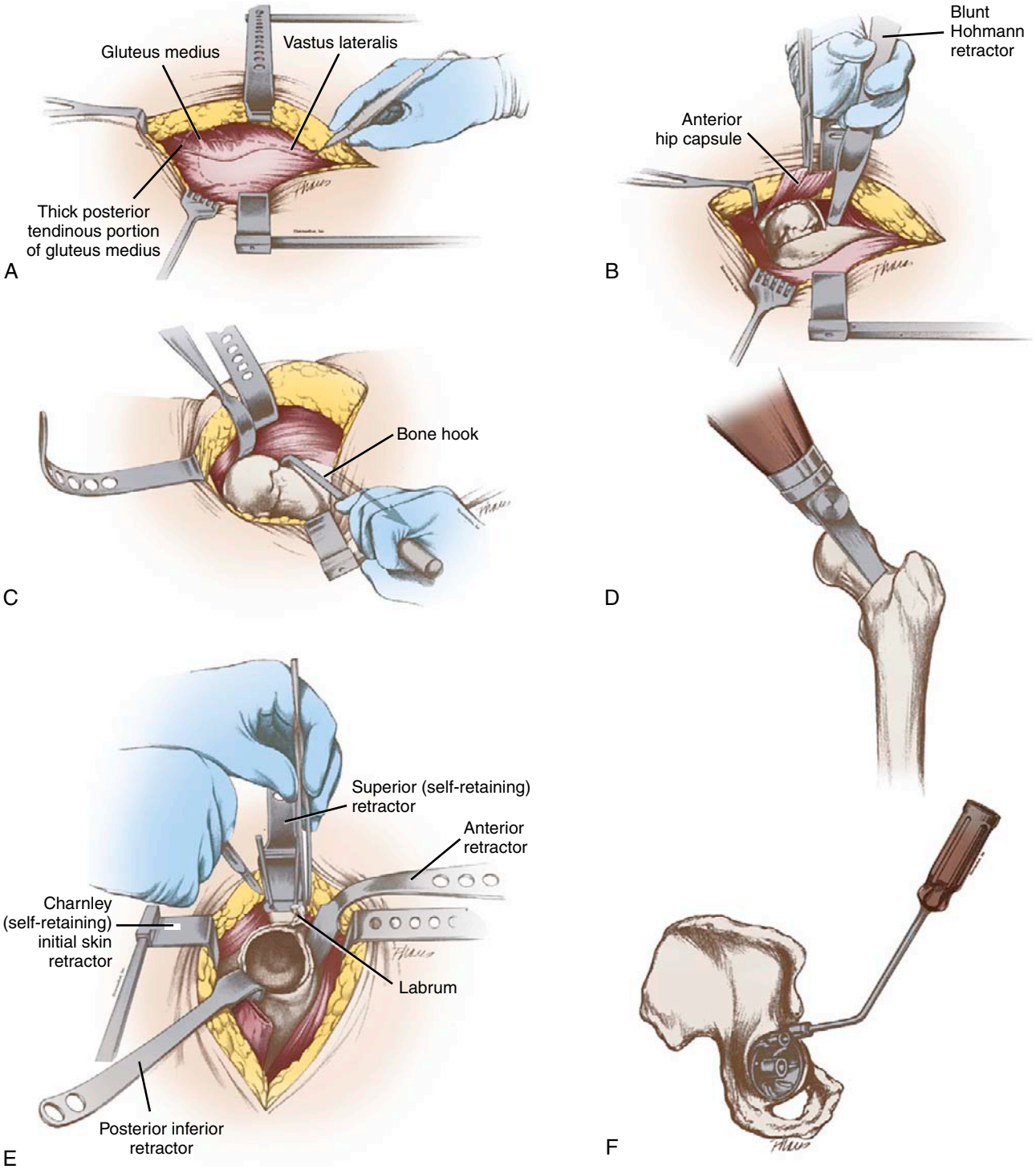


FIGURE 19-74 Noncemented hip reconstruction. **A**, After the incision, the Charnley retractor is placed, the fascia latae is incised, and the gluteus medius is detached. **B**, An anterior capsulotomy is completed. **C**, The hip is flexed, adducted, and externally rotated to dislocate from the acetabulum. **D**, The femoral neck is cut by use of an oscillating saw blade. **E**, The rim of the acetabulum is debrided of labrum, redundant capsule, and marginal osteophytes. **F**, The acetabulum is reamed; after reaming, the appropriate drill guide is inserted into the acetabulum.

Continued

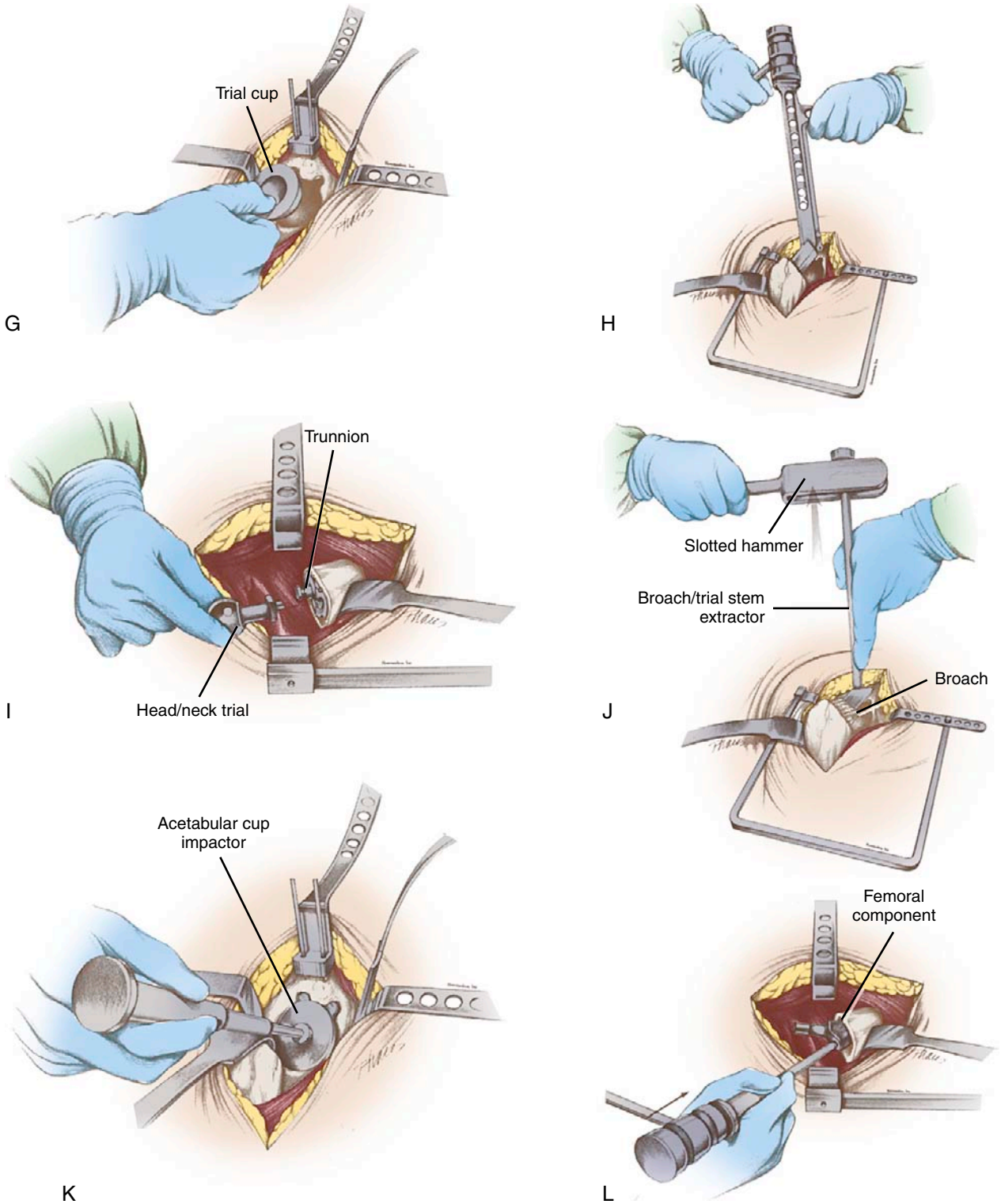


FIGURE 19-74, cont'd **G**, After drilling the holes for the acetabular fixation pegs, the trial acetabular cup is inserted. **H**, The proximal wedge of cancellous bone is removed, and the appropriate size of femoral broach is introduced down the axis of the femoral canal. **I**, The trial head is placed on the broach trunnion of trial reduction. **J**, With the slotted hammer, the femoral broach is extracted; the trial acetabular cup is removed. **K**, Acetabular fixation pegs are seated, the acetabular cup is introduced, and the component is seated. **L**, The femoral canal is irrigated with pulsatile lavage and dried with suction and sponges; the femoral canal is plugged and filled with methylmethacrylate; the femoral component is inserted.

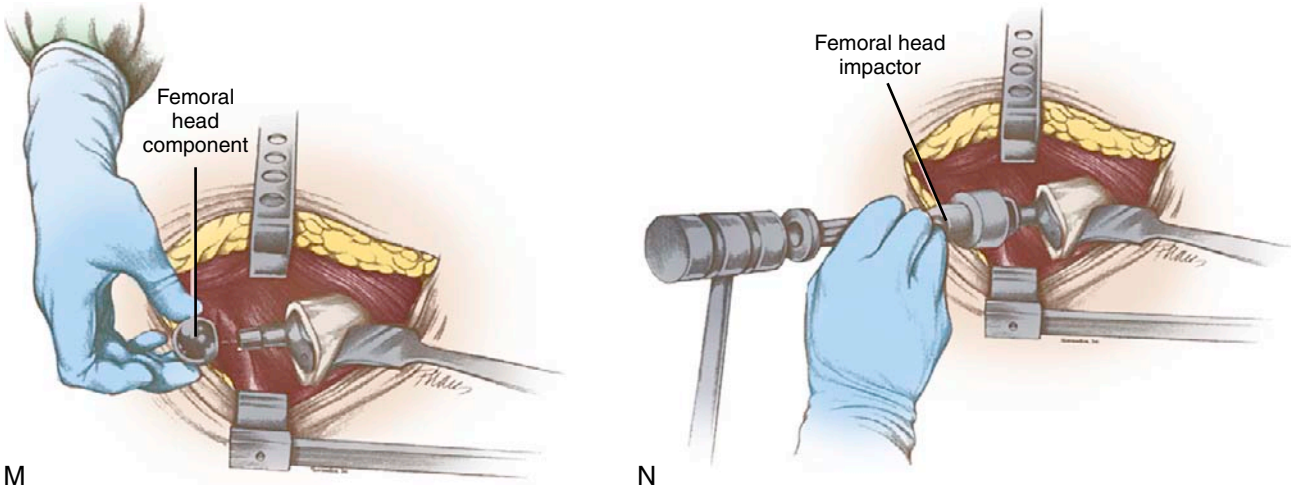


FIGURE 19-74, cont'd M, The femoral head component is placed on the trunnion. N, The femoral head is impacted, the femur is reduced, and the wound is irrigated before closure.

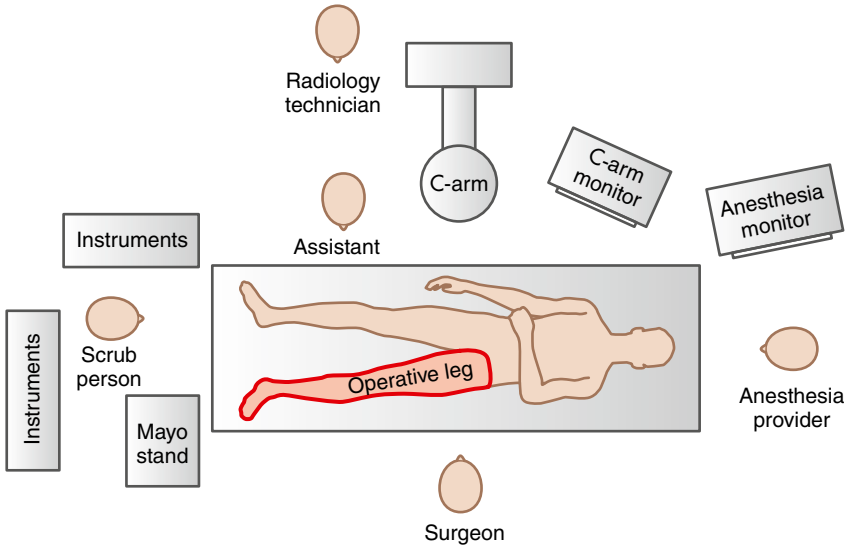


FIGURE 19-75 Illustration of room setup, including positioning of C-arm and monitor, for minimally invasive total hip arthroplasty (MITHA).

13. The femoral component is placed into the canal, and the modular head is seated on the trunnion.
14. Reduction of the hip is followed by standard closure with drains.
15. Abduction of the hip is maintained postoperatively with a foam abduction pillow if necessary.

Minimally Invasive Total Hip Arthroplasty. Minimally invasive total hip arthroplasty (MITHA) has resulted in minimized scarring, reduced patient morbidity, a shortened hospitalization period, and an accelerated rehabilitation process (Harby, 2005). MITHA can be performed with a single or double incision. For a single incision, the patient is placed in a lateral position; the patient is supine for a double-incision procedure. With double-incision MITHA, the acetabular and femoral components are inserted through two small incisions, one anterolateral and one posterolateral, each approximately 5 cm long. The technique spares the muscles and tendons around the hip.

PROCEDURAL CONSIDERATIONS. As with any joint replacement, templates of the x-rays preoperatively are recommended. A regular OR bed with x-ray capability is used. The perioperative nurse should alert the radiology department that fluoroscopy will be used. Equipment should be arranged carefully (Figure 19-75). The patient is positioned supine with a small bolster placed under the pelvis on the operative side. The patient's entire leg, from above the waist to the ankle, is then prepped and draped in the usual fashion. The time-out includes confirmation of the correct patient, site, side, procedure, position, and implants.

OPERATIVE PROCEDURE (VERSYS HIP SYSTEM)

1. The C-arm is used to define the femoral neck. The surgeon makes the anterior incision directly over the femoral neck from the base of the femoral head. The lateral femoral cutaneous nerve is identified and located, and then carefully retracted along with the sartorius using an Army-Navy retractor. A second retractor is used for the tensor fasciae latae laterally. This exposes the lateral border of the rectus femoris.

2. The surgeon uses the electrosurgical unit (ESU) for hemostasis of the lateral femoral vessels. The Army-Navy retractors are extended deeper as the rectus femoris is dissected with a #10 blade on a long handle. A long-tipped ESU pencil may also be used.
3. The surgeon incises the femoral capsule and fat pad. A Cobb elevator is used to move the tissue medially underneath the rectus muscles and laterally off the femoral neck, allowing exposure of the capsule over the femoral neck.
4. Two curved lit retractors are placed outside the capsule around the femoral neck, perpendicular to it. If additional leverage is needed, retractor handle extenders may be attached and used. The femoral capsule is incised in line with the femoral neck lateral to the midline to facilitate future placement of the head of the femoral prosthesis. Sutures can be used to retract the capsule so that the femoral head and neck are clearly visible.
5. Fluoroscopy may then be used to verify osteotomy position. Using the oscillating saw, the surgeon places a high femoral neck cut and uses a straight, 4-cm osteotome to complete it. A second cut is then made, and a threaded Steinmann pin is inserted to remove the small wafer of bone. This allows enough room for the surgeon to make the final femoral neck cut.
6. Fluoroscopy is used to check the angle and length of resection. It is important for the surgical team to help keep the leg in neutral position, especially during these cuts. The femoral head is then removed while the surgical assistant applies gentle traction on the leg.
7. Three lit anterior retractors are placed: one superiorly in the line of the incision, over the acetabulum, and the second and third at 90-degree angles to the first. Once the acetabulum is exposed, sharp and blunt dissection is used to remove remaining tissue and synovium.
8. Reaming starts with the acetabular reamer that is close to the template size. C-arm visualization is used during the reaming. Once reaming is completed to the acceptable size, the trial components are placed to determine fit. C-arm images are used to confirm location and size. The positioning bolster is removed at this time. The appropriate-size cup and liner are then chosen. The acetabular component is then seated using the offset shell inserter, retractors are removed, and the cup is impacted into place. Multiple images are taken to check the placement and position of the cup while impacting. The inserter is then removed. If screws are used, a drill, screws, drill guide, depth gauge, and flexible screwdriver will be required. Once the cup and screws are in place, their position is again checked with fluoroscopy. The liner is inserted.
9. The second incision is found by direct palpation. The nonoperative leg is adducted. The operative leg is fully adducted, externally rotated, and flexed over the nonoperative leg. Location is verified by fluoroscopy. A stab wound is made in the posterior lateral buttock and extended to 1.5 to 3 cm as needed. Sharp dissection is used to spread the tissue along the co-axial pathway to the piriformis fossa.
10. Downward pressure is applied to the operative knee to elevate the trochanter. The tissue protector is inserted. Reaming the femoral canal begins with the lateral reamers. All reamers should be inserted in the locked position. Once lateral reaming is complete, intramedullary reamers are used. Fluoroscopy is used at regular intervals throughout the reaming process to ensure centralization in the canal. The tissue protector is then removed.
11. The canal is rasped, with the initial rasp two to three times smaller than the template size of the canal. The rasp is tapped into place until fully seated; its position is verified with fluoroscopy. The canal is rasped until proper sizing and positioning are obtained. The C-arm is used to check the final depth, fill, and positioning of the rasp with the apex of the calcar.
12. Trial reduction is done with the final rasp in place. The provisional head is placed on the rasp, and the hip is reduced by providing longitudinal traction and internal rotation. The surgeon moves the hip through a full range of motion. Fluoroscopy may be used to check the levels of the lesser trochanters for possible leg length discrepancies. Once trial reduction is complete, the rasp is removed by way of a posterior exit and the head through the anterior incision.
13. Two lit anterior retractors are placed in the posterior incision to keep the tissue away from the stem as it is placed in the femoral canal. Once the implant is through the skin and properly rotated, the implant driver is attached. Gentle traction is placed on the leg in neutral abduction. Once the femoral component is within the capsule of the hip, the patient's operative leg is repositioned; it is fully adducted, externally rotated, and flexed over the nonoperative leg. The stem is impacted until it is fully seated. Fluoroscopy is used to ensure proper seating and alignment.
14. The surgeon pulls the neck of the femur through the wound and places the trial head. Traction is placed on the hip, and the hip is then turned into internal rotation. Range-of-motion and leg length assessment is then done.
15. After the final trial reduction is performed, the surgeon dislocates the hip to put the final head in place. Hip dislocation is done using a dull bone hook and external rotation of the hip. Two sutures are placed in the capsule: one medially and the other laterally. This is done before the head is reduced to prevent the capsule from invaginating posteriorly. The prosthetic head can then be seated and impacted. Gentle traction and internal rotation are used to reduce the hip. A final range-of-motion and leg length assessment is performed.
16. The surgeon irrigates the incisions with antibiotic irrigation. A local anesthetic such as bupivacaine (Marcaine) may be infiltrated into the incision, the two previously placed sutures tied, and additional sutures placed to fully close the capsule. A drain may be placed.

Total Knee Arthroplasty

Total knee arthroplasty is a surgical procedure designed to replace the worn surfaces of the knee joint. Patients complain of knee pain and instability. Degenerative rheumatoid or traumatic arthritis can result in severe destruction of the entire knee joint, or only the medial or lateral compartments of the knee joint can deteriorate as a result of extreme varus or valgus deformity. Arthroplasty of the knee has been successful in relieving these symptoms. Success depends on patient selection, component design, surgical technique, and rehabilitation.

The challenge of finding the optimal knee implant is in reproducing the complicated range of motion of the knee. Motion of the knee occurs in three planes: flexion and extension, abduction and adduction, and rotation. Designs of total

knees should allow preservation of the normal ligaments whenever possible while providing soft tissue balance when necessary to maintain stability.

Total knee implants may be classified into three different categories, according to the portions of the knee to be replaced. *Unicompartmental* implants are used to replace just one opposing articular surface (medial or lateral) of the femur and tibia. These implants, however, lost popularity as a result of biomechanical and technical pitfalls. *Bicompartmental* designs, mentioned only to demonstrate the progression of total knee design, replaced both the medial and lateral surfaces of the femur and tibia. Most of the total knee replacements completed today are *tricompartmental* implants, which replace not only the opposing femorotibial joint but also the patellofemoral joint.

The tricompartmental knees are further divided into three categories (Figure 19-76). *Unconstrained* prostheses have very little constraint built in between the femoral and tibial components and depend on the integrity of soft tissues to provide stability of the reconstructed joint. Where there is significant deformity and the need for soft tissue release, the surgeon may decide to use a *semiconstrained* prosthesis, which lends itself to more inherent stability necessitated by ligamentous deficiency. *Fully constrained* prostheses are linked together with pure hinges, rotating hinges, and nonhinged designs. They are used in the presence of considerable bone loss, instability, deformity, and revision surgery where bone loss has been significant. Fully constrained prostheses do not provide a normal range of motion, and such a lack of motion leads to excessive wear, implant loosening, and breakage.

Methods of fixation of total knee implants include both cemented and noncemented techniques. The noncemented variety encompasses both porous bony ingrowth and press-fit designs. The choice of implant and method of fixation depend on the predisposition of the bone, the patient's age and activity level, and the surgeon's comfort with a particular technique. Previous designs did not retain the posterior cruciate ligament, which possibly led to increased joint instability. Newer designs allow the posterior cruciate to be retained. Some surgeons believe that the retention of the posterior cruciate ligament dictates the need for absolute ligament balancing beyond what may be possible in the reconstructed knee.

In the interest of more cost-effective use of medical resources, new designs have been developed for the less-active patient with a shorter expected life span. The femoral component design is a symmetric design that can be used on either the left or the right knee. The tibial component is composed entirely of UHMWPE, thereby lowering manufacturing costs. Both components are placed with the use of PMMA.

Procedural Considerations. The perioperative nurse assists with positioning the patient supine. A tourniquet is applied to the upper thigh. The surgical prep is completed. A soft tissue set and a large bone set; the total knee instruments, trials, and implants of choice; a power drill and saw; PMMA and cement supplies; and a pulse lavage will be required.

Operative Procedure

NEXGEN TOTAL KNEE ARTHROPLASTY (Figure 19-77)

1. With the knee flexed, the surgeon makes a straight midline incision from 3 to 4 inches above the patella, ending at the patellar tubercle.
2. The capsule is entered medially. After making a median parapatellar incision, the surgeon places Kocher clamps on both lateral and medial sides of the capsule, and reflects the patella laterally to expose the entire tibiofemoral joint.
3. Hypertrophic synovium, a portion of the infrapatellar fat pad, is excised using a toothed forceps and knife or the ESU, and then the osteophytes are removed using a rongeur. This allows easy access to the medial, lateral, and intercondylar spaces and facilitates soft tissue releases, should the need arise.
4. The knee is flexed to 90 degrees, and Hohmann retractors are placed deep to the collateral ligaments and anterior to

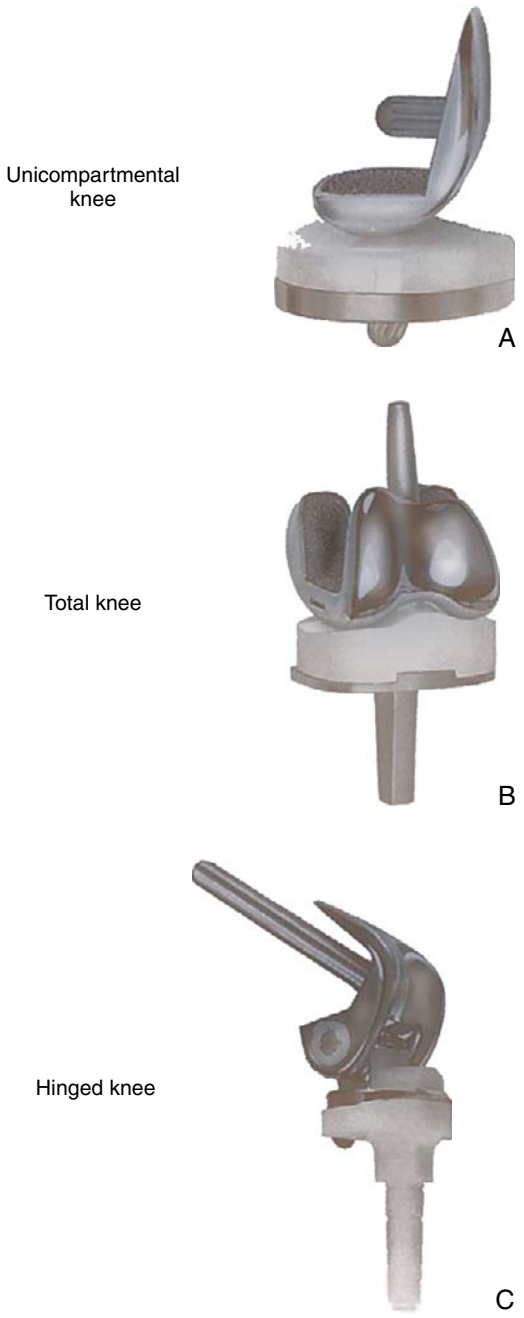


FIGURE 19-76 Knee arthroplasty implants. **A**, Unconstrained hinge. **B**, Semiconstrained hinge. **C**, Fully constrained hinge.

the posterior capsule as well as laterally to the patella to protect these structures during resection of the proximal tibia. A Richardson retractor is placed medially to protect the medial collateral ligament (MCL).

5. The surgeon positions the distal cutting alignment guide extramedullary and parallel to the proximal tibial spine. Proper rotational alignment is established by positioning the appropriate malleoli wings parallel to the transmalleolar axis. The alignment rod is proximally placed just slightly lateral to the tibial tubercle.
6. The osteotomy saw is then used to resect the proximal portion of the tibia. The distal cutting guide is removed. Alignment is checked with a Gerber guide (spacer block with the alignment rod) by placing the guide on the tibia. This checks the tibial cut for valgus alignment. The tibia is then sized with templates.
7. Before proceeding further, the surgeon ensures that the extremity can be moved into normal mediolateral (ML) alignment in extension. If not, additional soft tissue balancing is performed until the normal mechanical axis is obtained.

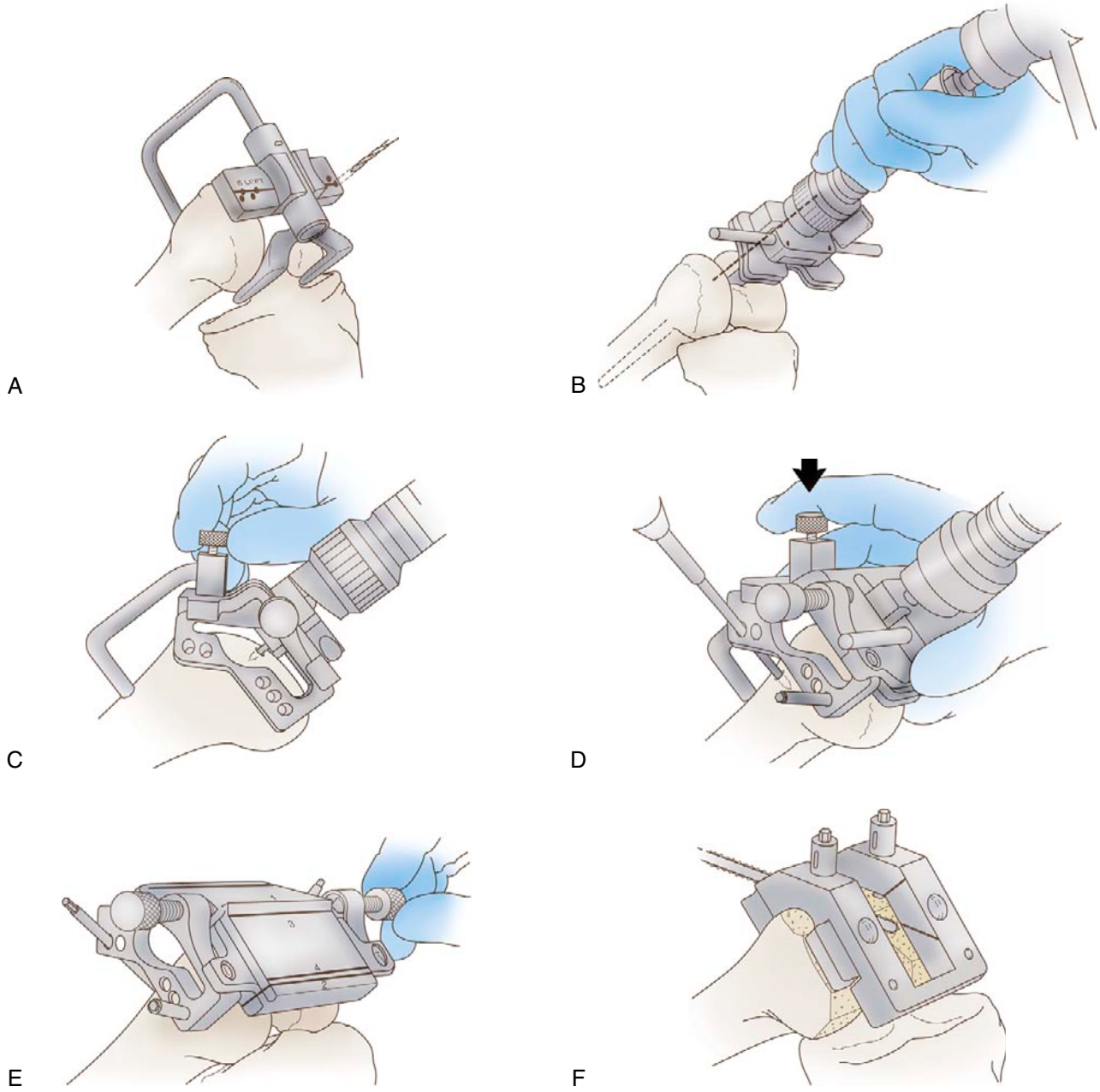


FIGURE 19-77 Total knee implant, instrumentation, and procedure. **A**, After exposure of the intercondylar notch, the femoral sizer is placed at the distal end of the femur. **B**, After the femoral canal is reamed, the femoral intramedullary alignment guide is inserted and passed up the medullary canal. **C**, Correct rotational alignment is maintained; the anterior femoral cutting guide is attached to the femoral intramedullary alignment guide. **D**, The femoral cutting guide is mounted in place. **E**, The femur is resected. **F**, Femoral cuts are completed.

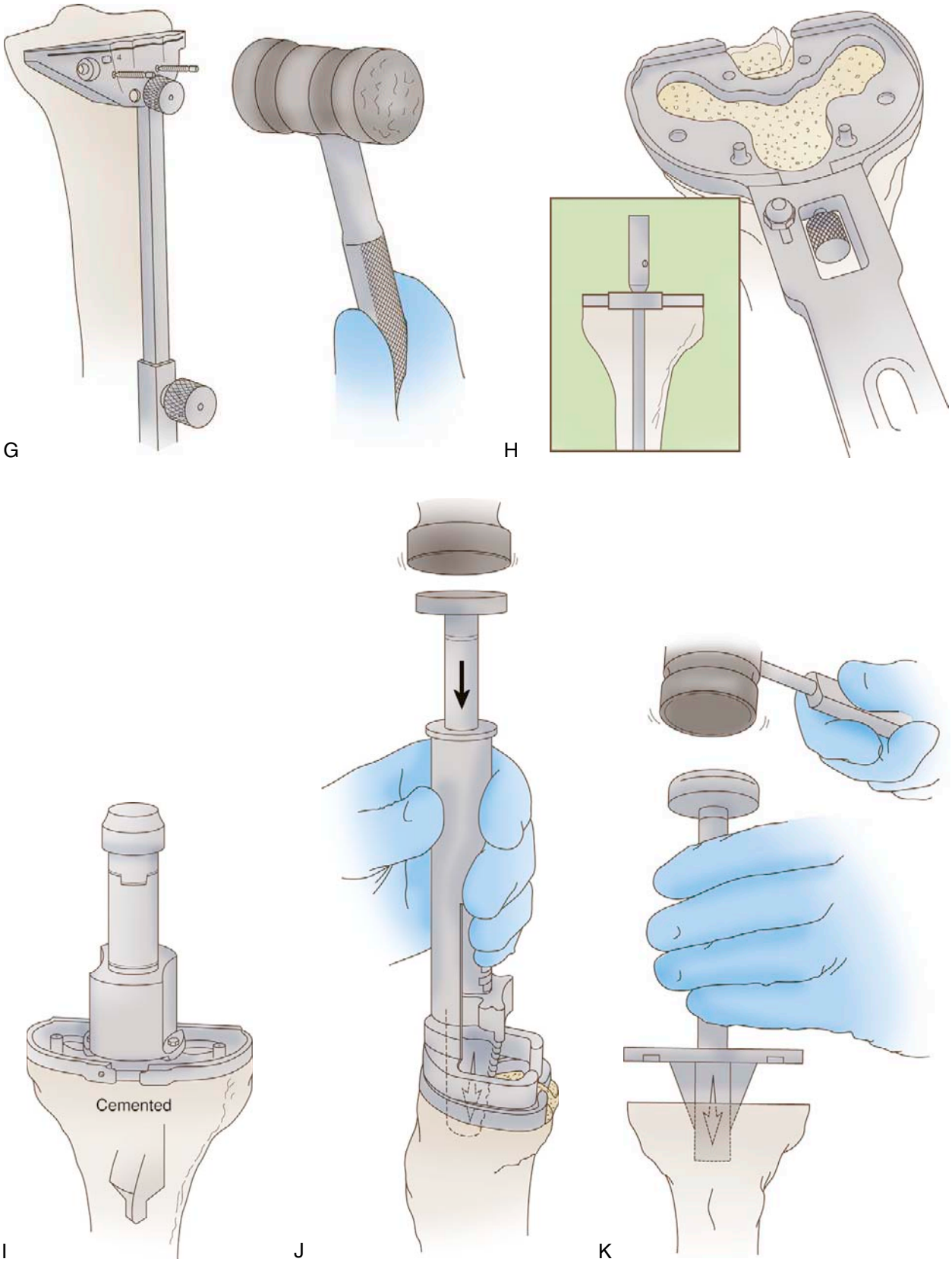


FIGURE 19-77, cont'd **G**, The tibial alignment guide is placed and secured; the tibia is resected. **H**, The tibia is sized. **I**, The tibia is reamed. **J**, The tibia is impacted. **K**, The tibial trial is inserted.

Continued

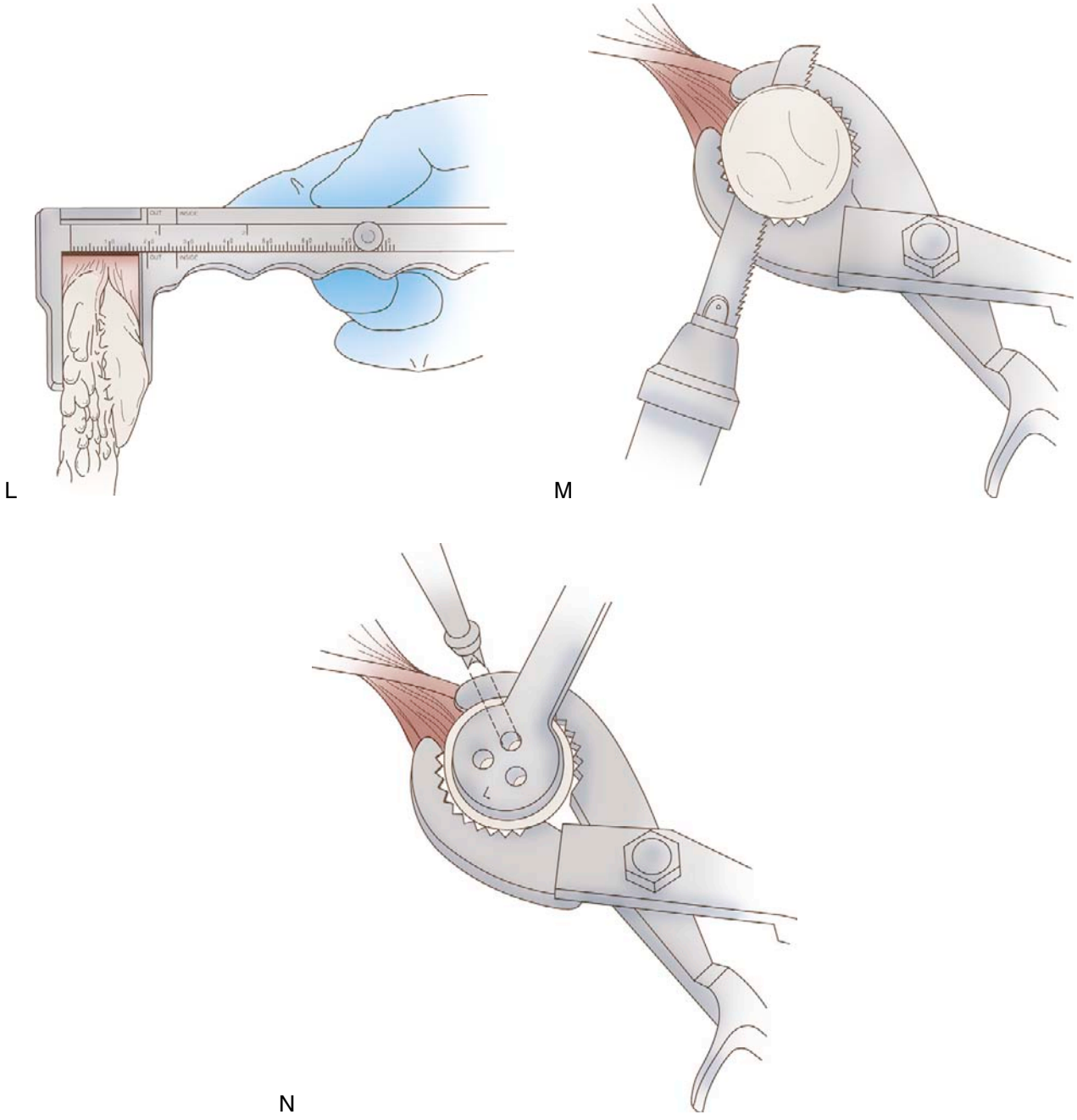


FIGURE 19-77, cont'd L, The patella is measured. M, The patella is sized. N, The patella is drilled.

8. The AP cutting guide is then used to size the femur. The guide yoke is attached to the AP block, and the yoke is slipped under the muscle anteriorly on the periosteum. The middle nail is hammered into place, while pressing down on the guide yoke. Then by pulling up on the yoke, the valgus alignment is achieved such that it is square with the tibial cut. The block is then nailed into place with two pins.
9. With the AP femoral guide in place, the surgeon positions right-angle retractors to protect the MCL and lateral collateral ligament (LCL). The anterior and posterior portions of the femur are resected. The tibial and femoral cuts are checked for balance and size at the same time with a tibial block.
10. Once the flexion balance is determined, the distal femoral cutting block is set. The tensor, placed in flexion, is then slowly moved into extension. Tension is placed on the extension gap by dialing between 30 to 40 pounds of pressure on the tensor. The amount of pressure dialed on the tensor is based on the patient's size and tightness of the ligaments. The distal cutting jig is then placed in the tensor. Once the jig is secured, the two pin holes are drilled and the tensor removed. The distal cutting guide is then placed in the exact two pin holes made by the distal cutting jig. The knee is then flexed, and the distal portion of the femur is resected.

11. The appropriate spacer block is then used to ensure equal tension in flexion and extension.
12. The knee is placed in flexion; the femoral notch and chamfer guide is centered between the epicondyles and impacted until fully seated. Three anterior fixation pins secure the guide to the femur. The surgeon drills two ¼-inch holes into the distal end of the femur, and cuts the anterior and posterior chamfers with the oscillating saw. The box osteotome is used to make the notch cut from the proximal end of the finishing guide. A power saw is used to resect the posterior femoral condyle remnants to ensure adequate flexion clearance. The femoral trial is then positioned.
13. The tibial size is reassessed using the tibial templates. The selected tibial template is then positioned rotationally and drilled, and the appropriate-size centering punch is used to cut through the subchondral bone. The tibial trial is then placed.
14. The surgeon measures the patella and places two towel clips onto the distal and proximal portions of the patella tendon, and then performs the appropriate amount of resection. The patellar template is placed over the resected surface, and the cruciate channels are created using the patellar drill through the slots in the template.
15. A trial reduction is performed. If this reduction proves satisfactory with regard to alignment and ligament laxity, the surgeon removes the trial components, irrigates with a pulsatile lavage, and places the permanent components. These can be inserted without bone cement, with bone cement, or with a combination of both.
16. Drains are placed in the joint depending on the surgeon's preference. The joint is closed in the usual fashion, and a compression dressing is applied to the leg. The tourniquet can be released before closure or after the dressing has been applied.

Postoperative care consists of rapid mobilization and strengthening, with a target discharge of 3 to 4 days postoperatively.

Stryker Navigation Total Knee Arthroplasty

PROCEDURAL CONSIDERATIONS (Figure 19-78). During the surgical approach, the company representative will be initializing (setting up) the Smart Tools instrumentation with the surgical technologist. Healthcare industry representatives can provide valuable technical support to the perioperative team. Integration of surgical instrumentation and computers results in the ability to build a customized, digital map of the patient's anatomy and navigate the surgical instruments according to this map. Successfully executed steps are marked with a blue checkmark and are graphically visualized. Proper setup is achieved when all Smart Tools are shown inside the camera's working space. Advantages to using a navigation system include the increased ability to verify the accuracy of cuts in less visible areas, decreased blood loss, and improved feedback to the surgeon about the patient's soft tissue balance.

A tourniquet, foot holder, and ESU are required. Antibiotics and heparin will usually be ordered.

OPERATIVE PROCEDURE

1. The capsule is entered medially. After making a median parapatellar incision, the surgeon places Kocher clamps on both lateral and medial sides of the capsule, and reflects the patella laterally to expose the entire tibiofemoral joint.

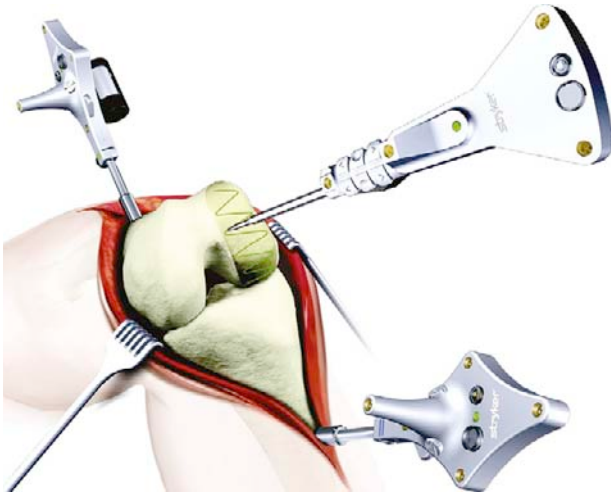


FIGURE 19-78 Stryker Navigation Tracking Equipment.

2. The surgeon begins to raise the medial flap using the ESU at the anterior tibia.
3. With a finger to retract medially, the surgeon places the tibial anchoring pin (self-tapping screws) at the distal aspect of the exposure. Drilling is then undertaken from the anterior to posterior tibial cortex using a 3.2-mm drill bit parallel to the joint line and rotated approximately 30 degrees medially.
4. Using a depth gauge, the surgeon rounds off to the size larger than measured (pins are available in 5-mm increments).
5. The surgical technologist places the pin on a T-handle for the surgeon to manually screw in the anchoring pin.
6. For the femoral anchoring pin, the surgeon next drills from the anterior to posterior femoral cortex, measures with a depth gauge, rounds up to the next larger size, and inserts the pin with a T-handle.
7. The blue tracker (B = bottom) is attached to the tibial pin and the green tracker to the femoral pin. Trackers should be placed so they are facing the camera attached to the navigation system.
8. The femoral head is registered. The hip is placed at 0 to 20 degrees of flexion and then at 45 degrees of flexion. As the leg is rotated, the LED locations yield a set of data points relative to the size of the femoral head.
9. The distal femur is then registered. The medial and lateral condyles, the center of the knee, and the AP axis of the knee are digitalized to identify the articulating surfaces.
10. The proximal tibia is then registered. The center of the tibia, AP axis, and medial and lateral tibial plateaus are traced in a similar fashion to the femur, which identifies the slope of the tibia.
11. The knee is moved through range of motion from full extension to full flexion. This kinematic datum is calculated and then recorded. Once data are recorded, the trackers are removed.
12. The surgeon excises any hypertrophic synovium and a portion of the infrapatellar fat pad using a toothed forceps and knife or ESU; the osteophytes are removed with a rongeur. This allows easy access to the medial, lateral, and intercondylar spaces and facilitates soft tissue releases, should the need arise.

13. The knee is flexed to 90 degrees, and Hohmann retractors are placed to the MCL and immediately anterior to the posterior capsule as well as laterally to the patella to protect these structures. A Richardson retractor is placed medially to protect the MCL. The surgeon uses a Kocher clamp and knife to resect the medial and lateral menisci as well as remnants of the anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL).
14. The surgeon places the navigated tibial cutting guide on the proximal tibia. A cutting guide is attached to the horseshoe device and then the blue tracker to the tibial anchoring pin and the green tracker to the femoral anchoring pin. Using two pins, the guide is anchored. The position is confirmed with the navigation system and the trackers and horseshoe device are then removed.
15. The surgeon uses a 5.5-mm round burr to open the tibial surface and then drive the keel punch slightly anteriorly. The guide and pins are then removed.
16. The horseshoe device is placed with the opening posterior on the distal femur with two pins. The distal femoral cutting guide is attached to the device, and the blue tracker is attached to the blue anchoring pins. Finally, the green tracker is attached to the femoral anchoring pins.
17. The surgeon manipulates the cutting guide to the distal femur. The first pin is driven into the guide and adjusted, and then the second and third pins are placed. The horseshoe and pins are removed. The saw is flushed with the cutting guide, the green top is attached, and the blue Gurba guide is set on the tibial surface to check the cuts.
18. The femoral 4-in-1 cutting guide is placed, and the pin is placed and cut with the saw. The LCL and MCL are protected with a finger or right-angle retractors and the pins removed.
19. The Booth retractor is then placed over the tibia. After the notch guide and pin are placed, the surgeon cuts the tibia to an appropriate depth, using a saw as well as chamfer cuts. The pins and guide are then removed.
20. Next, the patella is measured; then two towel clips are placed onto the distal and proximal portions of the patellar tendon, and the appropriate resection is performed. The surgeon places the patellar template over the resected surface, and creates the cruciate channels using the patellar drill through the slots in the template.
21. Trial components are placed, trackers attached, and the knee moved through a full range of motion. The trials and anchoring pins are then removed.
22. PMMA is prepared. Bone surfaces are irrigated with a pulsatile lavage, and the permanent components are placed. These can be inserted without bone cement, with bone cement, or using a combination of both.
23. Drains are placed in the joint depending on the surgeon's preference. The joint is closed in the usual fashion, and a compression dressing is applied to the leg. The tourniquet can be released before closure or after the dressing has been applied.

Postoperative care consists of rapid mobilization and strengthening, with a target discharge of 3 to 4 days postoperatively.

Total Knee Revision Arthroplasty. Revision arthroplasty may be indicated if the patient's original knee replacement wears out or loosens, or fails as a result of repeated dislocation, infection, or trauma. Total joint revision can be a very demanding and complicated procedure. Attention to detail, anticipation, and preparation are essential. Important patient information includes the preoperative x-rays, bone scan, laboratory results (including aspiration results), and physical findings.

PROCEDURAL CONSIDERATIONS. The perioperative nurse assists with placing the patient in supine position with a footrest for the affected leg. An OR bed with x-ray capability is used. Following the induction of anesthesia, the surgeon performs an EUA. Although one of the most difficult aspects of revision surgery is that there is no clear-cut sequence of events, it is best, if possible, to approach revision surgery using the same logical sequence for each procedure. This allows all members of the surgical team to anticipate the steps in the procedure and the needs of the patient. In the case of revision arthroplasty for infection, antibiotics are held, usually at the surgeon's request, to allow for one final attempt to recover an organism. Tissue and fluid cultures are obtained when the initial incision is made through the capsule and into the joint space. Once the cultures are obtained, antibiotics are given.

Instrumentation includes a basic knee set, primary total knee instrumentation, and trials (in case only one portion of the prosthesis is revised); revision instrumentation to extract the components and cement; instrumentation and trials for the revision components; cementing system and extra cement (usually double the amount of cement used in a primary total knee arthroplasty); and power equipment including saw, reamer, and burrs.

OPERATIVE PROCEDURE The previous skin incision is usually used. This maintains adequate blood flow to the skin. The skin is marked to reapproximate the skin edges after surgery. A tourniquet is used after determining that there are no contraindications based on the patient's medical and surgical history.

1. Using a #10 blade, the surgeon incises through the scar from the original surgery.
2. With heavy tooth forceps and blade, the surgeon undermines skin on each side of the incision; this allows the skin to be more easily closed at the end of the procedure.
3. Once at the capsule, a clean #10 blade is used to make a medial parapatellar incision into the joint. A Kocher is placed on the medial side of the capsule, and a towel clip is placed laterally, immediate to the patella, to aid with eversion.
4. Both tissue and fluid cultures are taken. Antibiotics are then administered by the anesthesia provider.
5. Using heavy tooth forceps or a Kocher, the surgeon performs a synovectomy with a knife or the ESU. A clean dissection is needed to allow visualization of the bone-prosthesis interface and to remove any synovitis caused by poly debris or metallosis (metallosis is a nonsuppurative osteomyelitis that occurs around metal implants as a result of corrosion or hypersensitivity reaction).
6. The surgeon uses a periosteal elevator to peel away the medial ligament, which was stripped during the original surgery.
7. The knee is dislocated with posterior placement of a Hohmann retractor immediately behind the tibia. A second Hohmann retractor is placed laterally to the patella and LCL. Medially, a Richardson retractor provides protection of the MCL.

8. If possible, the surgeon removes the poly tibia insert to allow better visualization and an increased work space.
9. Using an osteotomy saw with a small blade, the surgeon will proceed to remove the tibial plate at the bone-prosthesis interface. If the saw is unable to complete the cuts, ¼- or ½-inch curved osteotomes may be used to gain access to the posterior lateral corner. Cement is then removed from the canal using a Kocher, ¼-inch straight osteotome, chisels, mallet, and curettes. If the cement is deep, a heavy toothed alligator forceps may be required.
10. Once the tibia and cement are removed, the surgeon recuts the tibia surface using an osteotomy saw and alignment guide. Sometimes, the tibia is completely revised before the next step. If so, the tibial template, pins, mallet, and punch will be needed.
11. With the patella everted, a Booth retractor is placed under the femur. Using a ½-inch curved osteotome and mallet, the surgeon removes the femoral component. A ¼-inch curved osteotome may be required if there are metal pegs at the distal end on the femoral component or at the posterior edge of the prosthesis. Once both sides of the prosthesis are loosened, it should fall off. If not, a femoral distractor will be used.
12. Any remaining cement is removed using osteotomes, chisels, or the saw. Any cement in the canal will be removed with a Kocher or alligator forcep.
13. Next the posterior capsule is addressed. With the leg in extension, the surgeon places a lamina spreader between the femur and tibia. Using curettes and a rongeur, the scar on the posterior capsule is removed to improve postoperative range of motion.
14. Once the capsule is released, attention is turned to rebuilding the femur. This is done by using a series of guides and trial components.
15. Augmentation of both tibia and femur components can be done using either metal augments or bone grafting. Balance between the femur and tibia is obtained first in flexion and then in extension.
16. The last component to be revised is the patella. Two towel clips are placed, distal and proximal on either side of the patella, and the button is removed, using a large-blade osteotomy saw. All poly buttons can be readily removed by this method. However, a metal-backed patella requires the additional use of a ¼-inch osteotome. Any remaining cement is removed from holes with a curette or 6.0-mm burr on a drill. The patella will be recut using a large-blade osteotomy saw.
17. The guide is placed on the patella, and the drill is used for new holes. The trial button is placed, the patella inverted, and the knee placed through a range of motion.
18. All components are removed, and the knee is irrigated with antibiotic solution using pulsatile lavage. The bone edges are dried with suction and clean sponges. This is done while the cement is being mixed.
19. Components can be cemented all at once or in stages, depending on the surgeon's preference.
20. The femur is usually cemented first. The Booth retractor is placed under the femur, and cement is put on the posterior phalanges of the femoral component and then on the distal edges of the bone. The component is placed on the end of the femur and impacted with an impactor and mallet. The cement is removed using glue knives anteriorly, laterally, and medially. Posterior glue is removed using curettes. The Booth retractor is then removed.
21. Hohmann retractors are placed posteriorly and laterally; a Richardson retractor can be placed medially if necessary. The surgeon applies cement on the tibia surface and on the tip of the tibial stem. The tibial component is then placed and impacted. Remaining cement is removed using glue knives or bayonet forceps. The retractors are removed, and the knee is relocated.
22. Cement is applied to the patella in the predrilled holes as well as on the patella button itself. The button is placed on the patella and held with a patella clamp. Remaining cement is again removed using a glue knife or bayonets.
23. Drains are used at the discretion of the surgeon, and the wound is closed.

Total Shoulder Arthroplasty

Physically induced or accidental injury or degenerative arthritis may necessitate prosthetic replacement of the shoulder joint. The procedure may be a hemiarthroplasty with reconstruction of the humeral side or a total arthroplasty with replacement of the humeral head and glenoid (Figure 19-79).

Procedural Considerations. The patient is placed in a 30-degree semisitting position with the arm draped free on a padded armboard and the shoulder hanging slightly off the OR bed to allow movement through the entire range of motion. The perioperative nurse confirms that the patient's head is supported to avoid neck extension. A pad is placed beneath the scapula.

A soft tissue set and a large bone set; shoulder instruments; PMMA and cement supplies; the implants with associated instrumentation and trials; a power drill, reamer, and saw; and a pulsatile lavage system will be needed.

Operative Procedure

NEER TOTAL SHOULDER ARTHROPLASTY
(Figure 19-80)

1. The surgeon makes a 16-cm incision from the midacromion distally along the deltopectoral groove.
2. The cephalic vein is identified, and the surgeon opens and retracts the deltopectoral groove.
3. The deltoid attachment may be removed if the patient is large or muscular, which may affect rehabilitation.
4. The long head of the biceps is identified as the landmark between the tuberosities and rotator interval.
5. The surgeon elevates the subscapularis from the underlying capsule and divides it 2 cm medially to the bicipital groove, and places a stay suture.
6. The subscapularis is retracted medially with the lesser tuberosity, thereby exposing the joint and associated structures.
7. The capsule is exposed by elevation. The surgeon uses an elevator placed beneath the capsule to protect the axillary nerve. The long head of the biceps is left undisturbed and free in its groove so that it will continue to function as a depressor of the head after surgery.
8. After external rotation, the fractured humeral head is removed. The incision site is irrigated to remove blood and clots from the joint.
9. The surgeon examines the proximal humeral shaft to select the appropriately sized stem, available in various lengths and diameters.

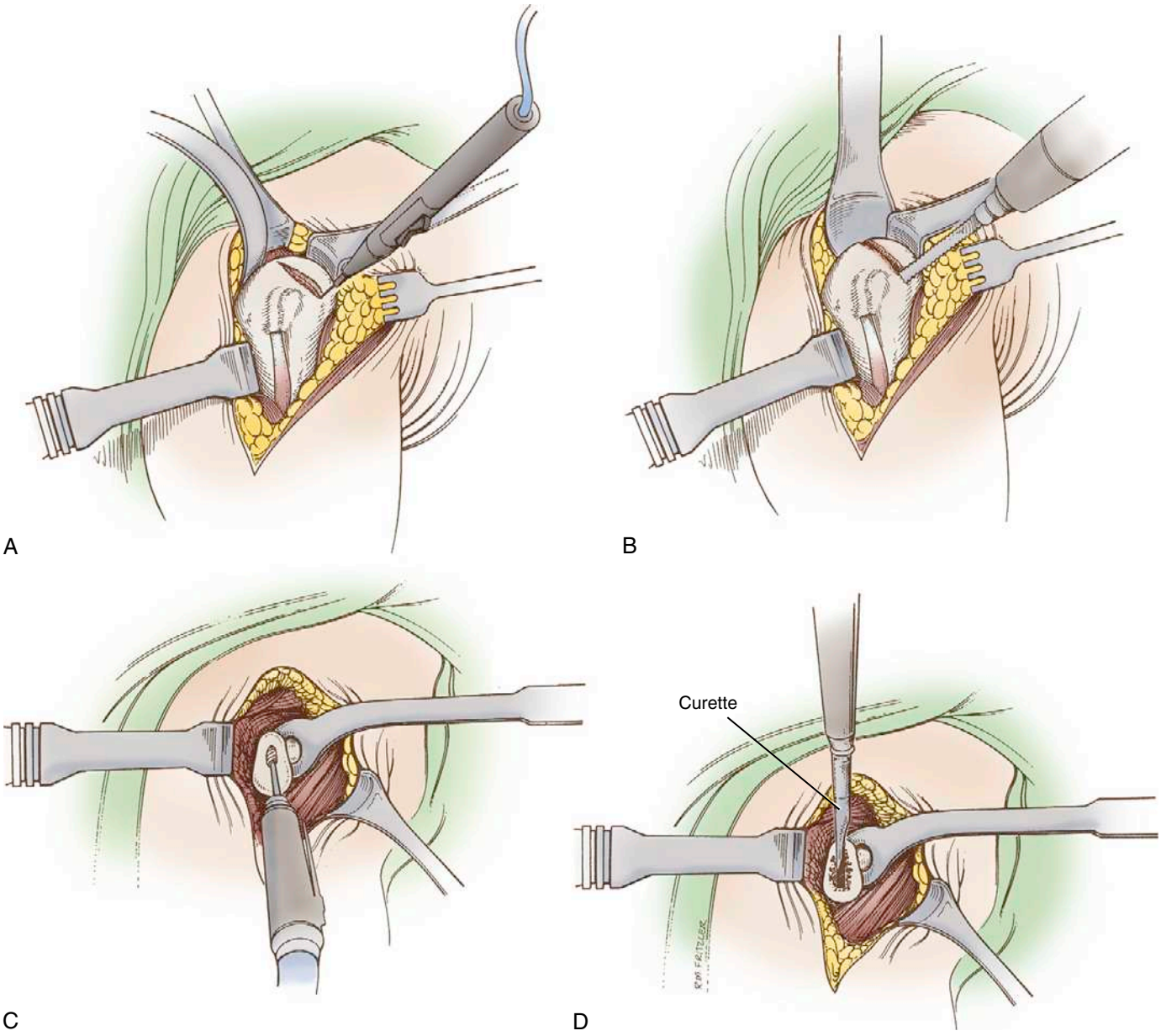


FIGURE 19-79 Total shoulder arthroplasty. **A**, The patient is positioned, and a deltopectoral incision is made to release the capsule. **B**, The humeral head is removed with a reciprocating saw. **C**, After exposure of the glenoid, a fenestration for the glenoid component is made. **D**, The glenoid bow is curetted.

10. Marginal osteophytes are trimmed.
11. The glenoid is inspected for integrity and sized for a prosthesis if it is to be replaced.
12. A central hole for a prosthesis fit is made into the glenoid with a high-speed burr and curette.
13. Stem diameter and length are estimated to check the prosthesis for fit. The largest stem diameter possible is used.
14. With the shaft held forward and upward, the surgeon locates the intramedullary canal with a long curette. A ¼-, ⅜-, or ½-inch drill bit is selected to correspond to the diameter of the canal; depending on the prosthesis stem length, the surgeon drills down the medullary canal 5 or 6 inches. Final preparation of the shaft is accomplished with the appropriately sized tapered reamer.
15. A heavy-gauge nonabsorbable suture is passed through holes that have been drilled on the tuberosities. The surgeon checks the length of the rotator cuff by pulling the tuberosities distal to the collar of the prosthesis.
16. Neck length and stability of the joint are determined before final impaction of the prosthesis.
17. A check for 35- to 40-degree retroversion is done by palpating the epicondyles at the elbow.
18. The implant is seated on the calcar with a driver and mallet, with its articular surface protected with a moist sponge. Just before final seating, further trimming of high spots with an osteotome or high-speed burr may be required. PMMA is used except in young patients, in whom a firm press-fit can be achieved.

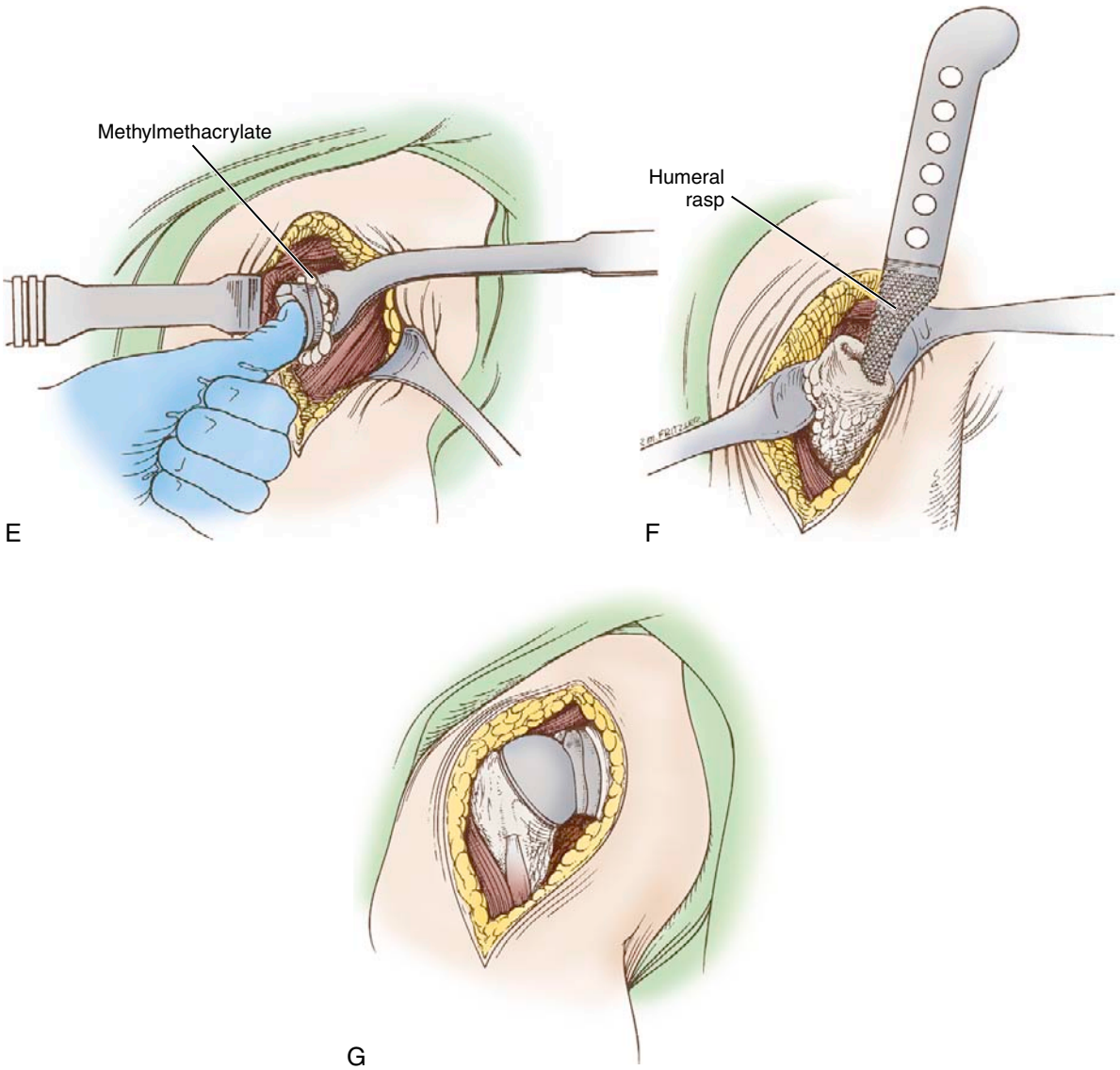


FIGURE 19-79, cont'd **E**, Cancellous bone is evacuated and cement impressed. **F**, The humeral shaft is rasped. **G**, The humeral component is inserted.

19. Wires or sutures are passed through the holes in the neck of the prosthesis, reducing the tuberosities beneath the collar, and are secured. If wires are used, they are buried in drill holes in the bone.
20. The surgeon reduces the shoulder. The interval of the rotator cuff is closed and the biceps tendon reattached if previously detached.
21. The joint is irrigated as each compartment and layer is closed.
22. A closed-drainage system is inserted between the rotator cuff and deltoid, avoiding contact of the drainage tubes with the axillary artery. Routine closure is accomplished.
23. Dressings are placed between the body and the arm. A shoulder immobilizer is applied.

Passive range-of-motion machines may be used for patients prone to adhesion or contracture. Pendulum and gentle exercise are permitted at 10 days.

Total Elbow Arthroplasty

While not as prevalent as arthroplasty of the shoulder, knee, or hip, total elbow replacement (Figure 19-81) is indicated for patients with traumatic lesions or excessive bone loss from rheumatic or degenerative arthritis, resulting in elbow instability and pain or bilateral elbow ankylosis. The design of implants and methods of fixation for postoperative stability have presented challenges that have been overcome in arthroplasty of other joints but remain a challenge in elbow arthroplasty. Postoperative stability of the elbow implant depends largely on the soft tissues surrounding the joint. There are devices that provide more constraint for the patient with significant soft tissue laxity or loss of bone stock. The Coonrad-Morrey, Tri-Axial, and Pritchard-Walker are just a few of the total elbow prostheses available.

The prosthesis may be used with or without PMMA, depending on the quality of the diseased bone and the design of the

FIGURE 19-80 Neer shoulder prosthesis.

implant. If PMMA is not employed, bone grafting with local bone that has been resected may be used to help seat the ulnar component snugly and achieve adequate bony contact against the porous coating of the metal ulnar component. After elbow arthroplasty, patients with degenerative arthritis generally have better results than those with injury.

Procedural Considerations. The perioperative nurse assists with positioning the patient in the supine or semi-Fowler position with the arm over the chest. A tourniquet is applied and can be inflated if needed. The arm is prepped from shoulder to fingers and draped. A soft tissue set and a small bone set; the total elbow implants and instruments; a power saw, drill, and burr; an awl; heavy-gauge wire; and a wire tightener will be needed. PMMA and cement supplies as well as a pulsatile lavage system are required if the prosthesis is placed with the use of PMMA.

Operative Procedure

1. The limb is exsanguinated, and the tourniquet is inflated to the desired pressure.
2. The surgeon makes a midline posterior incision, protecting the ulnar nerve.
3. The triceps mechanism is elevated in continuity with the periosteum, and the elbow joint is explored.
4. The surgeon explores the distal end of the humerus, proximal end of the ulna, and radial head while preserving the collateral ligaments.
5. The midportion of the trochlea is removed to allow access to the distal end of the humerus; the medullary canal is opened with a high-speed burr, and the canal is entered with a twist hand reamer.
6. The distal end of the humerus is notched with the appropriate cutting guide.
7. A high-speed burr is used to drill through subchondral bone to allow access to the medullary canal of the ulna and serially ream the canal.
8. After the humerus and ulna have been prepared for insertion of the trial prosthesis, the surgeon evaluates the elbow for flexion and extension. Bony adjustments are made where necessary.
9. The canals are cleaned of all bone fragments by irrigating with pulsatile antibiotic lavage.
10. The canal is dried before implant insertion, and the preparation is checked before the cement is mixed to ensure that the correct size of component is available.
11. The surgeon inserts the cement into the canals followed by the prosthesis. Flexion and extension of the elbow are avoided until the cement has hardened.
12. Any bone graft that may be required is secured with wire or pins.
13. The tourniquet is deflated, and hemostasis is achieved.
14. The triceps mechanism is repaired. The incision site is irrigated and closed. A drain may be inserted.
15. A long arm posterior splint is applied with the elbow at 90 degrees.

Total Ankle Joint Arthroplasty

Long-term results for total ankle arthroplasty, especially in the young population, are extremely poor. The procedure is reserved for older or more sedentary patients, especially those with subtalar or midtarsal arthritis. Ankle arthrodesis should be considered first in joint reconstruction. Indications for total ankle arthroplasty include (1) failed arthrodesis, (2) bilateral ankle arthritis when arthrodesis has already been performed on one ankle, (3) after talectomy because of avascular necrosis, and (4) revision of a previous arthroplasty. Total ankle replacement prostheses are made of high-density polyethylene and metal components.

Procedural Considerations. The patient is supine with the tourniquet placed. The leg is prepped and draped. A soft tissue set, a small bone set, the total ankle joint replacement instrumentation and implants, a power drill and saw, a pulsatile lavage system, and PMMA cement and supplies will be necessary.

Operative Procedure (Figure 19-82)

1. The surgeon makes an anterior incision over the ankle joint.
2. Using blunt and sharp dissection the surgeon exposes the tibiotalar joint and talus dome.
3. Once the center of the talus is identified and marked, a sizing template is used to mark the tibia.
4. A defect that is 1 inch wide by ⅜ inch deep is made using the air drill. Anchoring holes can be made in the tibia. The template is positioned in the defect while the foot is distracted.
5. The talus is marked, and using a reciprocating saw the surgeon makes a groove that is ½ inch deep by 3/16 inch wide to accommodate the talar component.
6. A trial fit is carried out to ensure that the talar unit is in the center of the talus and that the tibial unit is parallel to the plane of the floor, both centered over the dome of the talus.
7. Once trial reduction is complete, the talar and tibial components are cemented into place.
8. The ankle joint is irrigated and closed, a drain inserted, and a posterior splint applied.

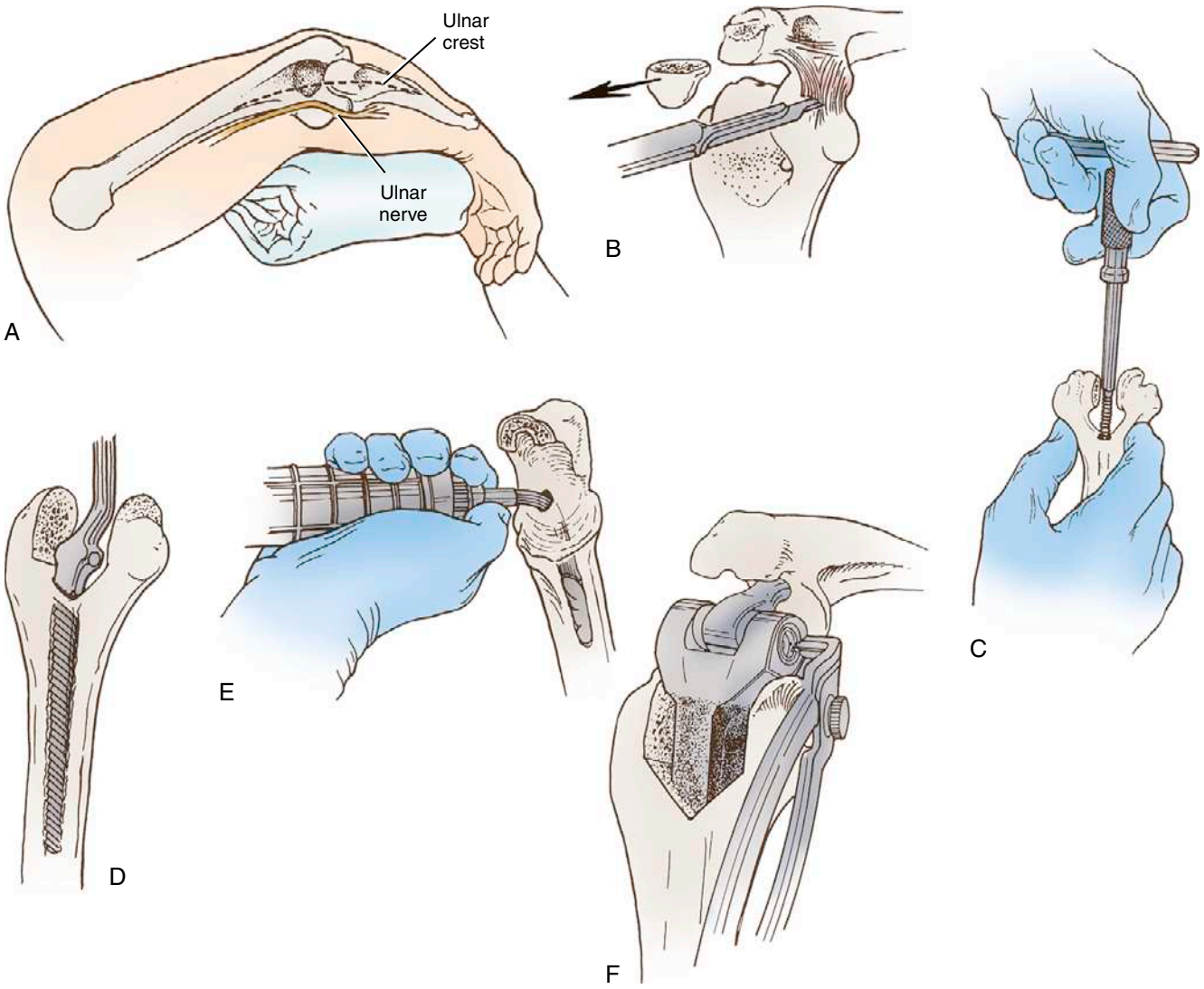


FIGURE 19-81 Total elbow arthroplasty. **A**, The arm is draped free, and the incision is made. **B**, The tip of the olecranon is excised with an oscillating saw. **C**, The canal is identified with a burr, and the canal is opened with a twist reamer. **D**, The capitellum is measured and cut. **E**, The medullary canal is cleaned and dried, and bone cement is inserted. **F**, The ulnar prosthesis is inserted, followed by cementing and inserting of the humeral components.

Metacarpal Arthroplasty

Metacarpal joint replacement is most often performed in patients who have pain or a disabling deformity associated with rheumatoid or degenerative arthritis of the metacarpophalangeal or interphalangeal joints. The results of rheumatoid reconstructive surgery are generally good, and pain can be eliminated and joint alignment and joint stability restored in the majority of patients. The greatest problems after surgery are weakness of grasp and pinch, and progression of the disease in adjacent joints.

Procedural Considerations. The patient is positioned supine with the arm extended on a hand table. A tourniquet is applied, and the entire extremity is prepped and draped. A hand set, instrumentation for implants, and implants are required, as well as a high-speed burr.

Operative Procedure

1. Incisions are made on the dorsum of the appropriate fingers.
2. The surgeon excises the proximal and distal portions of the joints and reams the intramedullary canals.
3. Sizers are used to facilitate a correct fit of the prosthesis.
4. Once the appropriately sized implant is determined, the surgeon positions it into the canal (Figures 19-83 and 19-84) and makes tendon and ligament repairs as indicated to improve stability.
5. The joint is irrigated and closed, and a bulky dressing is applied.
6. A short arm posterior splint is applied for immobilization.

Metatarsal Arthroplasty

Silastic implantation is indicated in the treatment of deformities associated with rheumatoid arthritis, hallux valgus, hallux rigidus, and a painful or unstable joint.

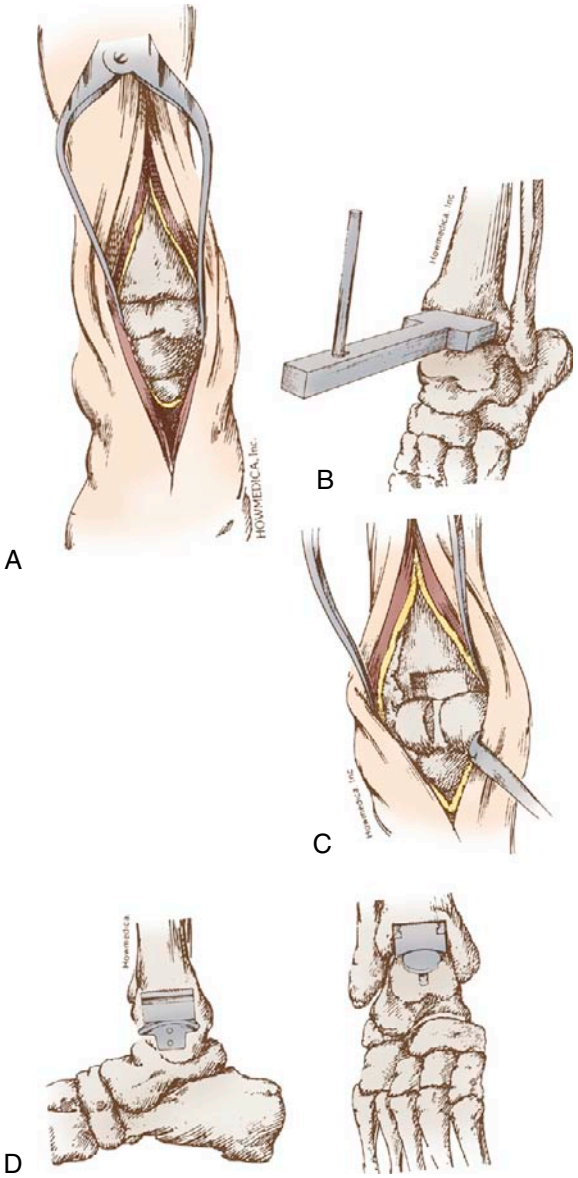


FIGURE 19-82 Total ankle arthroplasty. **A**, An anterior incision is made, and the tibiotalar joint and talus dome are exposed. **B**, The sizing template is used to mark the tibia. **C**, An air drill is used to create a defect, and anchoring holes are prepared. **D**, Trial reduction is completed, and the talar and tibial components are cemented into place.

FIGURE 19-83 Metacarpophalangeal implant.

Procedural Considerations. The patient is supine. A tourniquet is applied, and the entire extremity is prepped and draped. A small bone set is required, as well as the implant instruments and implants, a power wire driver, and the microsagittal saw.

FIGURE 19-84 Silastic implant for finger joint.

Operative Procedure

1. The incisions are made over the appropriate joints.
2. The surgeon resects the proximal phalanx and removes exostosis from the metatarsal head.
3. The medullary canal is reamed, and trial implants are fitted.
4. The surgeon determines the appropriate sized metatarsal implant and seats it.
5. The wound is irrigated and closed.
6. A bulky compression dressing and orthopedic shoe are applied for early ambulation.

ARTHROSCOPY

Progress and development of arthroscopy and arthroscopic procedures have changed the approach, diagnosis, and treatment of many joint ailments. Arthroscopic techniques require skill and accomplishment in identifying three-dimensional relationships. The advantages of arthroscopic surgery surpass the disadvantages. Among the advantages are (1) decreased recovery and rehabilitation time; (2) smaller incisions; (3) less inflammatory response; (4) less postoperative pain, scar, and extensor disruption; (5) reduced complications; (6) reduced hospital stay and cost; and (7) easier, more rapid surgical procedures (Ambulatory Surgery Considerations).

Disadvantages usually relate to the size and delicacy of the instruments. Maneuverability within a joint may be difficult and produce scuffing and scoring of the articular surfaces.

Improvements in scope and camera systems, sharper scope optics, and miniaturization have made operative arthroscopy a logical extension of diagnostic arthroscopy. Surgical arthroscopy has also been aided with the development of numerous second puncture instruments and devices to repair and excise defects. There are a multitude of motorized shaving and abrader systems. Irrigation systems provide regulated distention of the knee joint by infusing normal saline or lactated Ringer's solution. These systems may function by gravity flow or are mechanized with built-in microprocessors to monitor joint pressures and adjust accordingly. Lasers and ESUs can be used in tandem with arthroscopic equipment. Integrated video systems can record and store still and video images on film, tape, or digitally for education and documentation.

Arthroscopy is commonly performed on the knee, shoulder, and wrist. It is used less often in the elbow, hip, and ankle. Many corrective procedures that previously required an arthrotomy or other open procedure can be completed with the assistance of the arthroscope.

Arthroscopic equipment has certain requirements for care and handling. Fiberoptics, lenses, and cameras are heat-sensitive, requiring consideration for sterilization. Temperatures and moisture generated by steam autoclaves can damage materials used in video equipment or deteriorate the sealant, making the moisture accessible to the lens. Alternatives to steam sterilization for

AMBULATORY SURGERY CONSIDERATIONS

Arthroscopic Surgery

Ambulatory surgery has long been part of orthopedic surgery. Recent advances in minimally invasive surgery and postoperative pain management have led to even more orthopedic procedures being performed in an ambulatory setting.

The most important factor in ambulatory surgery is patient selection. Appropriate patient selection is essential for successful orthopedic ambulatory surgery. Surgical, anesthesia, and nursing departments should work together to define the criteria used to identify suitable candidates for ambulatory surgery. Red flags should identify any patient with potential problems that indicate inability to tolerate the surgical procedure as an outpatient.

Preoperative assessment can determine which patients are the best candidates for ambulatory surgery. Careful review of health history, social history, and potential limitations postoperatively is vital in the initial assessment. Special attention to mobility both preoperatively and postoperatively is key for the orthopedic ambulatory surgery patient. Patients who will experience significant limited mobility postoperatively, live alone with no help available postoperatively, and have multiple medical co-morbidities are not ideal candidates for orthopedic ambulatory surgery. Patient education is initiated during the preoperative assessment. Gait-training, pain management, postoperative instructions, and transportation should be addressed preoperatively. Arrangements for any special equipment necessary for postoperative recovery should be made preoperatively. Attention to postoperative details before surgery will prevent delays with patient discharge postoperatively.

The anesthesia evaluation is done during preadmission testing. At that time, the anesthesia provider will develop a plan of care best suited for the patient and the anticipated surgery. Patient co-morbidities, length of procedure, and positioning during the procedure as well as the surgery itself are taken into consideration when establishing a plan of care.

KNEE ARTHROSCOPY

Knee arthroscopy is a common orthopedic ambulatory surgery procedure. New technology and approaches in surgery allow additional procedures to be done through the arthroscope. Once the patient has been identified as a candidate for ambulatory surgery, preoperative planning for preadmission testing, anesthesia evaluation, and patient education begin. The popular choice of anesthesia is one of two types based on patient history. Choices include regional or general anesthesia. Most providers prefer regional anesthesia for knee arthroscopy because of the decreased complication rates postoperatively. On the day of surgery, the history and physical are again reviewed with the patient. The surgical site is marked according to standards established by The Joint Commission and hospital policy. The patient is taken to the OR, anesthetized, prepared, and positioned for surgery. With regional anesthesia, those patients who would like to remain alert during the procedure can do so, watch the surgery on the monitor, and even converse with the surgeon about the findings. Once the surgery is over, a local anesthetic is injected into the joint to minimize pain. The length of the postoperative period depends on the regional anesthetic and the dose used. Patients will regain sensation and motion from trunk down to toes. Strength should be taken into consideration when gait-training is initiated. Patients may be discharged once discharge criteria are met, physician orders are reviewed with the patient, written discharge instructions and prescriptions are given to the patient, and the responsible adult escort is present. Phone numbers for any emergency should be listed on both physician and hospital discharge sheets.

this equipment are ethylene oxide, cold sterilization, and high-level disinfection. Each requires consideration of patient care options for consistency. Equipment must be soaked according to the manufacturer's instructions, followed by complete rinsing and immersion in sterile water to prevent chemical burns. Cold-water sterilizing machines, which use bactericidal and sporicidal agents, can also be used to sterilize heat-sensitive equipment.

Scopes, lenses, and fiberoptic cords should be handled carefully, and cords should never be kinked or twisted. Gradual deterioration and fiber breakage occur in mishandled cables, and light cannot be transmitted. When stored, the cords should be loosely coiled or hung.

Two types of arthroscopy may be performed. *Diagnostic arthroscopy* is for patients whose diagnosis cannot be determined by history or physical examination or whose CT or MRI findings are insufficient to warrant surgical exploration. Diagnostic arthroscopy may be performed before an anticipated arthrotomy, and surgical treatment may be modified on the basis of the findings of the arthroscopic examination. *Operative arthroscopy* is for patients presenting with an intraarticular abnormality or ligamentous injury.

Arthroscopy of the Knee

The knee is the joint in which arthroscopy lends itself to the greatest number of diagnostic and surgical procedures (Patient Safety). Arthroscopic surgery of the knee is indicated for diagnostic viewing, synovial biopsies, removal of loose bodies, resection of plicae, shaving of the patella, synovectomy, partial meniscectomy, meniscus repair, and ACL reconstruction. Anesthesia for knee arthroscopy may be general, spinal, or local. Tourniquets are often placed on the thigh but are inflated only if bleeding obscures the view. If there are no contraindications, an epinephrine solution may be injected at the portal sites or diluted into the distention fluid.

Procedural Considerations. The perioperative nurse assists with positioning the patient in the supine position on a standard OR bed. The surgeon may perform EUA before the patient is placed in position for the arthroscopy. The foot end of the bed may be flexed 90 degrees (Figure 19-85). A lateral post can be attached to the bed at the level of the midthigh. This post can provide a method of countertraction to open the medial side of the joint, providing better visualization of structures. After the leg is prepped, the entire extremity is draped to allow complete range of motion and manipulation of the knee joint. The procedure requires specialized equipment for fluid collection and personnel protection.

Instruments and equipment needed for an arthroscopy depend on whether the procedure is diagnostic or operative. Diagnostic arthroscopy instruments include arthroscopy instrumentation (Figure 19-86); arthroscopes of 30 and 70 degrees; video with camera, light source, and peripheral equipment (Figure 19-87);

PATIENT SAFETY

Patient Safety in Office-Based Surgery

Recent trends to decrease healthcare costs have led to an evolution in surgery. Approximately 70% of patients are now undergoing surgery in outpatient settings, with up to 25% of those procedures performed in physician offices. Two thirds of all operations performed in 2006 were done as outpatient procedures. As we see a greater shift to office-based surgery (OBS), patient safety can be improved by clearly addressing particular issues within the physician office setting, including patient selection and informed consent, surgeon training, facility accreditation and maintenance, anesthesia guidelines, prevention of medication errors, CPR training and emergency transfer protocols, and reporting and disclosing of adverse outcomes. Nurses play an important part in OBS. Even though procedures are done in the office, the same standards of care apply. Equipment and instrumentation preparation, intraoperative patient monitoring, sterile technique, and specially trained personnel are vital. The use of preoperative and postoperative checklists by the surgeon guarantees patient safety during the perioperative period.

Modified from American Association of Orthopaedic Surgeons: *Patient safety in office-based surgery,* available at www3.aaos.org/member/safety/officeascreport.cfm. Accessed April 25, 2009.

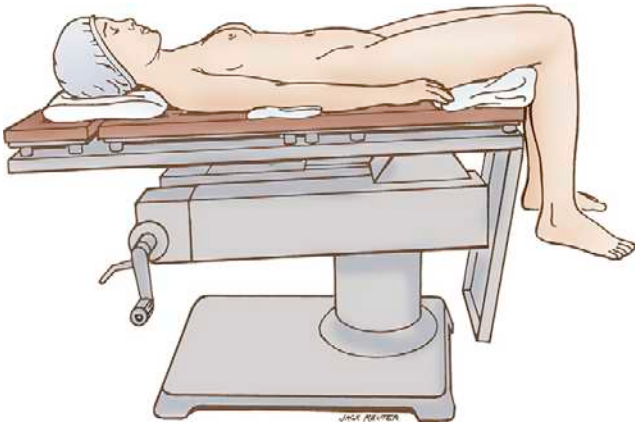


FIGURE 19-85 Positioning for a knee arthroscopy to enhance visualization.

an arthroscopy pump and tubing (Figure 19-88); inflow and egress cannulae (Figure 19-89); 3-L bags of normal saline or lactated Ringer's solution; and a spinal needle. Operative arthroscopy instruments depend on the procedure planned. Arthroscopic powered shavers and abraders (Figure 19-90) are almost universally used. Instruments specific for ACL reconstruction or meniscal repair will be needed if those procedures are planned.

Operative Procedure

DIAGNOSTIC ARTHROSCOPY

1. The surgeon marks the anteromedial and anterolateral joint lines and portal positions with a skin marker.
2. The skin areas for portal placement are infiltrated with 1% lidocaine with 1:200,000 epinephrine. If the knee has an effusion, the surgeon aspirates it with a 16-gauge needle on a 60-ml syringe, followed by injection of a small amount of distending fluid.
3. After a small stab incision with a #11 knife blade, the surgeon inserts the irrigation cannula and trocar into the lateral suprapatellar pouch near the superior pole of the patella. Lactated Ringer's or normal saline solution is connected to the cannula, and the joint is distended using gravity or a pressure-sensitive arthroscopy pump.
4. A stab incision is then made anterolaterally or anteromedially 2 to 3 mm above the tibial plateau or patellar tendon at the joint line. A sharp trocar and sheath are inserted through the stab wound and just through the capsule.
5. A blunt trocar is used to pass the sheath into the knee joint. The surgeon removes the trocar and inserts a 30-degree scope into the sheath. The light source and video camera are connected to the scope.
6. The inflow may remain in the suprapatellar area, and the egress tubing is connected to the arthroscope, or the position may be reversed.
7. A spinal needle can be introduced under direct vision to determine the best angle for an opposite portal for insertion of probes and operative instruments. The cruciates and menisci are probed to determine integrity and tears.
8. The scope is moved to the opposite portal to allow a complete examination to be performed.
9. The joint is irrigated periodically and at the end of the procedure to maintain good visualization and clear the joint of blood and tissue fragments.
10. The surgeon closes the portals with nylon or undyed polyglactin suture and ½-inch wound closure strips.
11. Bupivacaine (Marcaine) 0.25%, 30 ml, with epinephrine 1:200,000 may be injected intraarticularly to minimize bleeding and postoperative pain.
12. Gauze dressing, soft padding, and 4-inch and 6-inch elastic bandages are applied.

OPERATIVE ARTHROSCOPY. Operative arthroscopy includes procedures for resection of synovial plica, patellar debridement, excision of meniscal tears, partial or total meniscectomy, lateral retinacular release, removal of loose bodies, abrasion or drilling of osteochondral defects, synovectomy, treatment of osteochondritis dissecans, meniscal repairs, and ACL reconstruction.

Arthroscopic Resection and Repair of Meniscal Tear. Menisci are important structures in the knee joint that distribute load across the joint and provide capsular stability. A tear in the meniscus is the most common knee injury requiring arthroscopic surgery (Figure 19-91). Although both menisci can sustain tears, the medial meniscus is injured much more frequently than the lateral one.

Treatment of meniscus tears is aimed at preserving the structures. Some minor tears heal with cast immobilization, but some persist and cause symptoms. In these more severe cases, surgical intervention is necessary. A partial or complete meniscectomy may be necessary to alleviate troublesome symptoms such as locking, pain, and swelling (Figure 19-92). Partial meniscectomy is preferred, leaving a peripheral rim to share load bearing and stabilize the knee. Complete meniscectomy removes all of this load-bearing protection and also reduces knee stability. The goal is to leave an intact, balanced rim.

Arthroscopic meniscal repair is widely accepted as the standard of care. Arthroscopy provides better exposure than an arthrotomy does and enables the surgeon to approach the meniscus from the inner margin, where most tears begin.

FIGURE 19-86 Arthroscopy instrumentation.

FIGURE 19-87 Arthroscopy tower with video monitor, light source, camera, and shaver system.

FIGURE 19-88 Arthroscopy pump.

Suture repair is appropriate for meniscal tears occurring in the vascular zone (outer 10% to 25%), which heal predictably with repair and immobilization.

Operative Procedure

1. Steps 1 to 9 of the diagnostic arthroscopy procedure are repeated.
2. Working and scope portals are determined. The lateral bucket handle tear is identified, displaced, and reduced with a probe.
3. The attachment of the anterior horn of the meniscus is cut with a hook knife and clamped with a grasper.
4. An accessory portal is determined with a spinal needle.
5. The surgeon maintains traction and twisting motions on the meniscal horn to present a better edge to divide the remainder of the tear. Various scissors or push knives can be used to complete resection.
6. The motorized shaver is used to trim any frayed edges of the meniscus.

7. Limited debridement of chronic tears is completed to clean the edges.
8. When the medial meniscus is to be sutured, the surgeon places a cannula next to the inner edge of the tear. Two long meniscal-stitching needles with synthetic absorbable suture are inserted into the cannula, through the meniscus, across the tear, and through the capsule.
9. The surgeon palpates the needle tips beneath the skin, and makes a small incision to pull the suture out of the joint.
10. The sutures are tied over the capsule. Positioning the cannula enables either horizontal or vertical sutures to be placed.
11. After completing partial meniscectomy or suture repair, the surgeon irrigates the joint.
12. The incisions are closed, and the knee is lightly dressed and wrapped with soft rolled padding and elastic bandages.

FIGURE 19-89 Cannulae.

A

B

FIGURE 19-90 Arthroscopic shaver, **A**, with console, **B**.

Arthroscopic Anterior Cruciate Ligament Repair. The ACL is an important stabilizing structure of the knee and is the most frequently torn ligament. Injury is usually a result of simultaneous anterior and rotational stresses. Candidates for ACL reconstruction are active individuals with instability that is sufficient to interfere with their activities and that has failed to respond to bracing, rehabilitation, exercises, and other nonoperative treatment methods. The selected treatment method depends on the classification and severity of the tear, the experience and preference of the surgeon, and a history of a previous failed repair.

ACL reconstruction may be intraarticular, extraarticular, or a combination of both. Arthroscopic repair causes less patellar pain and decreased disturbance of extensor mechanisms and therefore is becoming the treatment of choice if there is no other significant capsular instability or gross disruption of the knee joint.

ACL repair most often involves replacement of the ligament with a substitute. Substitutes include autografts, allografts, and synthetic ligaments. Autografts are currently the method of choice, with a free central-third patellar tendon graft attached to patellar and tibial bone blocks used most often. The semitendinosus tendon and iliotibial band are sometimes used instead. Autografts may be used alone or augmented, although

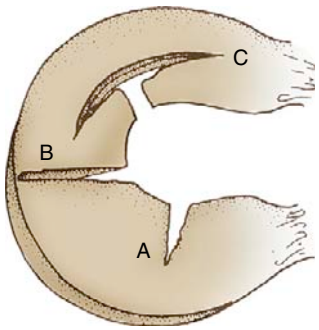


FIGURE 19-91 Meniscal tear. *A*, Incomplete. *B*, Complete. *C*, Incomplete longitudinal.

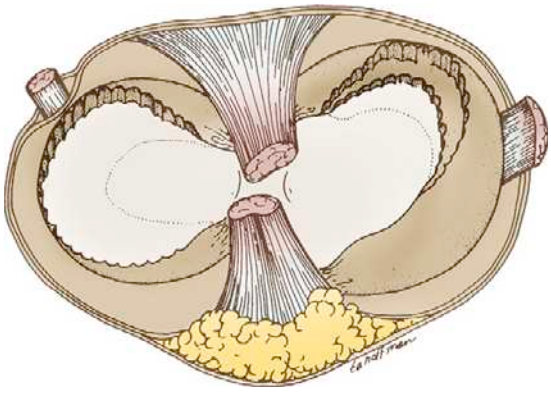


FIGURE 19-92 Lateral and medial meniscal excision.

synthetic augmentation devices have fallen out of favor because of the development of chronic synovitis.

Procedural Considerations. Instrumentation for an ACL repair includes all instruments required for an operative arthroscopy. In addition, an ACL reconstruction guide system, fixation device of choice (bone screws, staples, spiked washers, or interference screws), bone tunnel plugs (Figure 19-93), a power drill, and microsagittal saw will be needed. If the surgeon believes that isometric placement of the graft is important, a tension isometer will be needed, as well as a system for finding that intraarticular position.

Operative Procedure: Reconstruction of the Anterior Cruciate Ligament with Patellar Tendon Graft

1. The surgeon performs an EUA immediately after anesthesia induction to further evaluate the stability of the knee.
2. A diagnostic arthroscopy is then carried out through the standard anteromedial and anterolateral portals.

FIGURE 19-93 Example of a bone tunnel plug.

3. Any meniscal tears or other intraarticular injuries are treated before attending to the ligament.
4. The surgeon debrides any remaining ACL tissue with a full-radius resector.
5. A notchplasty is then performed, widening the intercondylar notch with a 4.5-mm arthroplasty burr, rasp, osteotome, and curettes. Notchplasty aids in arthroscopic visualization and protects the graft from abrasion and amputation.
6. After preparation of the intercondylar area, the surgeon makes a small incision on the distal lateral aspect of the femur and extends the incision to the flare of the lateral femoral aspect of the condyle. A femoral aiming device is positioned, and a guide pin is inserted from the femoral site into the posterosuperior region of the intercondylar notch at an isometric point (Figure 19-94). Another small incision is made anteriorly, below the knee and medial to the tibial tubercle.
7. The tibial aiming device is positioned, and the surgeon inserts a guide pin from the anterior tibial incision into the intercondylar notch, anterior and medial to the center of the tibial anatomic attachment site of the ACL.
8. The pins are then replaced with a heavy suture passing through the femoral and tibial pin sites.
9. Isometric placement of the guide pins is checked with a tensioning device that is attached to the heavy suture. The

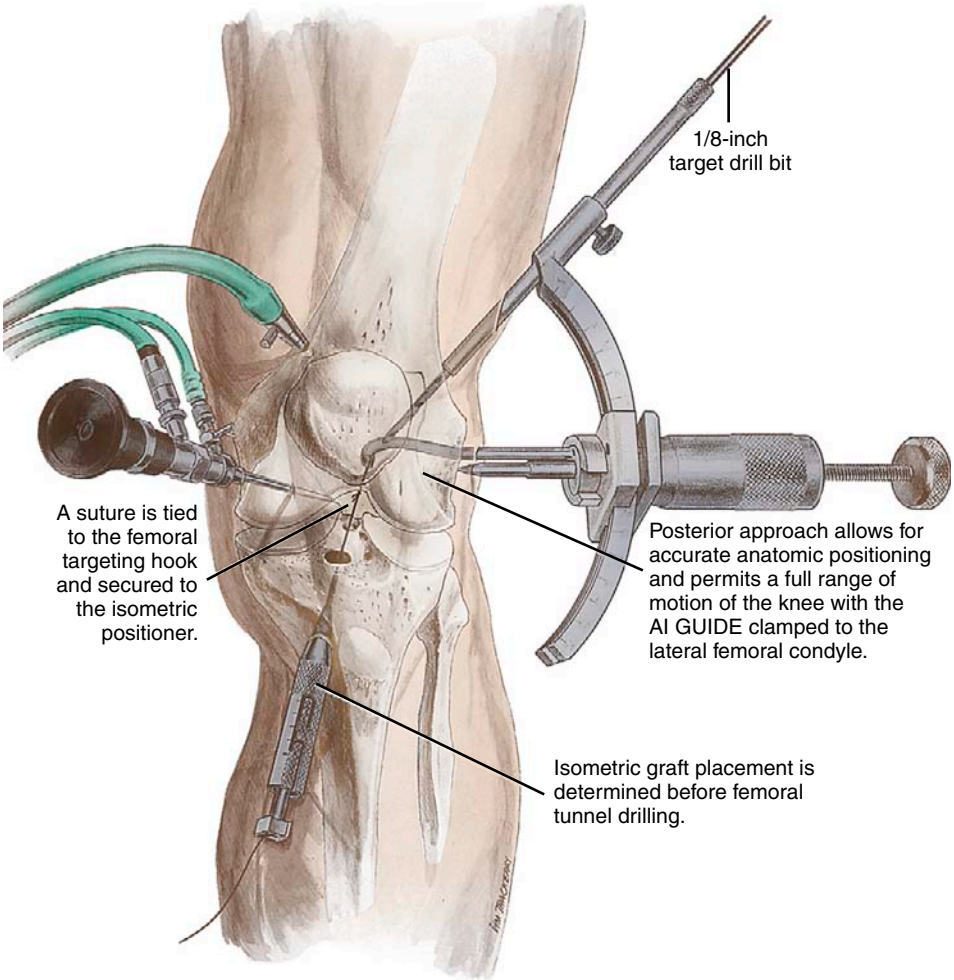


FIGURE 19-94 Femoral aiming device positioned for anterior cruciate ligament reconstruction.

knee is moved through a range of motion to determine correct isometric measurement.

10. Once isometric positioning is determined, the surgeon makes a longitudinal skin incision to the midline near the patellar tendon.
11. The central-third portion of the patellar tendon with tibial and patellar bone plugs is harvested with a mini-saw and osteotome. The graft is sized to the appropriate width, usually 10 to 12 mm, using sizing tubes (Figure 19-95).
12. Heavy nonabsorbable suture is placed through drill holes made at each end of the graft in the bone plugs (Figure 19-96).
13. The guide pins are then reinserted and overdrilled with cannulae that are close in width to the prepared graft. Overdrilling establishes the tunnels so that they are in the center of the previous insertion sites of the ACL.

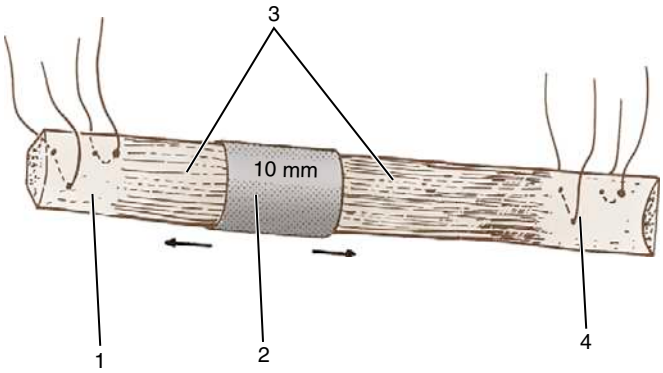


FIGURE 19-95 Sizing tubes are used to determine the minimum diameter of tunnel necessary for passage of the graft.

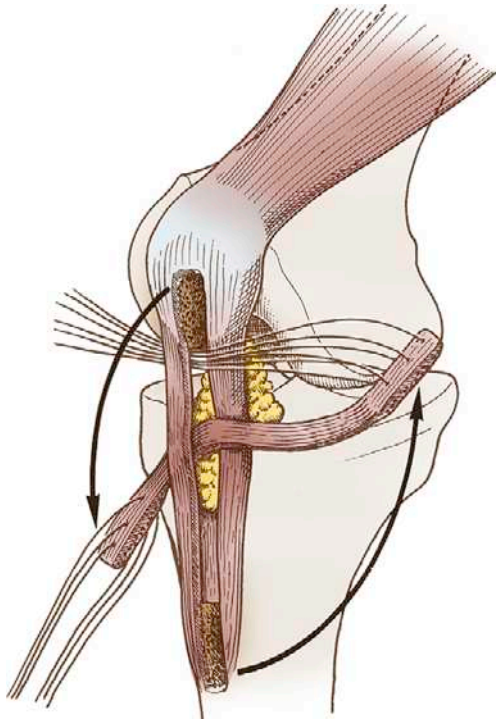


FIGURE 19-96 Three drill holes are placed into each bone block of the patellar graft, and a heavy suture is placed into each drill hole.

14. The surgeon smoothes the femoral and tibial osseous tunnels with curettes, a rasp, or an abrader. If the tunnels are made before the graft is harvested, they are temporarily occluded with bone tunnel plugs to minimize fluid extravasation.
15. Both ends of the graft are fixed with a barbed staple, bone screw with washer, interference screw, or ligament button (Figure 19-97).
16. The incisions and joint are irrigated and closed.
17. A hinged knee brace may be applied over the dressing. The brace allows 10 to 90 degrees of motion.

Arthroscopic Posterior Cruciate Ligament Repair. Surgical procedures for tears of the PCL are considered if significant disabling instability has occurred. Patients usually return to adequate function without operative treatment. The arthroscopic procedure for repair of the PCL is similar to the technique used to repair the ACL, except that isometric placement is posterior within the joint and the femoral attachment is proximal to the medial epicondyle.

Arthroscopy of the Shoulder

Shoulder arthroscopy is a useful diagnostic and therapeutic tool in the management of shoulder disorders. It is particularly beneficial in the evaluation and management of patients with chronic shoulder problems. Arthroscopy provides extensive visualization of the intraarticular aspect of the shoulder joint and is performed for removal of loose bodies; lysis of adhesions; synovial biopsy; synovectomy; bursectomy; stabilization of dislocations; correction of glenoid labrum, biceps tendon, and rotator cuff tears; and relief of impingement syndrome.

Procedural Considerations. The patient is either in the lateral position or in a sitting position using a "beach chair" positioner. The lateral position is maintained using a vacuum beanbag positioning device or lateral rolls with a kidney rest.

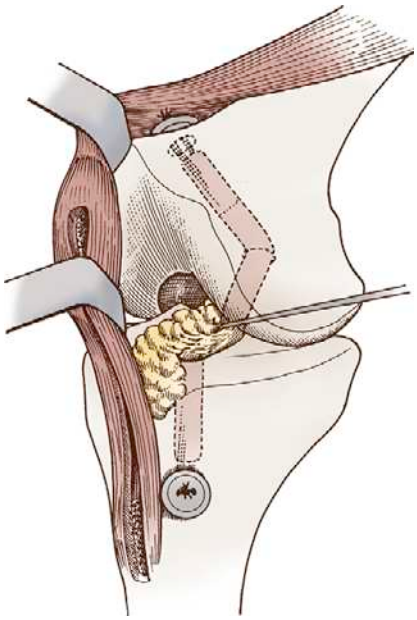


FIGURE 19-97 A patellar tendon graft is affixed by tying of sutures over bone buttons at the tibial and femoral drill holes.

Three-inch adhesive tape is secured across the patient's hips. Proper padding of the uninvolved axilla and lower extremity is important to prevent soft tissue or neurovascular problems. The affected extremity is placed in a shoulder suspension system, and Buck's traction or a Velcro immobilizer is applied to the forearm to achieve adequate distraction to the glenohumeral joint. The extremity is abducted 40 to 60 degrees and forward-flexed 10 to 20 degrees, with 5- to 15-pound weights placed on the pulley system. Weight may be added to further distract the glenohumeral joint, taking care not to overstretch the axillary artery.

The shoulder is prepped and draped free, permitting full range of motion during the procedure.

The operative instruments and arthroscope commonly used for the knee may also be used in the shoulder, plus an 18-gauge needle, switching sticks, and a Wissinger rod. A variety of fixation devices (screws and tacks) can be used to repair bony defects and tears of the labrum.

Operative Procedure (Figure 19-98)

1. An 18-gauge spinal needle is inserted through the posterior soft spot and directed anteriorly toward the coracoid process, where the surgeon's index finger has been positioned.
2. The glenohumeral joint is distended with normal saline or lactated Ringer's solution. This facilitates entry of the arthroscope.
3. Bupivacaine (Marcaine) 0.25%, 2 to 3 ml, with epinephrine 1:200,000 is injected along the needle track to minimize bleeding.
4. With the needle removed, the surgeon makes a stab incision with a #11 blade over the needle site.
5. The arthroscope sleeve and sharp trocar are then introduced through the posterior joint capsule.
6. Once the capsule has been penetrated, a blunt obturator replaces the sharp trocar to enter the joint.
7. The arthroscope is inserted and attached to inflow and outflow tubing, the video camera, and the light source.

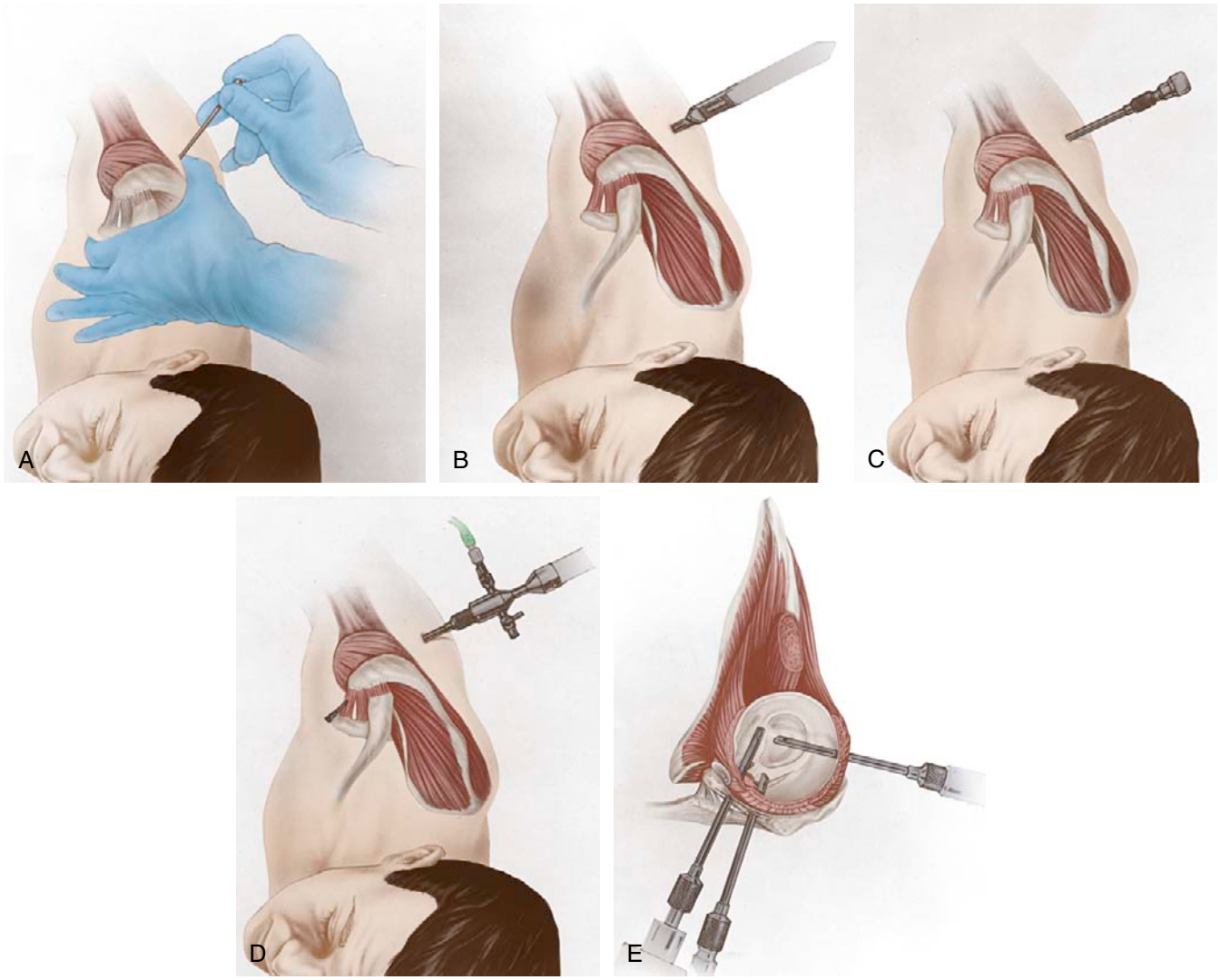


FIGURE 19-98 Shoulder arthroscopy. **A**, The spinal needle is inserted for dilation of the joint if indicated. **B**, An incision is made over the glenohumeral joint. **C**, The arthroscope sleeve and sharp trocar are inserted. **D**, The arthroscope is inserted and attached to the inflow and outflow tubing, video camera, and light source. **E**, Operative instruments are placed through the portal.

8. Operative instruments are placed through an anterior portal that is established laterally to the coracoid process by using a Wissinger rod. A third portal can be established near the anterior portal or supraspinous fossa portal. Switching sticks are used to change portals.
9. The surgeon moves the arm and rotates it as needed to visualize various structures in and around the joint.
10. Glenoid tears can be repaired with the insertion of an absorbable fixation tack.
11. At the conclusion of the procedure, the joint is irrigated. The surgeon may inject a long-acting local anesthetic into the joint and subacromial space through the portal to minimize postoperative discomfort.
12. The puncture wounds are closed and dressed with a sterile 4 × 4 gauze pad. The patient's arm is placed in a sling for recovery.

Arthroscopy of the Elbow

The elbow joint is accessible to arthroscopic examination, although it requires more attention to detail than the knee because instruments must be placed through deeper muscle layers and close to important neurovascular structures.

Arthroscopy of the elbow, both diagnostic and operative, has become fairly routine. Indications for its use include extraction of loose bodies, evaluation or debridement of osteochondritis dissecans of the capitulum and radial head, partial synovectomy in rheumatoid disease, debridement and lysis of adhesions of posttraumatic or degenerative processes at or near the elbow, diagnosis of a chronically painful elbow when the diagnosis is obscure, and evaluation of fractures of the capitulum, radial head, or olecranon.

Procedural Considerations. General anesthesia is preferred to local anesthesia because it affords complete comfort to the patient and provides total muscle relaxation.

The perioperative nurse assists with placing the patient in either the supine or the prone position. In the supine position, the forearm is flexed on an armboard or placed in a prefabricated wrist gauntlet connected to an overhead pulley device and tied off at the end of the OR bed. This provides excellent access to both the medial and lateral aspects of the elbow, allows the forearm to be freely pronated and supinated, and places the important neurovascular structures in the antecubital fossa at maximum relaxation.

A tourniquet is routinely used for hemostasis. The entire arm, including the hand, is prepped and draped.

The three portals most commonly used for diagnostic and operative arthroscopy of the elbow are the anterolateral, anteromedial, and posterolateral.

Operative arthroscopy instruments commonly used for the knee may also be used in the elbow. However, smaller-diameter scopes and instruments may be desired instead.

Operative Procedure

1. The surgeon outlines the bony anatomic landmarks with a sterile marking pen before initiation of the procedure. Lateral structures to be marked and identified are the radial head and the lateral epicondyle. The medial epicondyle is also marked.
2. An 18-gauge needle is inserted anteriorly to the radial head from the lateral side, and the joint is distended.
3. Once joint distention has been achieved with approximately 15 to 30 ml of lactated Ringer's or normal saline solution, the surgeon makes a stab wound incision with a #11 blade, and inserts the sharp trocar with cannula through the joint capsule.
4. The sharp trocar is replaced with the blunt obturator to provide safe entry of the cannula into the joint.
5. The scope replaces the blunt obturator and is attached to the video and light source.
6. A second portal and third portal are established anteromedially and posterolaterally for triangulation. With the patient's elbow flexed to 90 degrees and adequate distention maintained at the time of insertion of the instruments, the surgeon displaces the neurovascular structures anteriorly. This provides a greater area above the medial and lateral humeral epicondyles in which to insert the various instruments.
7. Outflow and inflow are controlled by alternating the valve on the scope or using a separate 18-gauge needle with drainage tubing.
8. After diagnostic and operative procedures have been completed, the joint is irrigated, the puncture sites are sutured, and a compression dressing is applied with soft rolled padding and elastic bandages.

Arthroscopy of the Ankle

The talocalcaneal articulations are complex and play an important role in the movements of inversion and eversion of the foot. The subtalar joints function as a single unit, but anatomically they are divided into anterior and posterior joints. The surgeon and perioperative nurse must be familiar with the extraarticular anatomy of the ankle to prevent neural or vascular damage.

Indications for ankle arthroscopy include osteochondral fragments or loose bodies, persistent ankle pain after trauma and despite adequate conservative treatment, biopsy, posttraumatic arthritis of the ankle joint, unstable ankle before lateral ligamentous reconstruction, and osteochondritis dissecans of the talus.

Procedural Considerations. General anesthesia is preferable because manipulation and distraction of the joint to obtain adequate arthroscopic viewing require muscle relaxation. The position of the patient is based on the surgeon's preference. The patient may be supine with the knee flexed approximately 70 degrees or supine with a sandbag under the buttock of the operative side. Ankle and thigh holders may be used; when better posterior visualization is necessary, a distractor may be used to increase the space between the tibia and talus. A tourniquet is placed around the upper thigh but is not used unless excessive bleeding, uncontrolled by irrigation, is encountered. Routine skin prepping and draping are done. Miniaturized instruments and needle scopes for the ankle are used.

Operative Procedure

1. Using a sterile marking pen, the surgeon outlines important extraarticular anatomic structures on the skin.
2. The ankle joint is then examined, using the anterolateral portal. The anteromedial joint line is palpated, and an 18-gauge, 1½-inch needle is inserted into the joint.
3. Sterile plastic extension tubing is attached to the needle, and a 50-ml plastic Luer-Lok syringe filled with normal saline is

connected to the tubing to distend the joint. Approximately 15 to 20 ml is needed.
4. After intraarticular injection is confirmed by the ease with which the saline can be injected and by palpation of the joint as it is distended, the surgeon makes a small incision with a #11 blade over the site of the anterolateral portal.
5. A hemostat is then inserted and used to dissect to the capsule.
6. The sheath of the arthroscope and sharp trocar are placed into the incision, angled approximately 30 to 45 degrees laterally, and inserted with a sharp plunge as joint distention is maintained. Entrance into the joint is felt as the sleeve and trocar "pop" through the capsule and is confirmed by the rush of saline on removal of the trocar from the sheath.
7. The arthroscope is inserted into the sheath, the needle is removed, and the plastic tubing and syringe are attached to the stopcock on the arthroscope sleeve. The video camera and light source are connected to the scope. Joint distention must be maintained.
8. Triangulation through other portals is easily done by first inserting the 18-gauge needle for localization while viewing with the arthroscope. Posterior viewing is done in the same fashion except that the patient is usually placed in the prone position and instruments are inserted through the posterior portals.
9. After the procedure is completed, the surgeon irrigates the joint, closes the wounds with wound closure strips or a single suture, and covers the wound with a dressing and short leg compression elastic wrap.

SURGERY OF THE SPINE

Treatment of Back Pain

Back pain is a natural result of degenerative and arthritic change, punctuated by protrusion or rupture of a disc. It gradually progresses but may also disappear gradually. With aging, a degenerative disc-space narrowing or facet arthropathy begins to appear radiologically. The lower lumbar spine carries the burden of the body's weight, holds a person upright, and returns the body to the vertical position from sitting, lying, or a bent-over position. Degenerative changes, ruptured disc, and facet arthropathy develop at the lowest two limb segments, where the greatest weight, torsion, and shearing stress occur. This degeneration sometimes extends into the upper and middle spine.

Cervical-spine degenerative disc narrowing also develops most often at the two lowest cervical spaces, which are also the levels of greatest stress resulting from movement of the head and neck. Sometimes lumbar or cervical degenerative changes develop early from excessive repetitive movements or injury.

Epidural steroid injections, electrodes, stimulators, braces, or traction may treat back pain. A natural recovery may result after 6 or 7 days of intense pain, subsiding between 6 weeks and 4 months. Motor and sensory deficits usually disappear with resolution of pain. The ability to recover without surgery depends on fragment size and compression on the nerve root. Neural compression remains the major indication for disc excision.

Spinal fusion is a consideration, usually for patients with demonstrable posttraumatic, postsurgical, rheumatoid, infectious, or neoplastic instability.

Procedural Considerations. After assessment, the patient-specific plan of care is implemented. Radiographs are obtained. The perioperative nurse assesses the patient's bilateral pulses and range of motion in all of the extremities. Elastic wraps or sequential compression devices may be placed. The patient is positioned prone to eliminate lordosis, reduce venous congestion, and keep the abdomen free with chest rolls or special frames after induction of general anesthesia. Depending on the extent of the procedure, blood availability may be required. The skin is prepped and the area draped. A spinal laminectomy set is used, in addition to a spinal retractor of choice and a bipolar ESU. Hemostatic adjuncts such as gelatin foam, oxidized cellulose strips, thrombin, and bone wax should be available.

Operative Procedure

LAMINECTOMY

1. The surgeon makes a midline incision over the affected disc and carries it sharply down to the supraspinous ligament.
2. The supraspinous ligament is incised, and the muscles are dissected subperiosteally from the spines and laminae of the vertebrae. These are retracted with a self-retaining retractor.
3. The surgeon denudes the laminae and ligamentum flavum with a curette.
4. A small part of the inferior margin of the lamina is removed with a rongeur.
5. The ligamentum flavum is grasped and incised where it fuses with the interspinous ligament, and this flap is then sharply removed to expose the dura.
6. The dura is then retracted medially, and the nerve root is identified.
7. Once identified, the nerve root is retracted medially so that the underlying posterior longitudinal ligament can be exposed.
8. The surgeon incises the posterior longitudinal ligament over the intervertebral space in a cruciate fashion, and enters the disc space with a pituitary grasping forceps.
9. The disc material is systematically removed, taking care not to exceed the distance to the anterior annulus. A complete search for additional fragments of nucleus pulposus, both inside and outside the disk space, is then carried out.
10. Residual bleeding is controlled with bipolar coagulation.
11. The surgeon closes the wound with absorbable sutures in the supraspinous ligament and subcutaneous tissue. Various nonabsorbable sutures or staples are used for skin closure.

Minimally Invasive Spine Surgery

Advances in technology have made minimally invasive spinal surgery (MISS) available to certain patients. Candidates for minimally invasive spine surgery are carefully selected by the surgeon. Conditions that may be amenable to MISS include disc herniation, spinal stenosis, and kyphosis. The need to convert from MISS to the traditional incision must be discussed with the patient before the surgery and the perioperative nurse and surgical technologist must prepare for that possibility. The microdiscectomy procedure, used to treat disc herniation, is described below.

Procedural Considerations. The perioperative nurse and surgical technologist ensure that all equipment is available and assembled before the patient's arrival into the OR. Equipment needed includes the C-arm, microscope, and radiolucent spinal table. After the administration of a general anesthetic,

FIGURE 19-99 Instruments used for tubular microdiscectomy.

the patient is positioned prone on the radiolucent spinal table. Care is taken to ensure proper padding of bony prominences and proper positioning of extremities. The skin is prepped and draped. Instrumentation for MISS includes the tubular microdiscectomy set and the tubular retractor (Figure 19-99). A high-speed drill and hemostatic agents such as gelatin foam, thrombin, and bone wax should be available. The perioperative nurse places sequential compression devices on the patient.

Operative Procedure

1. The surgeon inserts an 18-gauge spinal needle in the back at the level of the disc herniation and confirms the correct level with the C-arm.
2. The surgeon makes a 1- to 1.5-cm incision at the previously identified level.
3. A Cobb elevator and sequentially sized dilators are used to serially dilate the soft tissues, preserving the integrity of the muscles and ligaments.
4. The surgeon inserts a tubular retractor and connects the flex arm directly to the spinal table.
5. The tubular retractor is used as a viewing portal to visualize and operate on the spine (Figure 19-100).
6. The surgeon confirms the level again with x-ray and moves the draped microscope into position.
7. Using the long electrode on the ESU, the surgeon dissects the tissue.
8. A high-powered burr and/or assorted sizes of Kerrison punches are used to remove part of the caudal lamina.
9. Once nerve roots are identified, the surgeon enters the disc space and removes the extruded disc material with pituitary grasping forceps.
10. Gelatin foam and cotton pledgets are used to control bleeding along with the bipolar ESU.
11. The surgeon irrigates and closes the wound.

Pedicle Fixation of the Spine

Pedicle screw fixation (Figure 19-101) is a method of surgical fixation of the spinal column. Screw fixation was initially used in an attempt to avoid postoperative external immobilization and prolonged bed rest. Pedicle screw fixation has been used most often in degenerative processes, particularly iatrogenic instability after decompression, degenerative and isthmic spondylolisthesis, and diskogenic disease. It is also indicated for tumor, trauma, degenerative spinal disorders, postoperative hypermobility, and infection.

Three basic approaches for fixation have been described as the procedure has evolved. Each has improved on the first, based on anatomic placement of the screw. Positioning and placement of the screw within the spine are established after direct visualization of the pedicle.

Procedural Considerations. After the administration of a general anesthetic, the patient is positioned prone. The skin is prepped, and drapes are applied. A spinal laminectomy set is used in addition to the instrumentation and implants of choice, a spinal retractor, power equipment such as a high-speed motorized hand tool, and hemostatic adjuncts such as gelatin foam, thrombin, and bone wax. A bone graft set will be needed to harvest graft from the iliac crest.

Operative Procedure

1. The surgeon makes a standard midline incision. The surgeon follows the steps as described in the laminectomy procedure to expose the spine.
2. The areas of the pedicles to be fixated are located using external landmarks.
3. The surgeon removes the posterior cortical wall at the entrance site using a high-speed burr.

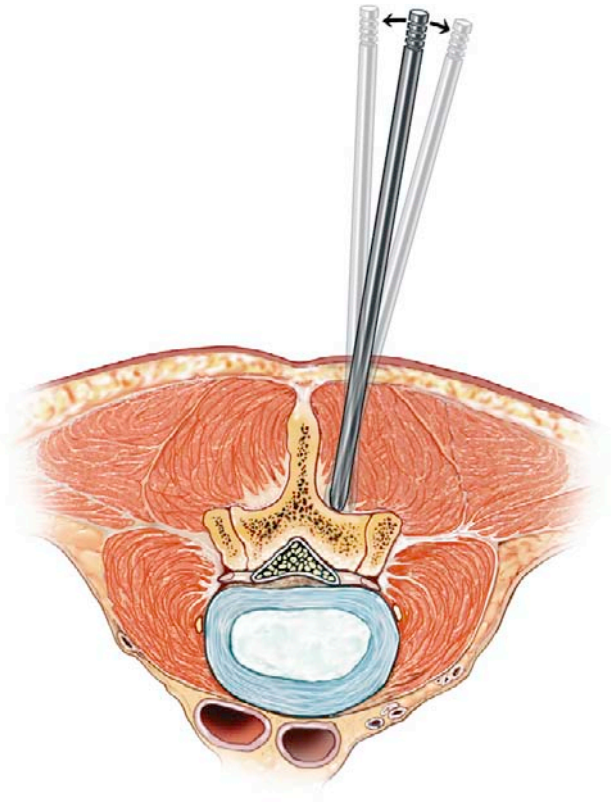


FIGURE 19-100 Wanding maneuver is used to change the position of the tubular retractor and reach different areas of the spine.

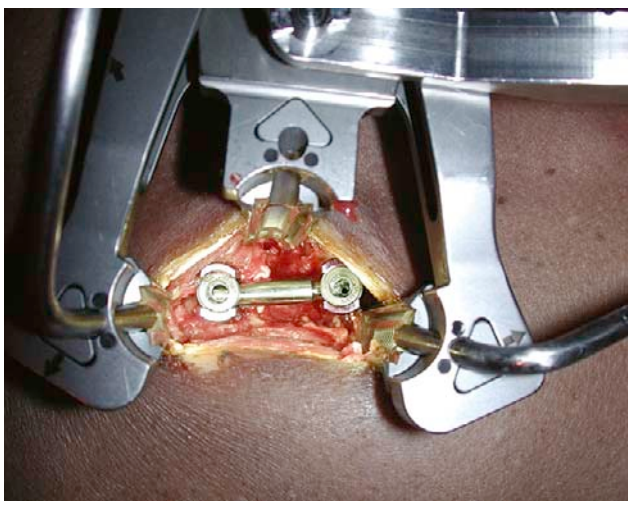


FIGURE 19-101 Pedicle screw placement using the MaXcess retractor and SpheRx fixation system by NuVasive, Inc.

4. A Penfield dissector is used to identify the entrance hole through the pedicle.
5. The surgeon inserts a gearshift probe to identify the path into the vertebral body.
6. The hole is tapped (5.5-mm tap) and widened.
7. The surgeon places the screw(s). Guidelines for screw sizes are 7 mm for S1, L5, and L4; 6.25 mm for L3 and L2; 5.5 mm for L1 and T12.

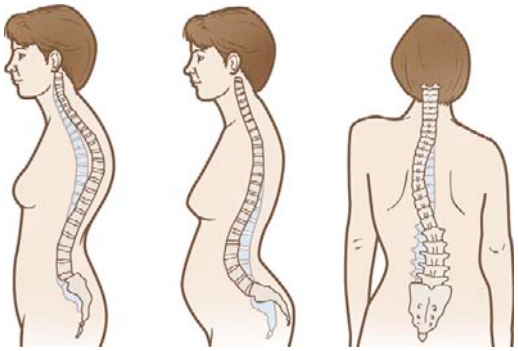


FIGURE 19-102 Scoliotic deformity.

8. A posterolateral graft is performed, using graft strips from the iliac crest.
9. The surgeon contours the plate or rod to approximate the patient's physiologic lordosis. The longitudinal device is locked onto the screws in the appropriate position.
10. A screw-plate system may require use of the oblique and transverse washers between the screw head and plate to provide a flush fit at the screw-plate interface.
11. The foramina are checked for patency before closure. The excess portion of the screw is cut close to the upper locking device.
12. A suction drain is placed; the wound is closed in layers.

Treatment of Scoliosis

Scoliosis is a three-dimensional deformity (Figure 19-102) with lateral deviation of the spinal column from the midline; it may include rotation or deformity of the vertebrae. Types are congenital, juvenile, adolescent, and adult. School screening programs provide quick and simple detection. For effective treatment of scoliosis, early detection is critical.

Scoliosis can be idiopathic (80% of the time) or congenital and may result from muscular or neurologic diseases or unequal leg lengths. Numerous posterior and anterior segmental spinal instrumentation systems are available for the treatment of idiopathic scoliosis. As a consequence, fixation strategies are more complex than they were with Harrington instrumentation. The newer systems provide better sagittal control and more stable fixation, allowing quicker mobilization of the patient. On thin patients, however, the bulk of these implants may be a problem.

Posterior Spinal Fusion with Harrington Rods. Posterior spinal fusion is most frequently performed in adolescence, when the laterally deviated curve is still flexible. Harrington rods are internal splints that help maintain the spine as straight as possible until the vertebral body fusion has become solid. Distraction rods are placed on the concave side of the curve, and compression rods are placed on the convex side. On the convex side of the curve, three to eight hooks are inserted in the transverse processes of the vertebrae and pulled together with a threaded rod. In this way the scoliotic deformity can be corrected as much as the flexibility of the spine allows.

The posterior elements of the vertebrae are denuded of soft tissue, and the bone graft is added. Blood loss can be expected, and an accurate record of the loss must be

maintained. After surgery the patient is placed in an immobilizing jacket.

Some disadvantages of the Harrington rod system over other systems are that there is only end-point fixation, rod breakage is increased, fixation is less, sagittal plane curves are difficult to manage, distraction for correction is not always desired, and the patient is required to wear a postoperative cast or brace. Other systems have evolved from the Harrington rods that are used for correction of some scoliotic deformities. It remains a feasible treatment of idiopathic scoliosis.

PROCEDURAL CONSIDERATIONS. The patient is placed in the prone position on a spinal table, or a spinal frame to facilitate respiration. Before the procedure begins, an x-ray cassette is placed under the patient so that a radiograph for accurate identification of the vertebrae to be fused can be taken during the operation. A single straight longitudinal incision is made down the midline of the back. Because of the amount of bleeding, the skin and subcutaneous tissues are often infiltrated with a vasoconstricting solution, such as epinephrine.

Basic spinal instrumentation and bone graft instruments are required, plus the Harrington rod instrumentation. A large pin cutter, designed to cut large pins but provided with a small end so that it will fit in the wound, should be available.

OPERATIVE PROCEDURE

1. The appropriate hooks are selected and inserted. A Harrington distraction rod of appropriate length is inserted through the two proximal self-adjusting hooks, which have been placed under the laminae.
2. A rod clamp is clamped onto the Harrington rod just below the hook, and a single regular spreader is used to obtain the first inch of distraction.
3. The Bobechko spreader is used to span over the first hook, closest to the smooth part of the rod, to apply distraction force on the most proximal hook.
4. Two C locking rings are inserted around the first ratchet immediately below the hook to prevent dislodgment of the hooks. The excessive length of protruding rod above the most proximal hook is removed with a rod cutter. The compression is tightened.

Luque Segmental Spinal Rod Procedure. The Luque segmental method employs smooth, L-shaped, stainless-steel rods, usually 3/16 or 1/4 inch in diameter, with sublaminar wires placed at every level possible. It is more secure and longer than the Harrington rod system and was the first system to employ multiple-point fixation. Luque instrumentation applies corrective forces to the spinal segments at each level, thereby spreading the corrective forces throughout the length of the deformity. Two Luque rods are wired to both sides of the spine. The rods are contoured to achieve no more than 10 degrees of increased correction beyond that exhibited on preoperative x-ray study.

PROCEDURAL CONSIDERATIONS. The patient is placed in the prone position as described for the Harrington rod procedure. Patient care is provided (see Laminectomy, p. 809). A straight midline incision is made in the back. Because of the amount of bleeding, the skin and subcutaneous tissues are often infiltrated with a vasoconstricting solution, such as epinephrine. Basic spinal instrumentation is required. In addition, Luque rods and instrumentation, a wire tightener and cutter, and bone graft instruments will be needed.

OPERATIVE PROCEDURE

1. The ligamentum flavum is detached, exposing the neural canal.
2. The surgeon passes doubled stainless-steel suture wire under the lamina. The wire loop is cut later to form two wires at each level.
3. Total bilateral facetectomies are made, forming posterolateral troughs for subsequent bone grafts.
4. Wedge osteotomies may be necessary in severe immobile curves to avoid stretching the spinal cord during correction.
5. The wire loop is cut, resulting in two separate wires at each level.
6. The L bend is secured to the base of the spinous process to prevent rod migration.
7. Initial placement of the convex rod is made.
8. Initial placement of the concave rod is made.
9. Transverse wiring is done to add increased stability to the system.
10. Stabilization of the lumbosacral joint is corrected by bending the rods distally to form sacral bars.

Cotrel-Dubousset System Procedure. The Cotrel-Dubousset system (Figure 19-103) provides three-dimensional correction of spinal deformities without sublaminar wiring and neurologic risks. This instrumentation permits distraction, compression, and derotation. The scoliotic curve is corrected by derotation and, at the same time, restores the normal sagittal contours. In addition to correction of scoliosis, the Cotrel-Dubousset system can be applied to correct kyphosis or lordosis and to stabilize and rebuild the spine after tumor resection or after injury. No external support is necessary. The Cotrel-Dubousset system has no ratchets or notches. It consists of metallic rods with diamond crosscut patterns on which hooks and screws can be positioned in any position, level, or degree of rotation. The rod is held in the open hooks with blockers. The rods are then interlocked by means of devices for transverse traction. The Cotrel-Dubousset system was the forerunner to the systems used today, such as the Texas Scottish Rite Hospital (TSRH) system and the Isola system.

PROCEDURAL CONSIDERATIONS. The patient is placed in the prone position after induction of general anesthesia. Patient assessment and precautions for the prone position are initiated. Basic spinal instrumentation is required in addition to the Cotrel-Dubousset system and instrumentation as well as the instruments used for harvesting the bone graft.

OPERATIVE PROCEDURE

1. Closed hooks are inserted at both ends of the surgical site, and open hooks are inserted at various levels between the closed hooks.
2. Decortication and facet excision are done at the remaining interposed vertebral levels for rod placement.
3. Bone graft is placed in the areas that will be under the rod.
4. The surgeon bends the appropriate concave rod to shape for sagittal-plane correction and manipulates it into the end hooks.
5. Stabilization along the length is achieved with blockers that anchor the rod into the open hooks.
6. The spine is then derotated using the rod holders. The frontal-plane scoliosis curve becomes the sagittal-plane kyphosis.
7. Hooks are reseated for secure fixation.

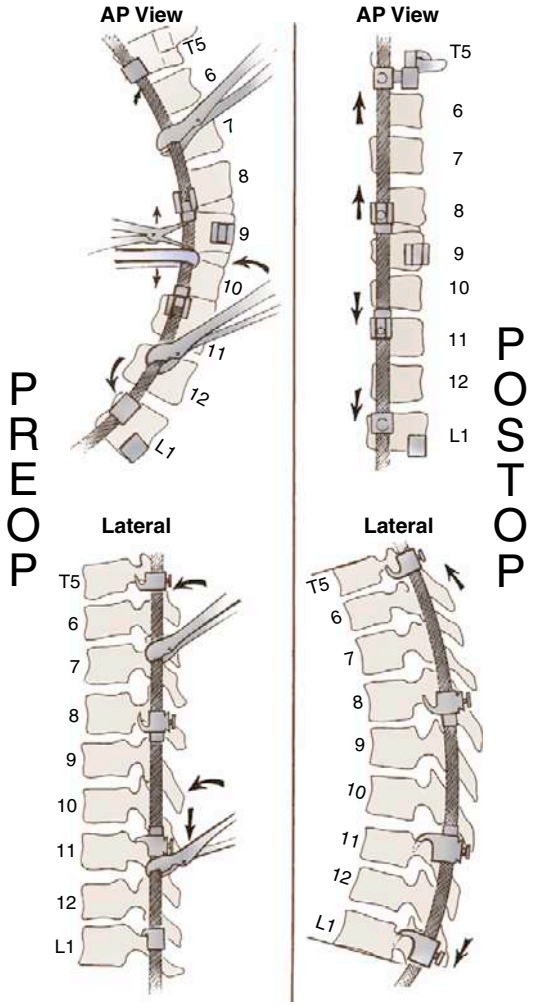


FIGURE 19-103 Cotrel-Dubousset system, representing rotation of rods.

8. To correct kyphosis, the surgeon bends the convex rod to shape and seats it.
9. Once the rods are placed, the surgeon applies the device for transverse traction (DTT), usually near the ends of the rods, to complete the stabilization.
10. Remaining bone graft is then applied to the fusion area.

Texas Scottish Rite Hospital (TSRH) Crosslink System. The TSRH crosslink system (Figure 19-104) is a multicomponent stainless-steel implant used to lock spinal rods together rigidly. Locking the rods increases construction stiffness and prevents rod migration. The system was originally designed for the Luque segmental system to prevent migration between the rods and wires before complete fusion occurred. By rigidly crosslinking the rods, loss of scoliotic correction was reduced. This system can also be used with the Harrington and Cotrel-Dubousset systems. Crosslinks are indicated when the rigidity of a spinal system alone is not sufficient to generate fusion in a reasonable amount of time.

PROCEDURAL CONSIDERATIONS. The patient is administered a general anesthetic and positioned prone. The skin is prepped, and drapes are applied. A spinal laminectomy set is used. Instrumentation and implants of choice, a spinal retractor, and power equipment such as a high-speed handheld tool will be necessary. Hemostatic adjuncts such as gelatin foam, thrombin, oxidized cellulose, and bone wax should be available.

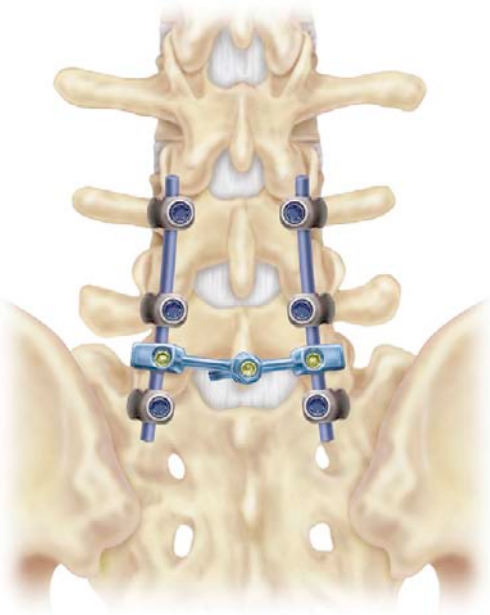


FIGURE 19-104 Texas Scottish Rite Hospital (TSRH) crosslink system.

OPERATIVE PROCEDURE

1. Eyebolts are placed on the spinal rods before the rods are implanted.
2. The rods are secured with hooks or wires, depending on the system used.
3. Once the rods are positioned, cross plates of varying widths accommodating different rod-to-rod distances are bolted in place between the rods and nuts.

Anterior Spinal Fusion with Isola Instrumentation. Isola instrumentation involves screw fixation into each vertebral body, complete disk excision and grafting, and segmental connection of the vertebral bodies. A semirigid rod connects the segments. The Isola anterior instrumentation is indicated in idiopathic scoliosis patients, approximately 10 to 30 years of age, with thoracolumbar or upper lumbar curves of 40 to 65 degrees.

PROCEDURAL CONSIDERATIONS. The patient is positioned in a lateral decubitus position so that posteroanterior and lateral intraoperative radiographs can be taken. The anesthesia provider should ensure incomplete pharmacologic paralysis, to allow for intraoperative neurophysiologic monitoring. In addition to a major soft tissue set and laminectomy set, the Isola instrumentation and implants, a vascular set, and power equipment will be needed.

OPERATIVE PROCEDURE

1. The surgeon approaches the spine through a transthoracic retroperitoneal (or retropleural retroperitoneal) approach, resecting the rib two vertebral levels above the upper instrumented vertebrae.
2. The sympathetic chain is mobilized laterally with the psoas.
3. The segmental vessels are temporarily occluded and, provided that there are no monitoring changes, ligated.
4. The discs are exposed to the far side to allow a full annulectomy. The bodies, however, are not exposed much beyond the midline.

5. A full 360-degree discectomy and annulectomy are done, exposing the posterior longitudinal ligament.
6. The surgeon places the screws in the vertebral body, placing the end screws first. Care is taken to place the longitudinal axis of the screw parallel to the endplate and at the apex of the vertebral body.
7. Screw placement is started with an awl and continued with a 5.5-mm tap, continuing until the tip just exits the far side of the cortex. The first one third of the hole is tapped with a 7.0-mm tap, and a 7.0-mm closed top screw with a washer is inserted. The screw must protrude through the opposite cortex by a thread or two. The same process is then repeated at the lower end vertebra.
8. The surgeon cuts the rod to the proper length and contours it to re-create the sagittal-plane angular position of the normal spine. It is then positioned in the end vertebra and used as a guide to locate the entry point for the intermediate screws.
9. Open-ended intermediate screws are inserted in a fashion similar to the end screws, taking care that their pathway is parallel to the end screws.
10. The rod is back-entered through the upper screw and then the lower screw and seated into the intermediate open screws. The open screws are capped, and the rod is rotated to place the sagittal-plane contour of the rod in the sagittal plane. An intermediate set screw is tightened to secure the new position of the rod.
11. As the remaining screws are tightened about the rod, it is essential that the disc spaces be opened completely. A Cobb elevator can be used to pry the disc space open.
12. Rib corticocancellous autograft is used to completely fill the disc spaces. The surgeon obtains the graft from the tenth rib (the usual site of entry), the twelfth rib (taken from inside the chest), and the eighth rib (taken from outside the chest).
13. The disc spaces are compressed to provide anterior column load-sharing. Care should be taken to ensure that the set screws are visited at least twice for the end-closed connections and three times for the center-capped connections.
14. Closure is in the standard manner, using chest tubes if the chest has been entered or a retropleural Hemovac if a retropleural retroperitoneal exposure has been done.
15. Postoperative care consists of an overnight intensive care stay with the patient sitting out of bed the next morning. A cast or brace is used at the physician's discretion. Activities are restricted for 6 to 12 months, until there is clear indication of graft incorporation.

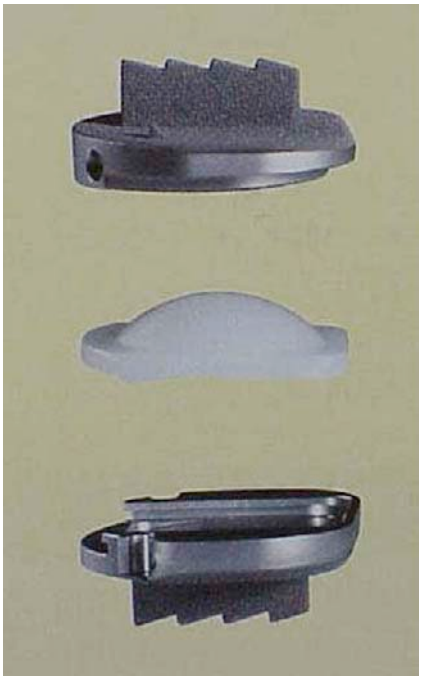


FIGURE 19-105 Three components of the ProDisc.

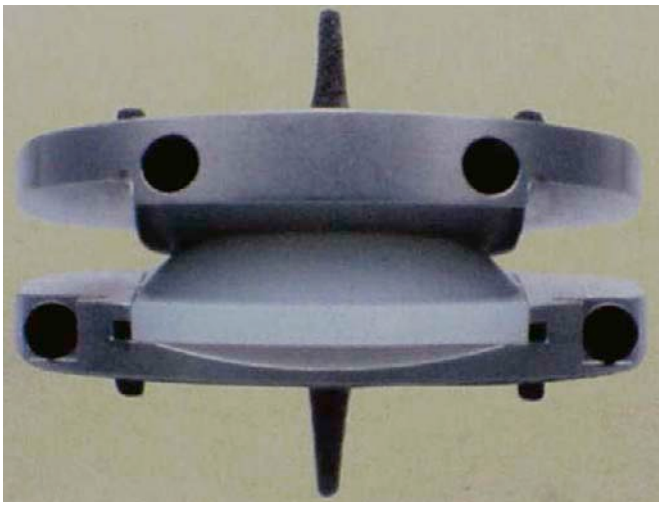


FIGURE 19-106 Assembled ProDisc.

Artificial Disc Replacement

Degenerative disc disease (DDD) occurs when the intervertebral disc (IVD) is worn because of aging or trauma. Discogenic back pain results from degeneration of the disc and is confirmed both by patient history and by radiographic studies. The IVD acts as the padding between the vertebrae. Once the IVD is worn out, pain, inflammation, and nerve impingement leading to numbness and muscle weakness can occur. Left untreated, nerve damage can be permanent. DDD occurs in 50% of people older than 40 years of age. Many patients are asymptomatic; however, those who are affected can be severely debilitated, changing their ability to cope with activities of daily living (ADLs) and affecting the quality of life. Artificial disc replacement (Figures 19-105 and 19-106) re-creates the natural disc function with preservation of spinal motion (Boughton, 2009b; Blumenthal et al, 2005; David, 2007).

Procedural Considerations. The perioperative nurse and surgical technologist collaborate to ensure the availability of implants with the manufacturer's representative and reconfirm this during the preoperative verification process. Other considerations for this procedure include the use of a blood salvaging system in both the intraoperative and postoperative periods. Templates of x-rays should be placed on the viewing box in the OR before the procedure. The patient is positioned supine on a Jackson table with the right arm draped across the body. A C-arm is used to identify the disc or discs to be replaced in the marked areas. In many institutions, laminar airflow is used.

Operative Procedure. The two general anatomic routes for anterior exposure to the lumbar spine are retroperitoneal and transperitoneal.

The *retroperitoneal approach* can proceed from a variety of incisions, including vertical midline, paramedian, oblique, and transverse. This is determined by both the spinal level and the number of lumbar levels to be exposed. An infraumbilical transverse incision can accommodate most approaches to the L4-L5 and/or S1 disc levels, whereas a more obliquely oriented incision is favored for accessing disc levels above L4.

The *transperitoneal route* is not generally used except in extenuating circumstances (e.g., prior extensive retroperitoneal surgery or revisional spine surgery).

1. The surgeon creates a midline incision and places a fixed retractor system to move the small and large bowel out of the field and facilitate direct visualization of the abdominal cavity. Trendelenburg's position can be used to assist with maintaining exposure.
2. For the L5-S1 level, the peritoneum superficial to the sacral prominence is incised.
3. The surgeon identifies the vascular structures, and uses blunt dissection to tease open the area of the facet of the disc.
4. The middle sacral vessels generally need to be divided to complete the exposure. Excessive electrocoagulation should be avoided to decrease the risk of injury to the sympathetic nerves.
5. Once the exposure is complete the surgeon will use a #3 long handle with a #15 blade to make an incision into the disc body.
6. The discectomy is completed using a rongeur and curettes to remove remaining disc tissue.
7. Correct sizing is determined using templates. Trial instrumentation is inserted and correct placement is verified with AP and lateral C-arm views.
8. The trial is centered in the AP plane, and the marker appears as a plus sign aligned with the spinous process. On the lateral x-ray, a hole in the trial represents the center of rotation.
9. Once correct placement of the trial is verified, the surgeon uses the ESU to mark the midline of the superior vertebral body and removes the trial.
10. Next, the pilot driver is aligned with the midline ESU mark.
11. The pilot driver that corresponds to the chosen footprint is then carefully impacted to verify the ability to accurately place endplates.
12. During this process, lateral C-arm imaging is used to accurately monitor the depths of the pilot driver.
13. Once the depth is achieved, the slap hammer is used, removing the pilot driver from the disc space.
14. The endplate insertion tips are then attached to the corresponding superior and inferior endplates.
15. The endplates are then carefully inserted into the disc space with the assistance of the guided impactor.
16. The insertion is monitored with fluoroscopy to accurately control the posterior depth and verify the appropriate lordotic angle.
17. With the superior and inferior endplates in place, the surgeon uses the spreading and insertion forceps to open the disc space.
18. Once the appropriate distraction is achieved, the size on the spacer can be used to select the appropriate core trial.
19. The appropriate core insertion tip is loaded into the core insertion instrument, and the sliding core is inserted between the endplates.
20. The surgeon releases the distraction on the spreading forceps, which allows the endplates to close around and engage the sliding core.
21. The core insertion instrument is removed and the final position verified using fluoroscopy (Figures 19-107 and 19-108).
22. The wound is irrigated and closed.

Vertebroplasty and Kyphoplasty

Vertebroplasty and kyphoplasty are used for the treatment of vertebral compression fractures attributable to osteoporosis or pathologic conditions. Bone cement is injected into the vertebral body to decrease back pain and prevent further vertebral body height loss. Ortiz (2008) describes the technique in the Research Highlight box.

PROCEDURAL CONSIDERATIONS. Patient selection is key in identifying appropriate candidates for this procedure. MRI is the most accurate radiologic diagnosis. Equipment includes C-arm, radiolucent OR table, and x-ray vests for staff as well as vertebroplasty system and cement injection system. Bone biopsy needles should be available. The C-arm must provide a good quality image; all key bony landmarks should be clearly visible. Positioning of the patient requires careful vigilance to prevent skin breakdown and nerve damage. After the administration of anesthetic, the patient is positioned prone with hyperextension of the vertebral compression fracture on the radiolucent OR table. The patient is then prepped and draped.

OPERATIVE PROCEDURE

1. After the patient is prepped and draped, the C-arm is placed in the area undergoing surgery.
2. Confirmation of the level of the vertebroplasty (or kyphoplasty) is determined.

RESEARCH HIGHLIGHT

Balloon Kyphoplasty

Physical function improved and patients experienced less disability following kyphoplasty than those patients who received conservative care. Immediate improvement in pain and quality of life was reported in 149 patients with compression fractures from osteoporosis, myeloma, or metastatic disease who underwent balloon kyphoplasty. The control group consisted of 151 patients who underwent conservative treatment of back pain. Conservative care included pain medications, bracing, physiotherapy, and bed rest. Based on SF-36 scores, results showed patients assigned to the kyphoplasty group had greater improvement than those patients randomized to nonsurgical care. In addition to improved physical capabilities, kyphoplasty patients also reported less back pain, less use of analgesics and walking aids, and fewer days of limited activity. There were no statistical differences between the groups in adverse events. Kyphoplasty is a minimally invasive surgery that produces improved quality of life with little risk.

From Boughton B: American Association of Orthopaedic Surgeons 2009: Balloon kyphoplasty produces better physical function, less disability than standard care, available at www.medscape.com/viewarticle/589132. Accessed April 25, 2009.

FIGURE 19-107 Implanted ProDisc.

FIGURE 19-108 Implanted ProDisc with patient bending backward.

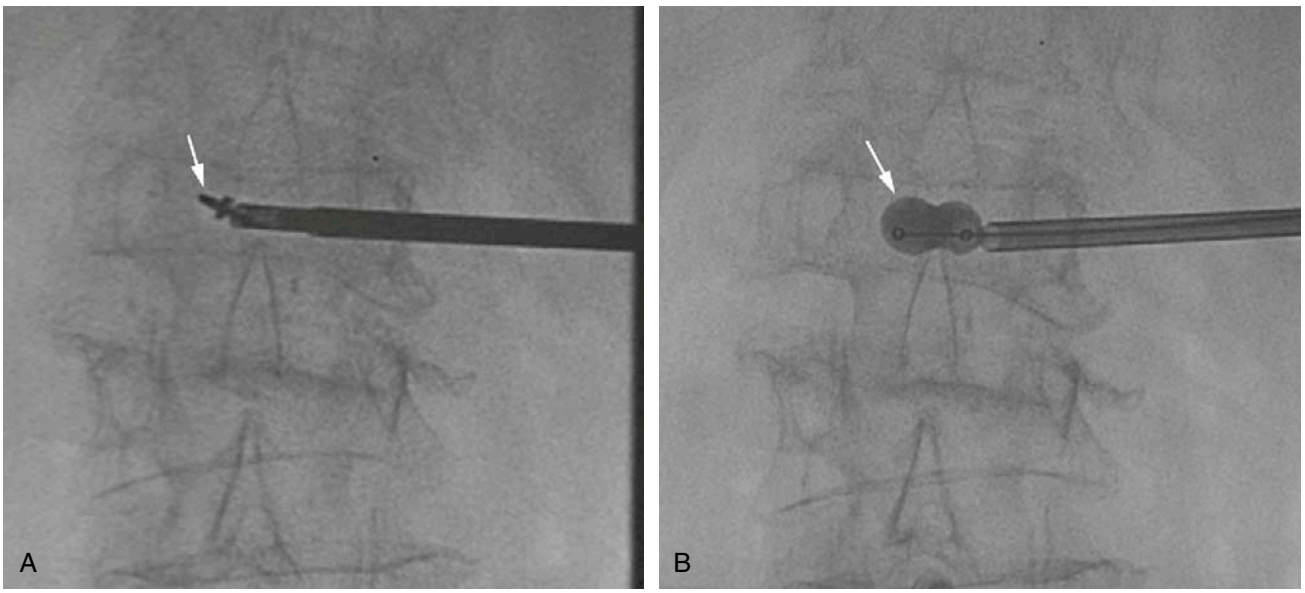


FIGURE 19-109 Vertebroplasty. **A**, Frontal fluoroscopic image shows multidirectional bone curette. **B**, Path of least resistance for subsequent balloon tamp inflation.

3. The surgeon inserts the appropriate gauge bone needle (11- to 13-mm gauge for vertebroplasty; 8- to 10-mm gauge for kyphoplasty) at the desired level and confirms the correct level with fluoroscopy (Figure 19-109, A).
4. For kyphoplasty:
   a. The inflatable balloon tamp is placed. Available tamps are 10, 15, or 20 mm in length, and styles include multi-, uni-, and bidirectional (Figure 19-109, *B*).
   b. After placing the tamp, the surgeon gradually inflates the balloon to 50 pounds per square inch (psi) and then continues inflation in increments of 25 psi until the desired pressure is achieved and either there is height restoration of the vertebral body or the tamp is in proximity to the cortical margin. Pressure is monitored by a manometer.
   c. Once the tamp has reach maximum inflation, the surgeon deflates the balloon. A cavity is left within the vertebral body.
5. Cement is mixed and then injected through the bone needle using a 1-ml syringe (Figure 19-109) under fluoroscopic control.
6. The needle is removed and a dressing is applied.

REFERENCES

American Association of Tissue Banks (AATB): Standards for tissue banking, McLean, VA, 2008, The Association.

American Board of Orthopaedic Surgeons (ABOS): available at www.abos.org/ModDefault.aspx?module=Public. Accessed June 23, 2009.

Association of periOperative Registered Nurses (AORN): AORN position statement on the role of the health care industry representative in the perioperative/invasive setting 2006, available at www.aorn.org/PracticeResources/AORNPositionStatements/Positions_HealthCareR. Accessed March 15, 2009.

Association of periOperative Registered Nurses (AORN): AORN position statement on patient safety 2007, available at www.aorn.org/PracticeResources/AORNPositionStatements/Position_PatientSafety/. Accessed March 15, 2009.

Association of periOperative Registered Nurses (AORN): *Perioperative standards and recommended practices*, Denver, 2009, The Association.

Barclay L et al: Guidelines address drug treatments to prevent osteoporotic fractures, 2008, available at http://cme.medscape.com/viewarticle/580715. Accessed June 23, 2009.

Blumenthal S et al: A prospective, randomized, multicenter food and drug administration investigational device exemptions study of lumber total disc replacement with the Chartie artificial disc versus lumber fusion: Part I: Evaluation of clinical outcomes, *Spine* 30(14): 1565–1575, 2005.

Boughton B: Certain factors increase risk for death after total hip arthroplasty, 2009a, available at www. medscape.com/viewarticle/588980. Accessed March 31, 2009.

Boughton B: Lumbar total disc replacement superior to spinal fusion for degenerative disc disease, 2009b, available at www.medscape.com/viewartical/588851. Accessed March 31, 2009.

David T: Long-term results of one-level lumbar arthroplasty: minimum 10-year follow-up of the Charite Artifical disc in 106 patients, *Spine,* 32(6):661–666, 2007.

Denholm B: Tucking patient's arms and general positioning, *AORN J* 89(4):755–757, 2009.

Guido GW: *Legal and ethical issues in nursing*, ed 4, Upper Saddle River, NJ, 2005, Prentice-Hall.

Harby K: Outpatient surgery in hip and knee arthroplasty requires comprehensive approach, 2005, available at www.medscape.com/viewarticle/500209. Accessed March 23, 2009.

Kleinert HE et al: Hand surgery, In Townsend CM, editor: *Sabiston's textbook of surgery*, ed 18, Philadelphia, 2007, Saunders.

Kolisek F et al: Clinical experience using a minimally invasive surgical approach for total knee arthroplasty: early results of a prospective randomized study compared to a standard approach, *J Arthroplasty* 22(1):8–13, 2007.

National Osteoporosis Foundation (NOF): Fast facts on osteoporosis, Washington, DC, National Osteoporosis Foundation, available at www.nof.org/osteoporosis/diseasefacts.htm. Accessed June 13, 2009.

Ortiz A: Vertebral body reconstruction: review and update on vertebroplasty and kyphoplasty, *Appl Radiol* 37(12):10–24, 2008.

The Joint Commission: Universal protocol UP.01.01.01, available at: www.jointcommission.org/NR/rdonlyres/E5943278-3B89-469F-A265-E5AFB8729AD0/0/NPSG_UniversalProtocol_AHC_20090512.pdf. Accessed March 15, 2009.

CHAPTER 20

Neurosurgery

DIANE L. FERRARA-HOFFMAN and SARAH J. KRIZMAN

Neurosurgery is possibly the most diverse, complex, and challenging specialty in surgery. Brain surgery is performed for head injury, tumors, vascular disorders, hydrocephalus, epilepsy, and Parkinson's disease. Neurosurgery also treats disorders of the spine from trauma and fractures, spinal cord injury, spinal stenosis, spinal tumors, and disk disease. In addition, neurosurgeons treat peripheral nerve disorders, carotid artery disease, chronic pain, and pediatric disorders. Advancements in the highly technical field of neurosurgery are constant.

Perioperative nurses and surgical technologists who care for neurosurgical patients are challenged by the need to have a working knowledge of neuroanatomy, function, and clinical presentations of the many neurologic conditions that require surgical interventions. Understanding the surgical procedure to be performed allows the perioperative nurse to anticipate and respond to the intraoperative needs of the patient and neurosurgical team, and also to surgical complications if they arise. Given the range and complexity of today's neurosurgical interventions an understanding of highly sophisticated equipment and instrumentation is necessary. Like all patients undergoing surgery, the neurosurgical patient is often vulnerable secondary to the presenting pathologic condition. For perioperative personnel to deliver sensitive, humanistic care in this highly technical environment, they must recognize and appreciate the individual's emotional and spiritual state, whether it is manifested by fear, pain, or grief. Reaching out and making the human connection allay the fear, moderate the pain, and facilitate the patient's grieving process. Information in this chapter will assist those working in neurosurgery to give optimal patient care.

Surgical Anatomy

The nervous system is the most complex and least understood of body systems. It is divided structurally into the central nervous system (CNS) consisting of the brain and spinal cord and the peripheral nervous system (PNS), which encompasses every neurologic structure outside the CNS, including the cranial and spinal nerves. The brain and spinal cord are protected by the skull and vertebral columns, respectively. The cranial nerves originate within the brain and emerge through openings in the skull to run peripherally. The spinal nerves that emerge from the spinal cord through the vertebral foramina also run peripherally.

The nervous system is divided functionally into a voluntary system and an autonomic, or involuntary, system. It provides a means of communication for the rest of the body. The functions of all body systems depend, in part, on nervous system function. In turn, the nervous system depends directly on circulatory system function to obtain life-sustaining glucose and oxygen. Nervous system functions include motor and sensory functions, orientation, coordination, conceptual thought, emotion, memory, and reflex response.

Nervous system tissue is composed of vast amounts of neurons and far more neuroglial cells. Neurons are intercommunicating nerve cells that encode, conduct, and transmit information to other neurons, muscle, and glandular tissue (Figure 20-1). They are composed of a body or soma with branches or extensions, called dendrites and axons, that communicate with other cells at synapses. Dendrites are short branches that conduct impulses toward the soma. Cell bodies and dendrites are mostly confined to areas of gray matter in the CNS. Axons are long branches, often encased in a white myelin sheath, that conduct impulses away from the soma. Axons pass into bundles of nerve fibers that tend to form tracts or pathways and are referred to as white matter. Tracts that cross midline to create a communication pathway from each side of the body to the opposite side of the brain are called commissures. Neuroglial cells support the neurons by creating and maintaining an appropriate environment in which neurons can operate efficiently. Glial cells include astrocytes, oligodendrocytes, ependymal cells, and microglia. The mutation of these cells can form a glioma, one of the more common brain tumors.

This chapter divides the nervous system into logical divisions within the framework of neurosurgical techniques. The brain and adjacent structures include the cranial nerves of the PNS, which are commonly encountered during brain surgery. Discussion of the spine and spinal cord includes the adjacent spinal nerves and the disks and ligaments that support the spine. Surgically significant pathology is incorporated with the normal anatomy of structures.

BRAIN AND ADJACENT STRUCTURES

Scalp

Scalp layers (Figure 20-2) include skin, subcutaneous tissue, galea, and periosteum. Scalp skin is thick. The subcutaneous tissue, which is exceptionally dense, tough, and vascular, is firmly attached to the galea. Most of the blood vessels lie superficial to the galea. The subgaleal space contains loose areolar tissue that permits mobility of the scalp. It is in this bloodless plane that the standard craniotomy scalp flap is created. The pericranium, or outer periosteum of the skull, separates the galea from the cranium.

The arterial supply of the scalp comes from the external carotid artery through the superficial temporal, posterior

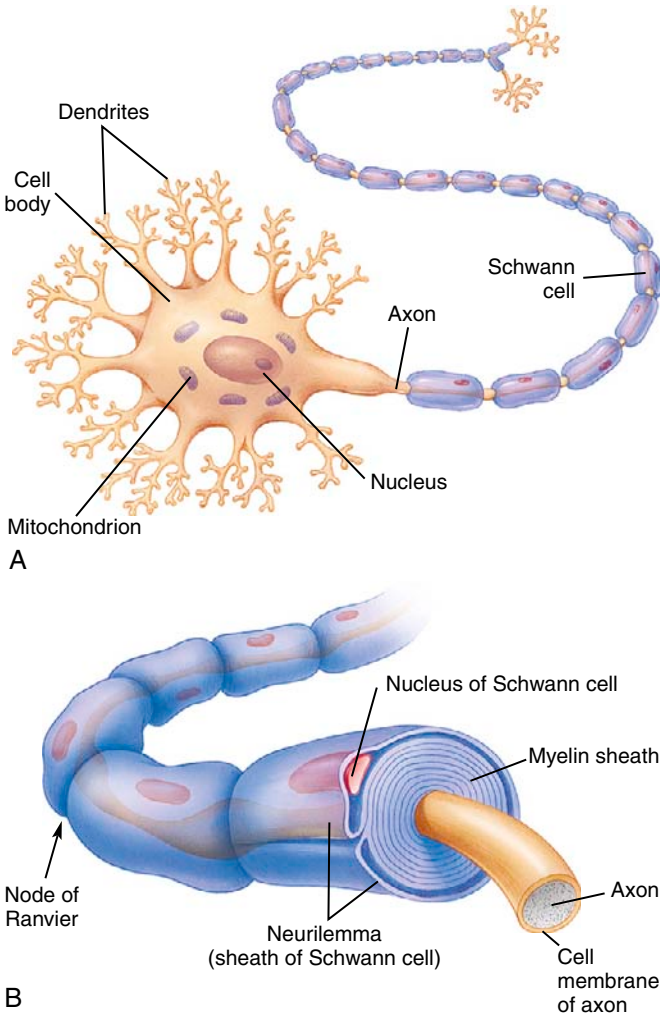


FIGURE 20-1 **A**, Many dendrites carry nerve impulses to the cell body, which then sends the nerve impulses along a single, long axon. Long axons are encased at intervals by a myelin sheath. **B**, A segment of myelinated fiber in cross section, showing myelin sheath composed of several layers of myelin, which insulate the axon.

auricular, occipital, frontal, and supraorbital branches. Most veins roughly follow the course of their corresponding arteries, except the emissary veins, which drain directly through the skull into the intracranial venous sinuses. The scalp, the extracranial arteries, and portions of the dura mater are the only pain-sensitive structures that cover the brain. The brain itself is insensate.

Skull

The skull provides protection for the brain. It is formed by 28 bones, most of which are paired although some in the median plane are single. Many of the bones are flat bones, consisting of two thin plates of compact bone encasing a spongy layer of cancellous bone containing bone marrow (see Figure 20-2). Infants are born with two fontanelles. These are openings in the skull that are located both anterior and posterior to the parietal bones (Figure 20-3). The posterior fontanelle is generally closed by 2 months and the anterior by about 18 months after birth. The bones of the skull are joined by bony seams called *sutures*. Eight bones form the walls of the cranial cavity, which houses the brain. There are four single bones (frontal, occipital, ethmoid, and sphenoid) and four paired bones (temporal and parietal) (Figure 20-4). The sagittal suture lies in the medial plane and joins the two parietal bones. The coronal suture joins the frontal and parietal bones. The squamous sutures border the squamous part of the temporal bones. The lambdoid suture joins the occipital and parietal bones. Skull bones vary in thickness and tend to be thinner where they are covered in muscles, for example, in the temporal and posterior fossae. The skull articulates with the first cervical vertebra to allow for flexion and extension of the skull. The skeletal surface landmarks of the head can be palpated and are commonly used to plan surgical approaches (Figure 20-5).

The interior of the skull is anatomically divided into three cranial fossae: anterior, middle, and posterior (Figure 20-6). The anterior fossa is limited posteriorly by the sphenoid ridge, along which pituitary tumors and aneurysms of the circle of Willis are generally approached. The frontal lobes and olfactory bulbs and tracts lie in the anterior fossa. The temporal lobes lie in the middle fossa, which is shaped like a butterfly. The sella turcica, formed by the sphenoid bone, is the most central part of the middle fossa and houses the pituitary gland. The floor and lateral walls of the middle fossa are shaped from the greater wings of the sphenoid bone and parts of the temporal bone, which house the internal and middle ear structures. The posterior fossa, the largest and deepest fossa, is formed by the occipital, sphenoid, and petrous portions of the temporal bones; the cerebellum and brainstem lie here, as do many cranial nerves. The foramen magnum, the largest opening in the skull, provides passage for the spinal cord to join the brainstem in the posterior fossa. Numerous other openings exist in the base of the skull for passage of arteries, veins, and cranial nerves.

Skull Fractures. The severity of skull fractures depends on the degree of resulting brain injury. Simple skull fractures can be serious if they cross major vascular channels in the skull. If vessels are torn, epidural or subdural hematomas may form. Depressed skull fractures require a surgical procedure to elevate the depressed bone. Open skull fractures should be irrigated copiously and closed to prevent infection. Basilar skull fractures may cause cerebrospinal fluid (CSF) rhinorrhea or otorrhea. A few patients with these CSF leaks require surgical repair if they do not resolve after 2 weeks.

Deformities of the Cranium. Craniosynostosis is the most common pediatric skull deformity seen and treated by the neurosurgeon. The phenomenon is a premature closure or lack of formation of cranial sutures, leading to cosmetic abnormalities, eventual life-threatening intracranial pressure (ICP) increases, and arrested brain development unless diagnostic and surgical interventions ensue. Cranial remodeling is most often undertaken during the first year of life, when brain capacity triples (see Chapter 25).

Meninges

The brain and spinal cord are completely enveloped by the meninges, which are three membranes that provide support and protection. The meningeal layers from superficial to deep are the dura mater, arachnoid mater, and pia mater (see Figure 20-2).

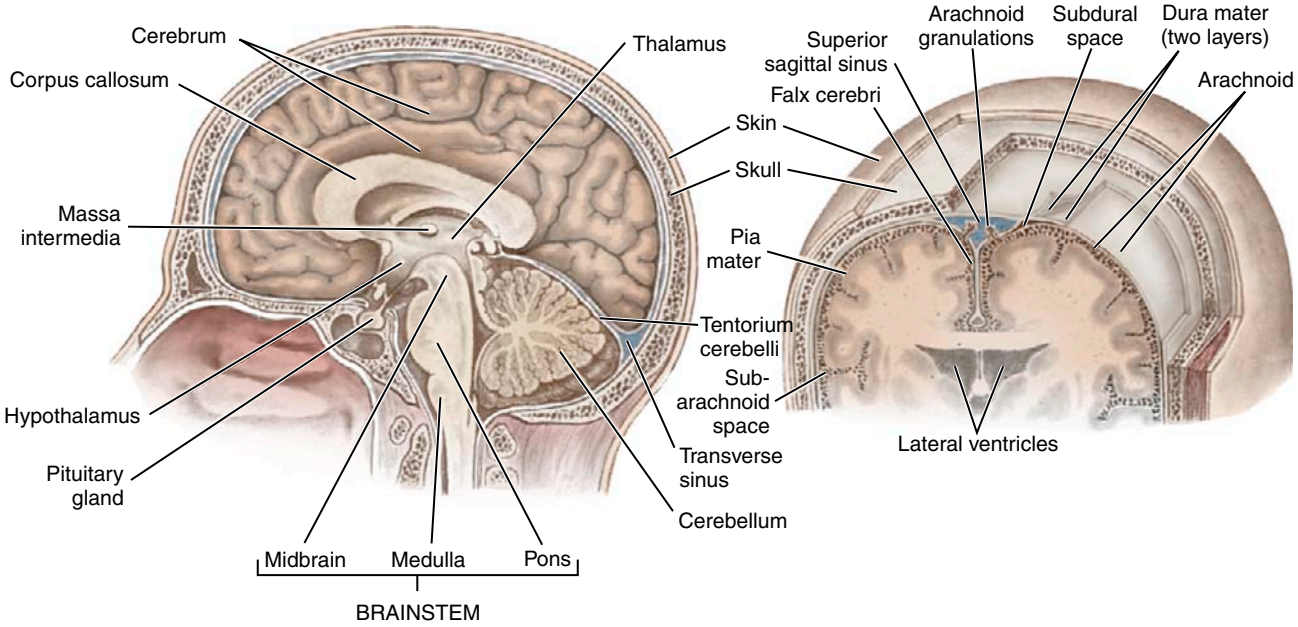


FIGURE 20-2 Scalp is composed of the following layers: skin, subcutaneous tissue, galea, and periosteum. Skull bone has three tables: outer, diploë (or spongy layer), and inner. Dura mater lies beneath skull and completely encapsulates brain. Other structures are identified for reference and are described in text.

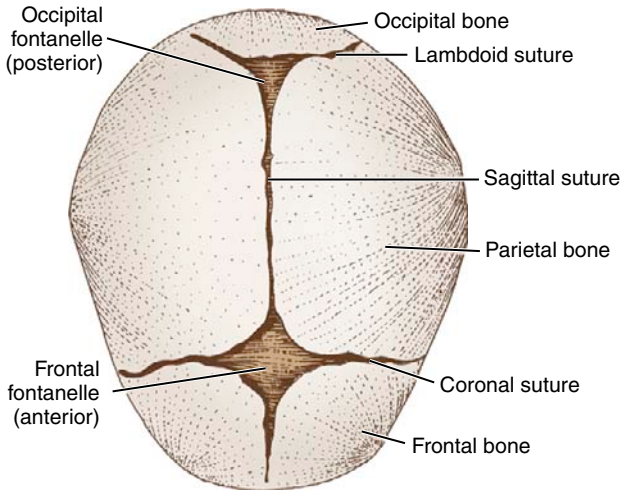


FIGURE 20-3 Skull at birth viewed from above.

The space superficial to the dura is known as the epidural space. The cranial meninges are located between the skull and the brain.

The dura mater is a tough, shiny, fibrous membrane that is close to the inner surface of the skull and folds to separate the cranial cavity into compartments. The largest fold is the falx cerebri—an arch-shaped, vertically placed, midline structure separating the right and left cerebral hemispheres (see Figure 20-2). A smaller fold of dura mater, the falx cerebelli, separates the cerebellar hemispheres vertically. A transverse fold, the tentorium cerebelli, forms the roof of the posterior fossa. The tentorium supports the temporal lobe and occipital lobes of the cerebral hemispheres. Below the tentorium lie the cerebellum and brainstem. Structures above the tentorium are referred to as *supratentorial* and those below as *infratentorial* (Figure 20-7). At margins of these dural folds lie large venous sinuses that drain blood from the intracranial structures into the jugular veins. Accidental breaching of a sinus during surgery can cause severe bleeding that is difficult to control and may put the patient at risk for a venous air embolism. Several arteries also lie within the layers of the dura. The largest is the middle meningeal, a source of serious epidural hemorrhage if torn by an overlying skull fracture. The rigid skull makes hemorrhage and swelling in the brain critical events. The volume of the intracranial cavity is fixed. Increasing the intracranial contents by a hemorrhage, tumor, or edema may lead to serious ICP problems. Pressure on brain tissue may cause irreparable damage.

Beneath the dura mater is a transparent membrane called the *arachnoid*. Although the outer layer of arachnoid closely approximates the dura mater, the space between is considered the subdural space. The inner arachnoid layer forms innumerable weblike filaments that bridge to the surface of the brain (see Figure 20-2). The arachnoid passes over the sulci and fissures of the brain, without dipping into them. The arachnoid is separated from the pia mater beneath it by the subarachnoid space, which is filled with CSF that bathes the brain. Around the base of the brain, particularly, this space becomes enlarged to form cisterns. The major intracranial nerves and blood vessels pass through these compartments. Intracranial approaches can be charted in terms of the basal cisterns.

The pia mater, the innermost membrane, closely follows the contours of the surface of the brain into the sulci and fissures. Only the microscopic subpial space separates the pia from the brain. The pia mater has a rich vascular network. Vascular fringes of pia mater project into the ventricles to form the choroid plexus of the ventricles, which produce CSF.

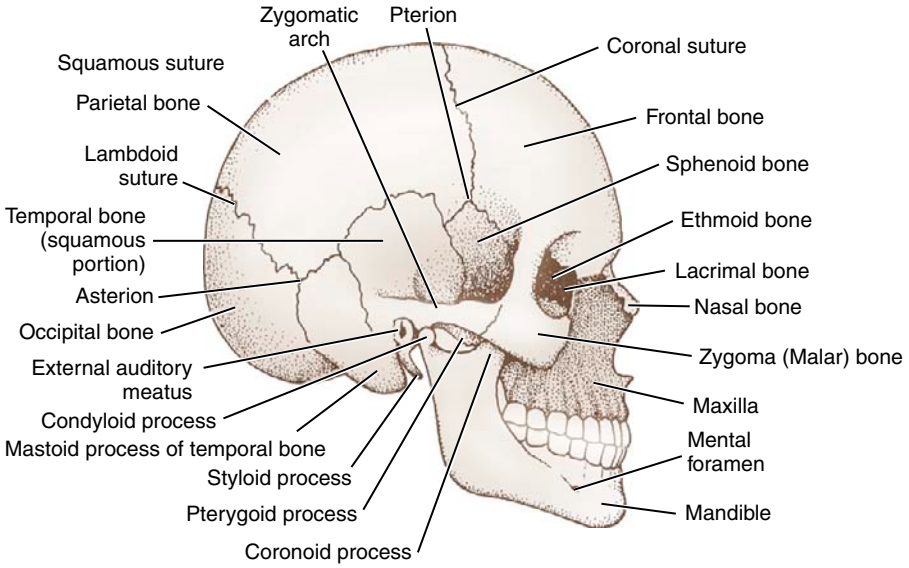


FIGURE 20-4 Skull viewed from right side.

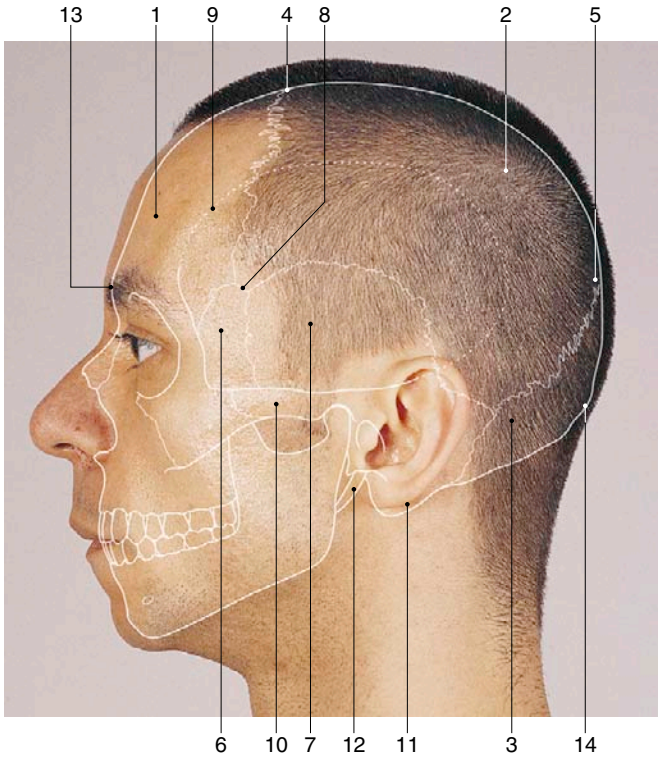


FIGURE 20-5 Lateral aspect of the head: bones. *1,* Frontal. *2,* Parietal. *3,* Occipital. *4,* Bregma (anterior fontanelle). *5,* Lambda (posterior fontanelle). *6,* Greater wing of sphenoid. *7,* Squamous temporal. *8,* Pterion. *9,* Temporal lines. *10,* Zygomatic arch. *11,* Mastoid process. *12,* Styloid process. *13,* Glabella. *14,* External occipital protuberance.

Brain

The anatomy of the brain, formally known as the encephalon, can be considered in multiple ways. Based on prenatal development, the principal divisions from rostral (head) to caudal (tail), descending toward the spinal cord, are the forebrain or prosencephalon, the midbrain or mesencephalon, and the hindbrain or rhombencephalon. The rhombencephalon is subdivided into the cerebellum, the medulla oblongata, and the pons. The prosencephalon includes the diencephalon and the telencephalon, or cerebrum. The medulla oblongata, pons, and midbrain are collectively referred to as the brainstem (Figures 20-7 and 20-8).

Cerebrum. The right and the left cerebral hemispheres are the largest parts of the brain and occupy the anterior and middle fossae. Each hemisphere is divided into frontal, parietal, occipital, and temporal lobes. The two hemispheres are separated by the longitudinal fissure and the falx cerebri but remain connected underneath the falx by a large transverse bundle of nerve fibers called the corpus callosum (see Figure 20-8). Each of the cerebral hemispheres controls sensation and motor activity to and receives sensory stimuli from the opposite half of the body.

The convoluted surface of the cerebrum consists of gray matter, called the *cerebral cortex,* which contains the cell bodies of the many nerve pathways of the brain. The underlying white matter contains millions of myelinated nerve axons and is relatively avascular compared with the cortex. The nerve pathways, or fiber tracts, are of three types: (1) commissural fibers, which pass from one cerebral hemisphere to the other; (2) association fibers, which connect regions of gyri and lobes longitudinally within a cerebral hemisphere; and (3) projection fibers, including the great motor and sensory systems, which run vertically to connect the cortical regions with other portions of the CNS.

The surfaces of the hemispheres form convolutions called *gyri* and intervening furrows called *sulci,* which serve as anatomic landmarks. Two sulci of particular anatomic importance during surgery are: (1) the lateral sulcus, or sylvian fissure, which divides the temporal lobe from the frontal and parietal lobes, and (2) the central sulcus, or fissure of Rolando, which separates the frontal from the parietal lobe. The central sulcus also separates the motor cortex (precentral gyrus) from the sensory cortex (postcentral gyrus). The motor cortex lies anterior to the central sulcus, and the sensory cortex lies posterior to the central sulcus. Both the motor cortex and the sensory cortex can be represented by a topographically organized map called a homunculus that proportionately represents each body part at the area of the gyri that controls it. The diagrams illustrate how the number of neurons corresponds to the degree of motor

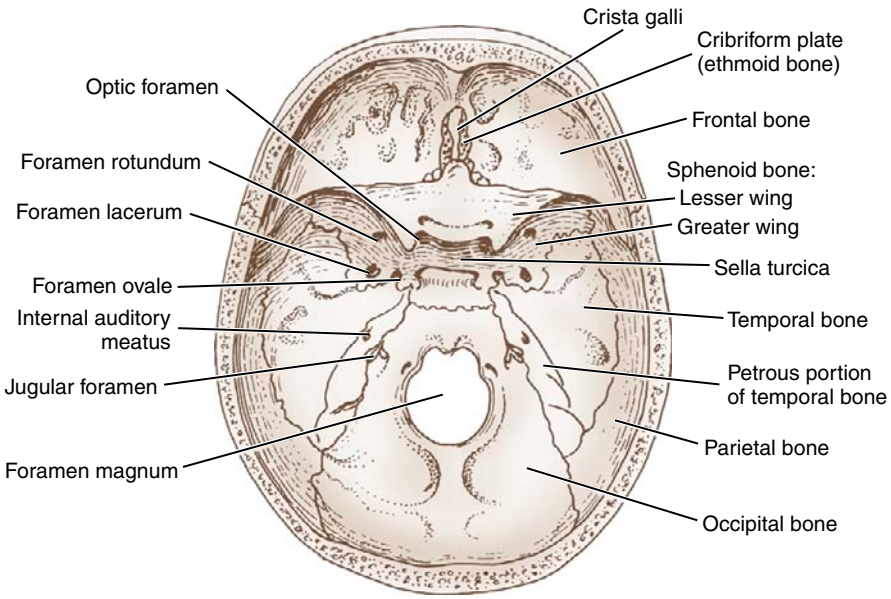


FIGURE 20-6 Floor of cranial cavity.

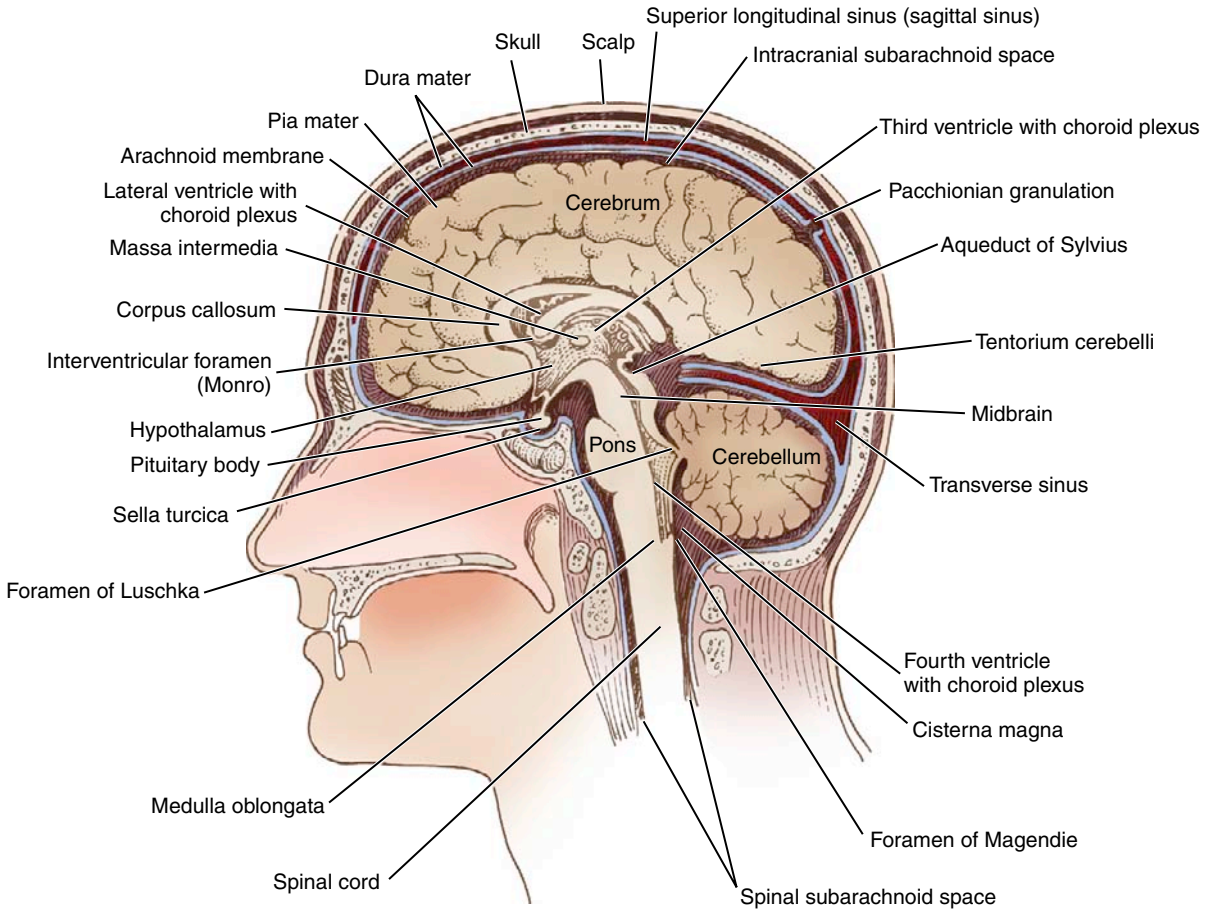


FIGURE 20-7 Sagittal section of head showing cerebrospinal fluid spaces and their relationship to venous circulation and their principal subdivision of the brain and its coverings.

and sensory control required. For example, areas that need more fine motor control, such as the fingers and face, have a higher concentration of neurons than other areas. Keep in mind that the left motor and sensory cortices control the right side of the body and vice versa (Figure 20-9). Destruction of an area of motor cortex results in loss of voluntary motor function on the corresponding area of the opposite side of the body (Figure 20-10).

The frontal lobe is anterior to the central sulcus and controls the higher functions of intellect and abstract reasoning,

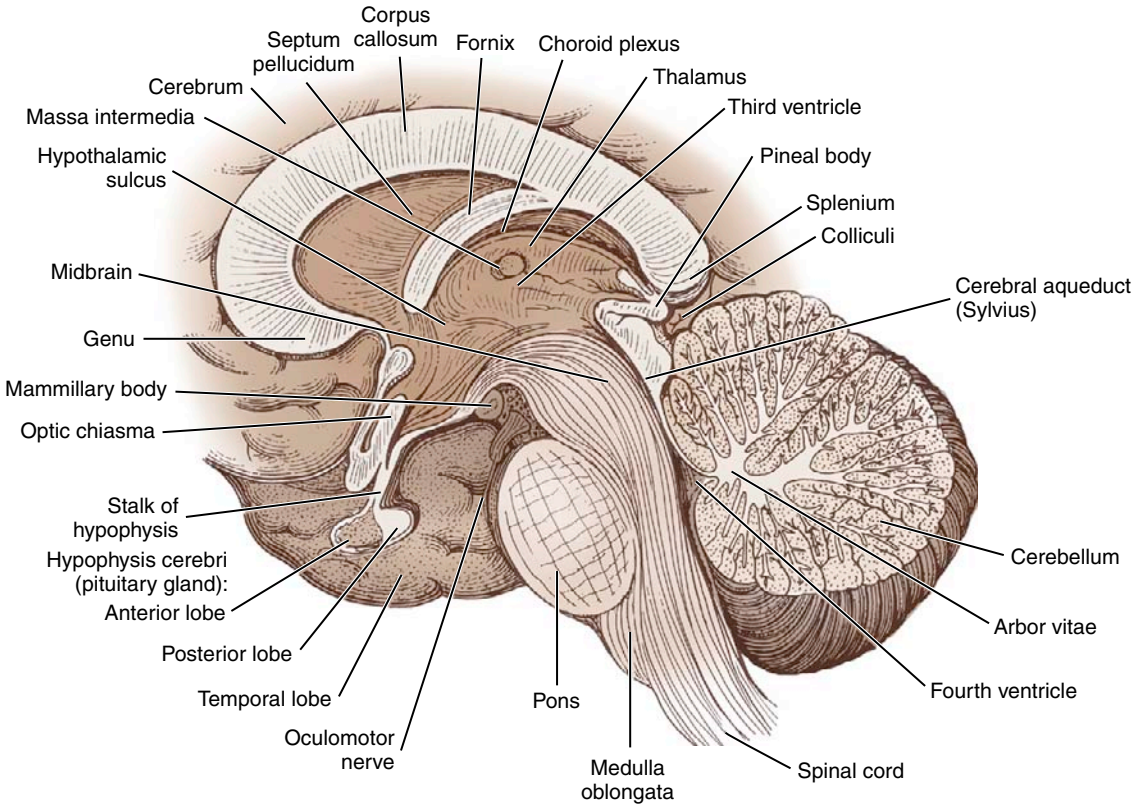


FIGURE 20-8 Sagittal section through midline of brain showing structures around third ventricle, including corpus callosum, thalamus, and hypothalamus.

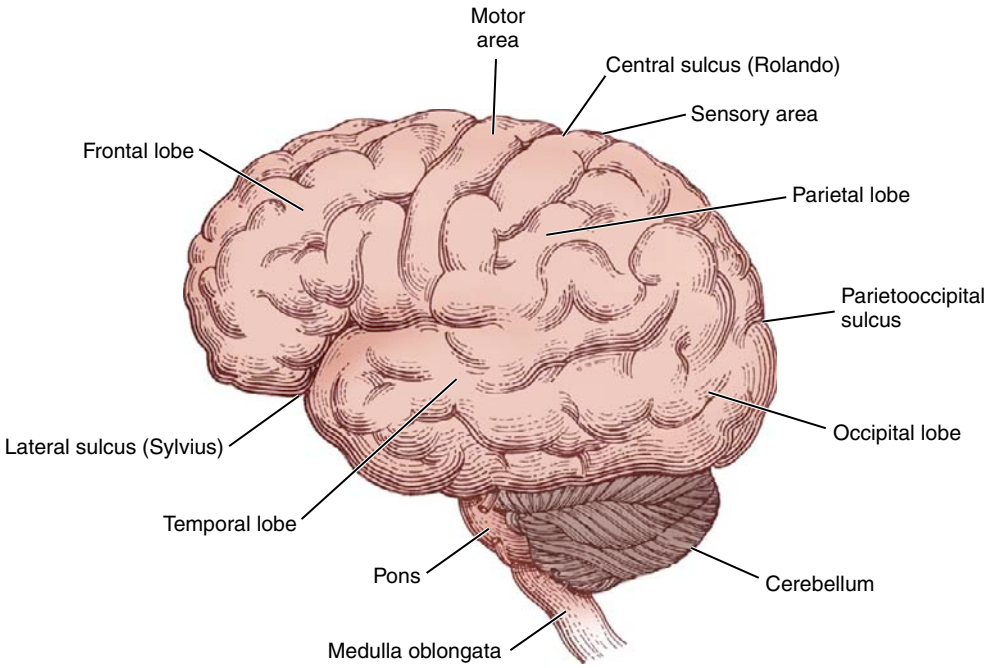


FIGURE 20-9 Lateral view of cerebral hemisphere (showing lobes and principal fissures), cerebellum, pons, and medulla oblongata.

along with movement, language, and personality. Posterior to the central sulcus is the parietal lobe, extending back to the parietooccipital fissure. This area contains the final receiving and integrating station for sensory impulses, such as pain and touch, from the contralateral side of the body. It is also involved with special relationships and object identification. The occipital lobe lies posterior to the parietooccipital fissure. It receives and integrates visual impulses and registers them as meaningful images (see Figures 20-9 and 20-10).

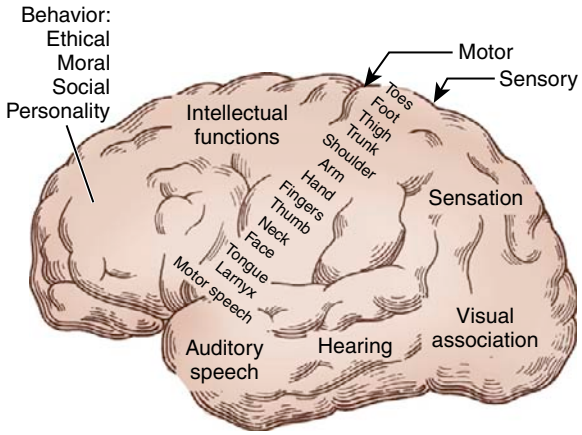


FIGURE 20-10 Principal functional subdivisions of cerebral hemispheres.

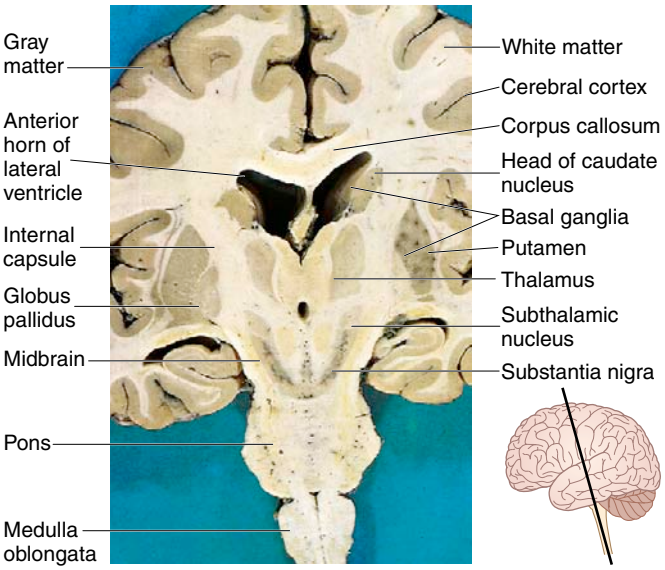


FIGURE 20-11 Oblique coronal section through the cerebral hemisphere and brainstem showing the disposition of gray and white matter, the basal ganglia, and the internal capsule.

Inferior to the lateral sulcus, in the middle fossa, is the temporal lobe, which is involved with memory, speech, and smell. Lesions of the left temporal lobe in right-handed persons and in many left-handed persons may affect the comprehension and verbalization of words, resulting in aphasia. The insula (island of Reil) is an area of cortex that lies deep within the lateral sulcus and can be exposed when the upper and lower lips of the fissure are separated. The insula is believed to be involved with smell, taste, touch, and possibly language.

The limbic system consists of large parts of the cortex near the medial wall of the cerebral hemisphere (cingulate and parahippocampal gyri) along with the hippocampus, amygdala, and septum. It is closely and significantly connected with the hypothalamus. It has a diffuse distribution in the brain, and many components of the limbic system have overlapping functions. The hippocampus is critical for learning and memory. The amygdala regulates the perceptive and expressive aspects of emotional and social behavior. The limbic system affects endocrine and autonomic functions of the body, recent memory, emotions, behaviors, and motivational and mood states. Restlessness and hyperactivity may result from lesions of this area.

The basal ganglia are subcortical collections of nuclei (gray matter) that include the caudate nucleus, putamen, and globus pallidus (collectively referred to as the *corpus striatum*); the substantia nigra (which is located in the midbrain); and the subthalamic nucleus (part of the diencephalon). The basal ganglia influence movement and behavior through projections to the thalamus and brainstem and subsequently the cortex (Figure 20-11). The basal ganglia function to promote and support patterns of behavior and movement that are appropriate in a given situation and to inhibit unwanted or inappropriate behavior and movements. Disorders of the basal ganglia are principally characterized by abnormalities of movement, muscle tone, and posture. Damage to these neural components may cause rigidity of the skeletal muscles and various types of spontaneous tremors.

Diencephalon. The diencephalon is composed of the thalamus, hypothalamus, epithalamus, and subthalamus and surrounds the third ventricle. The thalamus is the major relay station for incoming sensory stimuli. Except for some olfactory impulse transmission, all sensory information transmitted to the cerebral hemispheres is relayed through the thalamus. This is also true for motor pathways from the cerebellum and basal ganglia. Because of the central role of the thalamus in perception of body sensations, surgical lesions can be made in this area in an attempt to alleviate pain.

Along the floor of the third ventricle is the hypothalamus (see Figure 20-8), which is concerned principally with the autonomic regulation of the body's internal environment and is intimately connected with the pituitary gland. It controls fluid and electrolyte balance, appetite, reproduction, thermoregulation, immune response, and many emotional responses. It influences levels of attention and consciousness. The pituitary gland is suspended from the base of the hypothalamus by the pituitary stalk. It secretes multiple hormones that are regulated by the hypothalamus. A pituitary tumor can result in a hormonal imbalance. It can also encroach on the optic chiasma, causing vision changes.

The subthalamus is a complex region of nuclear groups and fiber tracts, including the subthalamic nucleus, which is considered with the basal ganglia. The epithalamus consists of multiple nuclei and the pineal gland, an endocrine gland that regulates the circadian rhythm.

Brainstem. The brainstem consists of the midbrain, pons, and medulla oblongata. It is located in the posterior fossa and forms the floor of the fourth ventricle. It is the site of many ascending and descending fiber tracts that allow for communication among the structures of the brain and between the brain and spinal cord. All but 2 of the 12 cranial nerves attach to the brainstem. The short, stocky portion of the brain, between the cerebral hemispheres and pons, is the midbrain (see Figure 20-7), also referred to as the *mesencephalon*. It is composed of the cerebral peduncles, the substantia nigra, numerous nerve tracts and nuclei, and association centers that control the majority of eye movements. Immediately below the midbrain is the pons, which contains control areas for horizontal eye movement and face movement. The medulla oblongata is continuous with the spinal cord at the foramen magnum. It contains the vital cardiovascular and respiratory

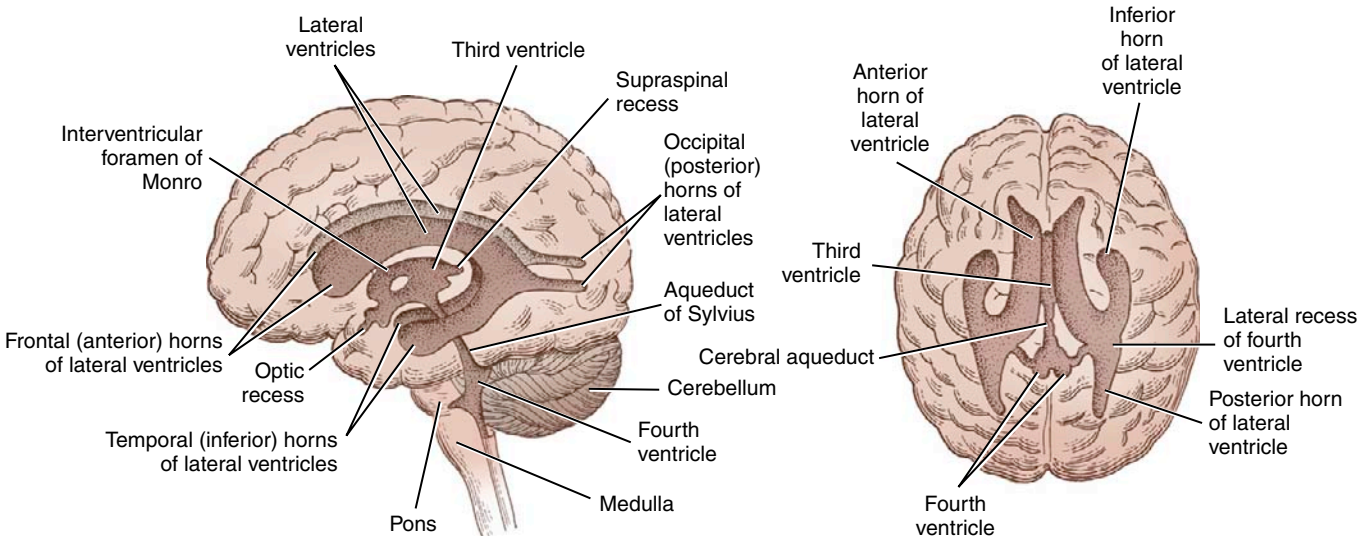


FIGURE 20-12 Ventricular system showing its relationship to various parts of brain.

regulatory centers (see Figure 20-9). Damage to the brainstem is often devastating and life-threatening, because it can affect movement, senses, consciousness, perception, and cognition.

Cerebellum. The cerebellum, which occupies most of the posterior fossa, forms the roof of the fourth ventricle (Figures 20-8 and 20-12). It has two lateral lobes, or hemispheres, and a medial portion, the vermis. The fissures of the cerebellum are small and run transversely. The cerebellum is concerned principally with balance and coordination of movement. It has many complex connections with higher and lower centers and exerts its influence unilaterally—in contrast to the cerebral hemispheres, which act contralaterally. By splitting the vermis in the exact midline, a satisfactory exposure of tumors that lie in the fourth ventricle is obtained without sacrificing the important cerebellar functions.

Pathologic Lesions of the Brain. An estimated new 22,070 brain and other nervous system cancers were estimated to occur in 2009 (American Cancer Society [ACS], 2009). Brain metastases outnumber primary neoplasms by at least 10 to 1, and they occur in 20% to 40% of cancer patients. Because no national cancer registry documents brain metastases, the exact incidence is unknown, but it has been estimated that 98,000 to 170,000 new cases are diagnosed in the United States each year (National Cancer Institute [NCI], 2009).

Multiple factors are suspected of playing a role in the pathogenesis of intracranial neoplasms. Early diagnosis simplifies surgical treatment because increased ICP and severe neurologic changes are not usually present. Brain tumors are either malignant or benign, depending on the cell type. Primary tumors generally do not resemble the carcinomas and sarcomas found elsewhere in the body and rarely metastasize outside the CNS. Both primary and metastatic tumors of the brain and its membranes are included in the term *intracranial tumors*.

Traditionally, tumors are classified by cell type; however, classification of brain tumors is an evolving process. The widely used World Health Organization (WHO) system lists more than 120 types of brain tumors (NCI, 2009). Table 20-1 gives the approximate percentage of CNS tumors by histologic type. A brief description of a select list of brain tumors follows:

TABLE 20-1

Frequency of Primary CNS Tumors in Adults

Tumor Type	Percentage
Glioblastoma	50
Meningioma	17
Astrocytoma	10
Pituitary adenoma	4
Oligodendroglioma	3
Ependymoma	2
Medulloblastoma	2
Neurilemmoma	2
Hemangioma	2
Craniopharyngioma	1
Pinealoma	1
Sarcoma	1
Others	5

Modified from Janus TJ, Yung WKA: Primary neurological tumors. In Goetz CG: *Clinical neurology,* ed 3, Philadelphia, 2007, Saunders.

1. *Tumors of intraepithelial tissue* encompass gliomas, tumors believed to originate from neuroglial cells.
   a. Astrocytomas are the most common of all primary brain tumors. They usually occur in the cerebellum of children and the cerebrum of adults. They are often cystic and discrete in children and infiltrating and ill-defined in adults. Astrocytomas are classified in the WHO system based on the principal cell type and on the degree of anaplasia as grade I to IV, with grade I being the more favorable type of tumor and grade IV being the most malignant. Glioblastoma multiforme (GBM), a grade IV astrocytoma, is an infiltrative, fast-growing, rapidly recurring cerebral tumor that occurs most frequently in the sixth and seventh decades of life. It is the most common type of primary brain tumor, accounting for about 50% of gliomas (Sloan et al, 2005). It is one of the few tumors that is capable of invading both cerebral hemispheres by crossing the midline. Areas of necrosis are characteristic.

Recent studies have consistently demonstrated the benefits of radical surgical resection. Postoperative radiation therapy significantly improves survival. Even with aggressive multimodality therapy, median survival is less than 1 year and 5-year survival is less than 5% (Sloan et al, 2005).

b. Oligodendroglioma, typically found in the cerebral hemispheres, is usually infiltrating but occasionally moderately well-defined. It frequently presents in middle age with seizure. It is now believed that the true incidence of oligodendrogliomas is 5% to 15% of gliomas, much higher than previously thought. Therapy usually consists of surgery followed by radiation therapy and chemotherapy (Sloan et al, 2005).

c. Ependymoma occurs most frequently in children and is likely to arise in or near the ventricular walls. It commonly occurs in the fourth ventricle, where it abuts or involves vital medullary centers. It also frequently metastasizes into the subarachnoid spaces. This tumor accounts for 3% to 4% of gliomas. Surgical resection followed by radiation therapy is the usual treatment. The 5-year survival rate is 73% (Central Brain Tumor Registry of the United States [CBTRUS], 2007-2008).

d. Medulloblastoma is a fast-growing, rapidly recurring tumor of the vermis of the cerebellum and fourth ventricle that usually occurs in young children. It characteristically metastasizes into the subarachnoid spaces, usually spreading to the base of the brain by this route. It accounts for 15% to 20% of childhood intracranial brain tumors and is the most common malignant pediatric brain tumor.

2. *Tumors of the meninges (meningiomas)* commonly occur in people in the fourth to sixth decades of life (Al-Mefty and Heth, 2005). They are usually benign, circumscribed, slow-growing tumors, arising from arachnoid cells with secondary attachment to the dura. Various factors have been implicated in the development of meningiomas. They typically involve the cortex and bone of the skull with growth. They can be very vascular and may adhere to the dural venous sinuses or major arteries, making their complete removal challenging. However, meningiomas often can be totally surgically removed.

3. *Tumors of the cranial nerves (vestibular schwannomas)* are benign; they usually arise from the neurilemma sheath cells of the vestibular portion of the eighth cranial nerve within the auditory meatus. The term *acoustic neuroma* is a misnomer. These tumors grow slowly to fill the cerebellopontine angle and may indent the brainstem. Presenting symptoms include hearing loss, tinnitus, and disequilibrium.

4. *Hemopoietic neoplasms and lymphomas:* CNS involvement with lymphoma may occur secondarily from a systemic lymphoma or may arise primarily in the CNS (CBTRUS, 2007-2008). The main role for surgery is for tumor biopsy. Stereotactic techniques are well suited for these often-deep tumors. The standard treatment after biopsy is radiation therapy, allowing for a median survival of 10 months. Adding chemotherapy can prolong survival (Greenberg, 2005).

5. *Germ cell tumors* occur in the midline (suprasellar and pineal region). Other than benign teratomas, all intracranial germ cell tumors are malignant and may metastasize by way of CSF and systemically. Tumors of the pineal region are very challenging to the neurosurgeon. Open microsurgery, endoscopy, and stereotactic biopsy are surgical options. Pineal region tumors often cause hydrocephalus. An endoscopic third ventriculostomy or a shunting procedure is routinely performed to alleviate the symptoms of hydrocephalus. Radiation therapy, chemotherapy, and radiosurgery are also treatment considerations.

a. Germinoma is a neoplasm arising from germ cells. Survival with germinomas is much better than with nongerminomatous tumors (teratoma, embryonal cell carcinoma, choriocarcinoma).

b. Teratoma is a congenital tumor containing embryonic elements.

c. Embryonal cell carcinoma consists of a highly primitive group of neoplasms that arise in childhood. Predominantly large hemispheric masses involving deep supratentorial structures, these tumors are highly vascular and have poor prognoses. The primitive neuroectodermal tumor (PNET) is one such tumor.

d. Choriocarcinoma is an extremely rare, very malignant neoplasm.

6. *Cysts and tumorlike lesions* include the following types:

a. Epidermoid and dermoid cysts are developmental, benign tumors typically located in the suprasellar region.

b. Colloid cysts are slow-growing benign tumors. They classically occur in the anterior third ventricle, blocking the foramen of Monro and causing obstructive hydrocephalus.

7. *Tumors of the sellar region* include the following types:

a. Pituitary adenomas can be classified as nonfunctioning or functioning. Nonfunctioning pituitary adenomas account for approximately 30% of pituitary tumors, usually occur in people in the fourth and fifth decades of life, and do not cause clinical hormone hypersecretion. They are typically large and cause hypopituitarism or blindness from regional compression. The usual treatment is endoscopic or microscopic transsphenoidal removal of the tumor (see Transsphenoidal Hypophysectomy, p. 876). Following operative decompression, vision improves in approximately 80% of patients (Oyesiku, 2005). Radiation therapy or stereotactic radiosurgery may also be used. Functioning pituitary adenomas secrete excess quantities of pituitary hormones. The question of medical versus surgical treatment is ever present in the management of this group of patients. Adenomas may be further subdivided into microadenomas, which are less than 1 cm in diameter and usually discovered because of an endocrinopathy, and macroadenomas, which are larger than 1 cm and usually present with compressive effects of the tumor (Oyesiku, 2005).

(1) Chromophobe tumors are relatively common in the anterior pituitary glands of adults. They cause compression of the pituitary, adjacent optic chiasma, and hypothalamus. Compression of the hypothalamus may lead to diabetes insipidus.

(2) Eosinophilic adenomas are secretory, causing an excessive amount of growth hormone in the serum.

(3) Basophilic adenomas are responsible for the excessive secretion of corticotropic, gonadotropic, and thyrotropic hormones. Acromegaly or, less commonly,

Cushing's syndrome may occur and cause the patient to seek help long before the tumor has expanded sufficiently to compromise the optic chiasma.

(4) Prolactin cell adenoma exhibits considerable differences in clinical presentation, depending on the gender of the patient. In women of reproductive age, the onset of amenorrhea and galactorrhea with associated infertility is an obvious sign. The diagnosis of a prolactinoma is established early in the course. In men, the clinical endocrinal symptoms, which include decreased libido and impotence, are not as conspicuous and initially may be disregarded by the patient. As a result, male patients frequently do not seek medical attention until the tumors are large and have spread beyond the confines of the sella turcica.

b. Craniopharyngiomas account for 2.5% to 4% of intracranial tumors, with 50% occurring in childhood (Greenberg, 2005). They arise from the region of the pituitary stalk and typically contain both solid and cystic components. Calcification above the sella turcica is often seen radiographically. In addition to headache, vertigo, vomiting, and papilledema, diabetes insipidus and visual field changes are common. Although complete surgical removal is often impossible if it adheres to the carotid artery or hypothalamus, a subtotal resection with radiation offers favorable results.

8. *Metastatic tumors* are the most common brain tumor seen clinically, making up about half of brain tumors. They usually arise from carcinomas, more rarely from sarcomas, and occasionally from melanomas and retinal tumors. The most common sources are lung and breast cancer. The management of brain metastasis is complex and controversial. The current principal options for treatment include whole-brain radiation therapy, surgery, and stereotactic radiosurgery. The most important prognostic variables are the extent of systemic disease and the patient's functional status and age. These factors, along with the size, number, and location of tumors, guide treatment decisions. Median survival only increases from 3 to 6 months with radiation therapy and steroids to 9 to 12 months with surgery and stereotactic radiosurgery (McCutcheon, 2005).

A brain lesion is diagnosed by history, neurologic examination, diagnostic studies (especially computed tomography [CT] scan and magnetic resonance imaging [MRI]), and biopsy. The manifestations of an intracranial tumor fall into two classes: those resulting from irritation or impairment of function in specific areas of the brain directly affected by the tumor and those resulting from diffuse increased ICP. The most common presentation of brain tumors is progressive neurologic deficit, usually motor weakness. Headache and seizures are also common presenting symptoms (Greenburg, 2005).

Large left or bifrontal lobe tumors may cause striking personality changes and depressive symptoms. Lesions in the left frontotemporal region, where motor speech originates, lead to aphasia. Parietal lobe lesions may result in contralateral weakness and sensory changes, along with defects in the perception of objects. Occipital tumors produce hemianoptic visual defects.

Cortical tumors frequently produce focal seizures of diagnostic value. The onset of epileptiform seizures in an adult is often associated with an intracranial neoplasm. Posterior fossa tumors often manifest their presence by blocking the CSF circulation, but they may also destroy cerebellar function, resulting in incoordination, ataxia, scanning speech, and deafness.

Treatment of brain tumors, although based on the characteristics of the tumor, can involve administration of steroids or antiepileptic medications, management of hydrocephalus, surgery, radiosurgery, radiation, and chemotherapy.

The presentation of multiple brain lesions in a patient is of grave concern, and an infective process should be considered along with the possibility of multiple tumors. Stereotactic biopsy of the lesion is most likely to provide a diagnosis. The operative team may be required to employ precautions to prevent the spread of an unknown infective process. Identification of the infective agent and process determines proper treatment.

Ventricular System and Cerebrospinal Fluid

Within the brain are four communicating cavities, or ventricles, filled with CSF. In the lower medial portion of each cerebral hemisphere lies a large lateral ventricle that resembles a wishbone and is separated anteriorly from its counterpart by a thin septum (see Figure 20-12). Each lateral ventricle has a body and three horns: frontal, occipital, and temporal. Below the bodies of the lateral ventricles is a central cleft, or third ventricle. It communicates anteriorly with the lateral ventricles through the foramen of Monro and posteriorly with the fourth ventricle through the aqueduct of Sylvius—a long, narrow channel passing through the midbrain. The fourth ventricle is a cavity in the posterior fossa, between the cerebellum and the brainstem. In the roof of the fourth ventricle is the foramen of Magendie, an opening into the cisterna magna; at the lateral margins are the two foramina of Luschka, which open into the cisterna pontis. These cisterns are cavities that serve as reservoirs for CSF.

Much of the CSF originates in the choroid plexuses of the ventricles. These are tufted, vascular structures that allow certain fluid elements of the blood to pass through their ependymal linings. The choroid plexus is found along the floor in each lateral ventricle, on the roof of the third ventricle, and in the posterior portion of the fourth ventricle. Most of the fluid is formed in the lateral ventricles and flows through the interventricular foramen of Monro to the third ventricle and through the aqueduct of Sylvius to the fourth ventricle, where it escapes into the subarachnoid space of the basal cisterns through the foramina of Magendie and Luschka. From the basal cisterns the fluid flows around the spinal cord, over the cerebellar lobes, around the medulla and the base of the brain, and over the cerebral hemispheres in the subarachnoid space. The fluid is absorbed into the venous circulation through villi of the arachnoid (pacchionian granulations) into the great dural venous sinuses, particularly the superior sagittal sinus, and by diffusion through perivascular, perineural, and periradicular channels (see Figure 20-7).

Spinal fluid bathes the brain and spinal cord, helps support the weight of the brain, and acts as a cushion for the brain and spinal cord by absorbing some of the force of external trauma. By variation in its volume, it aids in keeping ICP relatively constant. If the brain atrophies, the amount of CSF increases to fill the dead space; if the brain swells, the amount of CSF decreases to compensate for the increase in brain mass. The fluid can

carry certain drugs to diseased parts of the brain. It does not, however, play a significant role in supplying nutrition to the structures that it bathes. The total amount of circulating CSF averages 150 ml in the adult. The ventricles contain about 25 ml, and the remaining CSF circulates in the cranial and spinal subarachnoid space. CSF is secreted at a rate of between 21 and 24 ml/hr, or approximately 450 ml/24 hr. This means that in an adult, CSF is recirculated about three times each day.

Pathologic Conditions Related to Cerebrospinal Fluid. CSF can be examined by the lab to provide diagnostic information. CSF is most commonly obtained by way of lumbar puncture (LP). Because the subarachnoid space surrounding the brain is freely connected to the subarachnoid space of the spinal cord, any abnormal increase in ICP will be directly reflected as an increase at the lumbar site. Tumors, infection, hydrocephalus, and intracranial bleeding can cause increased intracranial and spinal pressure (Pagana and Pagana, 2009). LP is contraindicated when ICP is increased from a suspected intracranial mass that is causing neurologic symptoms. In this situation, the sudden reduction in pressure from the release of CSF could cause brain herniation. The ventricular fluid normally has a protein content of 5 to 15 mg/dl, whereas the protein content of spinal fluid is 25 to 45 mg/dl. These values may be considerably elevated in pathologic conditions of the CNS. The characteristics of normal spinal fluid are as follows:

- Appearance: clear and colorless
- Pressure: less than 20 cm H_2O
- Glucose: 50 to 75 mg/dl, or two thirds of blood glucose level
- Chloride: 700 to 750 mg/dl
- Cells: white blood cells (WBCs)—neonate, 0 to 30 cells/μl; 1 to 5 years, 0 to 20 cells/μl; 6 to 18 years, 0 to 10 cells/μl; adult, 0 to 5 cells/μl
- Protein: lumbar, 15 to 45 mg/dl
- Culture: no growth
- Gamma globulin: 3% to12% of total protein (Pagana and Pagana, 2009)

Elevations in CSF pressure can be caused by an expanding mass within the skull, such as a tumor, hemorrhage, or cerebral edema; an increase in formation or decrease in absorption of fluid, as in meningitis, encephalitis, and other febrile conditions; an increase in venous pressure within the skull from an obstruction to normal venous drainage; a blockage of absorption by inflammatory conditions of the arachnoid and perivascular spaces; any mechanical obstruction of the ventricular or subarachnoidal fluid pathways; or decreased absorption of CSF. These pathologic conditions can cause a dangerous increase in ICP, which ultimately could result in brain herniation and death.

The rate of absorption and production of CSF is related to the osmotic and hydrostatic pressures of the blood. Intravenous (IV) injection of hypertonic mannitol, commonly used with a nonosmotic diuretic, can be employed to pull fluid from tissue to the vascular space for excretion by the kidneys, resulting in systemic diuresis and a decrease in ICP.

Hydrocephalus is a condition marked by an excessive accumulation of CSF, resulting in dilation of the intracerebral ventricles where CSF is synthesized and circulated. Enlargement of cerebral ventricles is the result of CSF blockage and interruption of CSF circulation or CSF reabsorption. The causes of hydrocephalus are many, including congenital conditions, aqueductal stenosis, tumors or cysts of the ventricular system, subarachnoid hemorrhage (SAH), posterior fossa tumors, or trauma with increased ICP. Noncommunicating (obstructive) hydrocephalus involves an obstruction of CSF pathways. In communicating hydrocephalus, the normal CSF pathways are open; however, there is an abnormality in CSF absorption with increased ICP. Normal-pressure hydrocephalus (NPH) is a communicating hydrocephalus that produces a normal pressure on random LP (Greenberg, 2005). NPH most commonly develops in the elderly, probably because of abnormal CSF absorption; however, the cause may not be apparent. Symptoms of dementia, unsteady gait, and urinary incontinence are seen with normal pressure and chronic hydrocephalus. Those with acute hydrocephalus present with headache, nausea, vomiting, drowsiness, and papilledema.

The appropriate surgical procedure depends on the precise type of hydrocephalus. Whenever possible, an obstructing lesion that causes hydrocephalus should be surgically removed. For some cases of obstructive hydrocephalus, endoscopic third ventriculostomy may be possible. With endoscopic third ventriculostomy, CSF can be diverted by surgically creating an opening at the floor of the third ventricle, thus eliminating the need for a shunt. However, treatment of hydrocephalus in both the adult and pediatric populations is generally by placement of a ventriculoperitoneal (VP) shunt (Wang and Avellino, 2005). With acute symptoms, temporary placement of an external ventriculostomy catheter used to measure the ICP and drain CSF may be preferred, thus postponing or eliminating the need for a permanent VP shunt.

Cerebral Blood Supply

The brain requires 20% more oxygen than any other organ to maintain its high level of metabolic activity. The arterial supply to the brain enters the cranium through the two internal carotid arteries anteriorly and the two vertebral arteries posteriorly. These communicate at the base of the brain through the circle of Willis (Figure 20-13), which ensures continuity of the circulation if any one of the four main channels is interrupted. However, these connections are extremely variable and do not always have functional anastomoses. The main branches for distribution of blood to each hemisphere of the brain from the internal carotid arteries are the anterior and middle cerebral arteries. Each artery nourishes a specific area of the brain (Figures 20-13 and 20-14). The anterior cerebral artery supplies the anterior two thirds of the medial surface and adjacent region over the convexity of the hemisphere, thus including about half of the frontal and parietal lobes. The middle cerebral artery supplies most of the lateral surface of the hemisphere, including half of the frontal, parietal, and temporal lobes. The posterior cerebral artery, which originates at the basilar artery, supplies the occipital lobe and the remaining half of the temporal lobe, principally on the inferior and medial surfaces. The brainstem and cerebellum are supplied by branches of the basilar and vertebral arteries.

The cerebral veins do not parallel the arteries as the veins do in most other parts of the body. The external cortical veins anastomose freely in the pia mater, forming larger cerebral veins, and as such they pierce the arachnoid membrane, cross the subdural space, and empty into the great dural venous sinuses. A subdural hemorrhage after head trauma may arise from disruption of these bridging vessels; an epidural hemorrhage

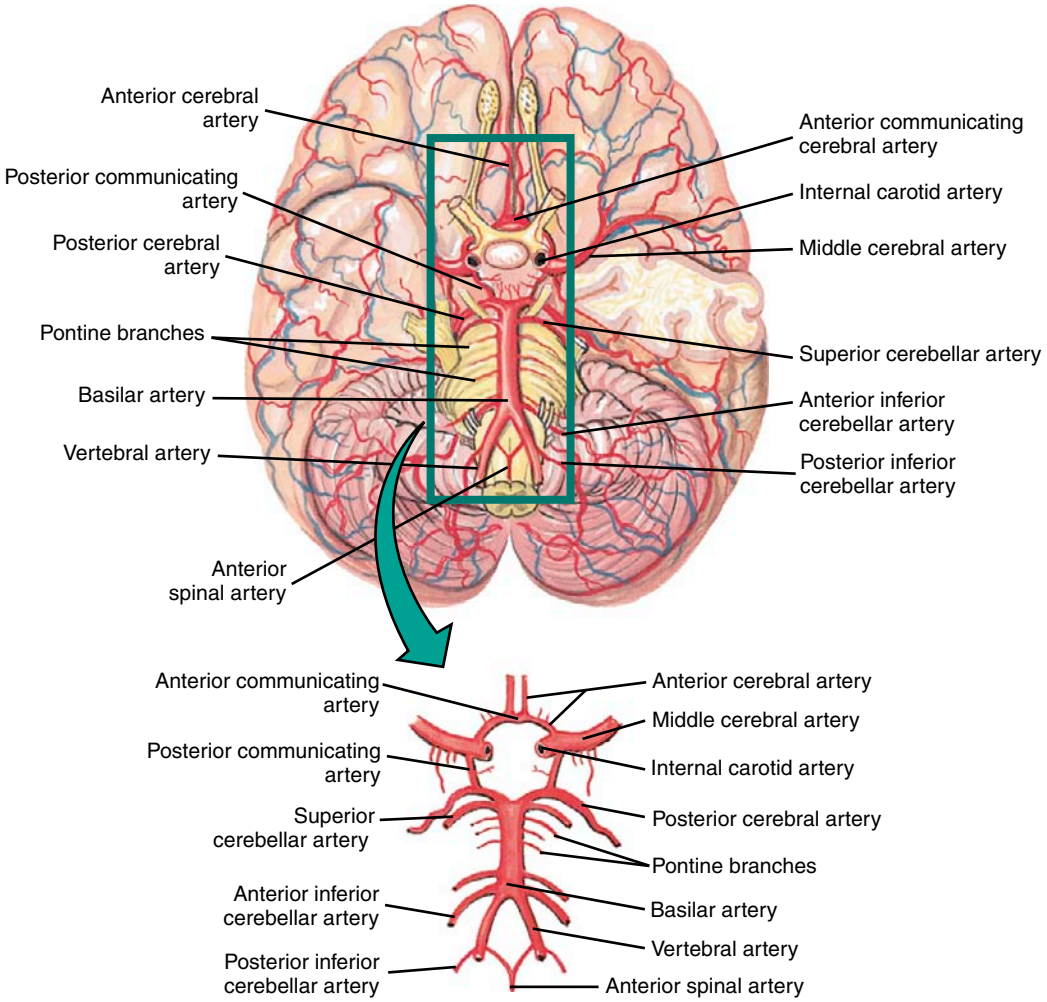


FIGURE 20-13 Principal cerebral arteries and circle of Willis *(box)*.

often results from lacerations of the middle meningeal artery—a branch of the external carotid artery that supplies the dura mater. The deep cerebral veins, which drain the interior of the hemispheres, empty principally into the great vein of Galen and the inferior sagittal sinus (Figures 20-15 and 20-16).

The blood transports oxygen, nutrients, and other substances necessary for the proper functioning of living tissue. The needs of the brain for oxygen and glucose are critical. The brain can store only small amounts of oxygen and energy-producing nutrients. Constant flow of blood to the brain must be maintained.

The brain uses oxygen in the metabolism of glucose—the chief source of energy. Protein and fat metabolism plays little part in energy production. In the face of an oxygen deficit, the survival time of CNS tissue is very short. In the presence of low levels of blood glucose, CNS function is compromised and unconsciousness results.

Generally, all factors affecting the systemic blood pressure indirectly affect the cerebral circulation. The brain normally receives 20% of the cardiac output. The cerebral blood flow is kept constant by an autoregulation phenomenon such that increases in blood pressure lead to vasoconstriction of cerebral arteries and decreases in blood pressure cause cerebral vasodilation to maintain a relatively constant cerebral blood flow. When the mean arterial pressure falls below 60 mm Hg, the autoregulation mechanism usually fails.

Vascular Pathologic Conditions of the Brain. Vascular lesions of the brain are most often diagnosed in people who present with acute, spontaneous intracranial hemorrhage.

ANEURYSMS. Aneurysms arise from a complex set of circumstances involving a congenital anatomic predisposition and local or systemic factors that weaken the arterial wall, leading to dilation. The majority of these lesions occur at the branching points of large subarachnoid conducting arteries. The greatest vulnerability to aneurysmal development occurs at points of vessel bifurcation. Acute SAH in this setting can lead to vessel vasospasm (with greatest risk at 4 to 10 days after the SAH), cerebral ischemia, hydrocephalus, increased ICP, diabetes insipidus, syndrome of inappropriate secretion of antidiuretic hormone (SIADH), respiratory failure, brain injury, and risk of rebleeding. The vessels of the circle of Willis are most often implicated, including the posterior communicating artery, anterior communicating artery, middle cerebral artery, carotid artery, posterior inferior cerebellar artery, vertebral artery, and basilar artery. Surgical intervention techniques are based on the characteristics of the aneurysm. Small neck aneurysms may be occluded using coils placed by means of

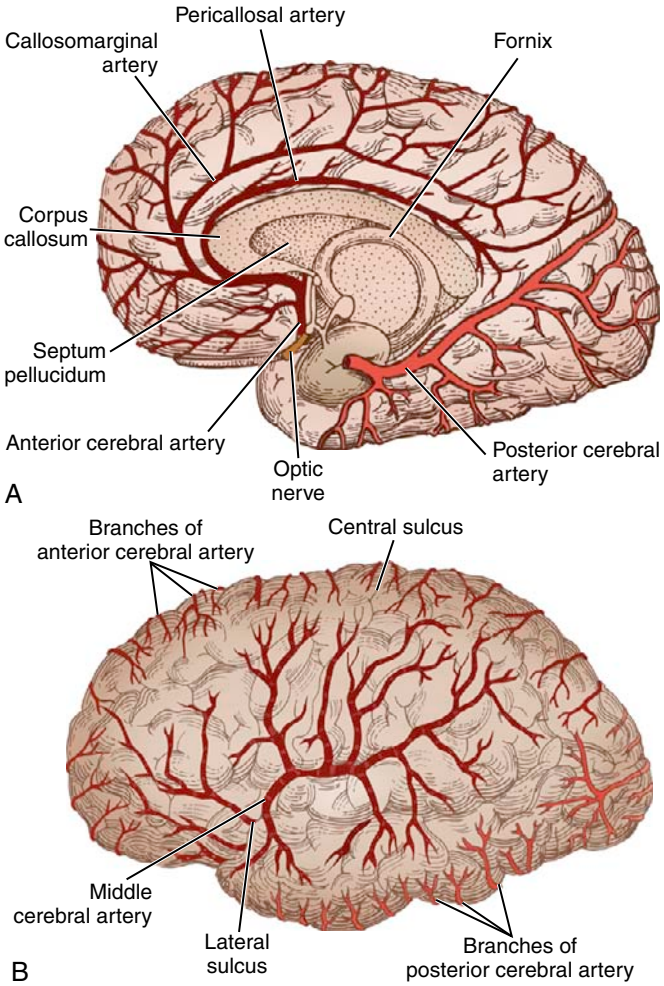


FIGURE 20-14 **A**, Arteries of medial surface of brain. **B**, Arteries of the lateral surface of brain.

interventional radiology techniques. Aneurysmal clipping by way of a craniotomy approach is most often used to treat broad neck aneurysms.

VASCULAR MALFORMATIONS. Vascular malformations of the CNS are characterized by congenital lesions that have the potential to produce symptoms any time during the life of an individual with the malformation. Types of vascular malformations include arteriovenous malformations (AVMs), cavernous malformations, capillary telangiectasias, and venous malformations. AVMs are complex lesions in which direct shunting of arterial blood to the venous system occurs. The vascular channels are tightly packed and have a propensity to hemorrhage. Capillary telangiectasias are small vascular malformations commonly seen in the pons. They rarely bleed. Cavernous malformations are cystic vascular spaces, similar to capillary telangiectasias but larger and with a tendency to bleed. Venous malformations are the most common type, comprising anomalous veins, a single tortuous vein, or a number of smaller veins joining at a single point. These are considered benign and rarely bleed. Surgical excision of the cavernous malformation and the AVM is recommended.

HEMATOMAS. Hematomas are collections of blood that coagulate to form space-occupying lesions. An intracerebral hemorrhage, the cause of stroke in many hypertensive patients, results in hematoma formation most often in the basal ganglia, subcortical white matter, cerebellum, and brainstem. These hematomas compress vital structures, depress consciousness, and can be catastrophic. They are often inoperable (Greenberg, 2005).

Intracranial trauma can cause a shearing of arterial and venous vessels that results in hematoma collections in the epidural and subdural spaces. These space-occupying lesions raise ICP and often result in serious neurologic disruption (Figure 20-17). Epidural hematomas are often the result of a blow to the head causing a tear in the middle meningeal artery, which lies on the dura under the skull. These arterial hemorrhages can be life-threatening in that they can cause rapid deterioration in level of consciousness secondary to size of the bleed and brain displacement by the hematoma (Figure 20-18). In contrast to an epidural hematoma, a traumatic subdural hematoma usually results from venous bleeding and collects more slowly. Bridging veins in the subdural space are torn; blood escapes, dissecting a space between the dura and the arachnoid, and collects over one cerebral hemisphere (Figure 20-19). Subdural hematomas may be acute, subacute, or chronic (Figure 20-20). Chronic hematomas can often be evacuated through burr holes, but acute hematomas may require a craniotomy to remove the clot and control bleeding.

CEREBRAL ISCHEMIA. Any area of the brain can become ischemic from an arterial occlusion or embolization. Symptoms may be gradual or sudden. Intracranial plaques most commonly form at the bifurcation of the internal carotid artery, into the middle and anterior cerebral arteries. In select cases, extracranial-intracranial arterial microanastomosis can be performed. Carotid endarterectomy can be performed for extracranial lesions of the carotid artery (see Chapter 26).

Cranial Nerves

Twelve pairs of cranial nerves arise within the cranial cavity (Figure 20-21). Although they are part of the PNS, from a surgical standpoint they are considered with the head.

First Cranial Nerve. The olfactory nerve, a fiber tract of the brain, is located under the frontal lobe on the cribriform plate of the ethmoid bone. It transmits the sense of smell. Frontal lobe tumors, fractures of the anterior fossa of the skull, and lesions of the nasal cavity may affect the olfactory nerve.

Second Cranial Nerve. The optic nerve is a fiber tract of the brain. It originates in the ganglion cells of the retina and passes through the optic foramen in the apex of the orbit to reach the optic chiasma. A partial crossing of the fibers occurs there; so the fibers from the nasal half of each retina pass to the opposite side. Posterior to the chiasma, the visual pathway is called the *optic tract*. Still farther back, it becomes the optic radiation. Lesions in various parts of this pathway produce characteristic defects in the visual fields. For example, a lesion near the chiasma usually destroys the temporal vision of each eye (bitemporal hemianopia), whereas a lesion of the occipital lobe produces impairment of vision (homonymous hemianopia), affecting the right or left halves of the visual fields of both eyes.

Lesions that affect the optic nerve and are treated by neurosurgery include primary gliomas of the nerve, pituitary tumors that press on the optic chiasma, and occasionally meningiomas of the optic nerve sheath or in the region of the sella turcica

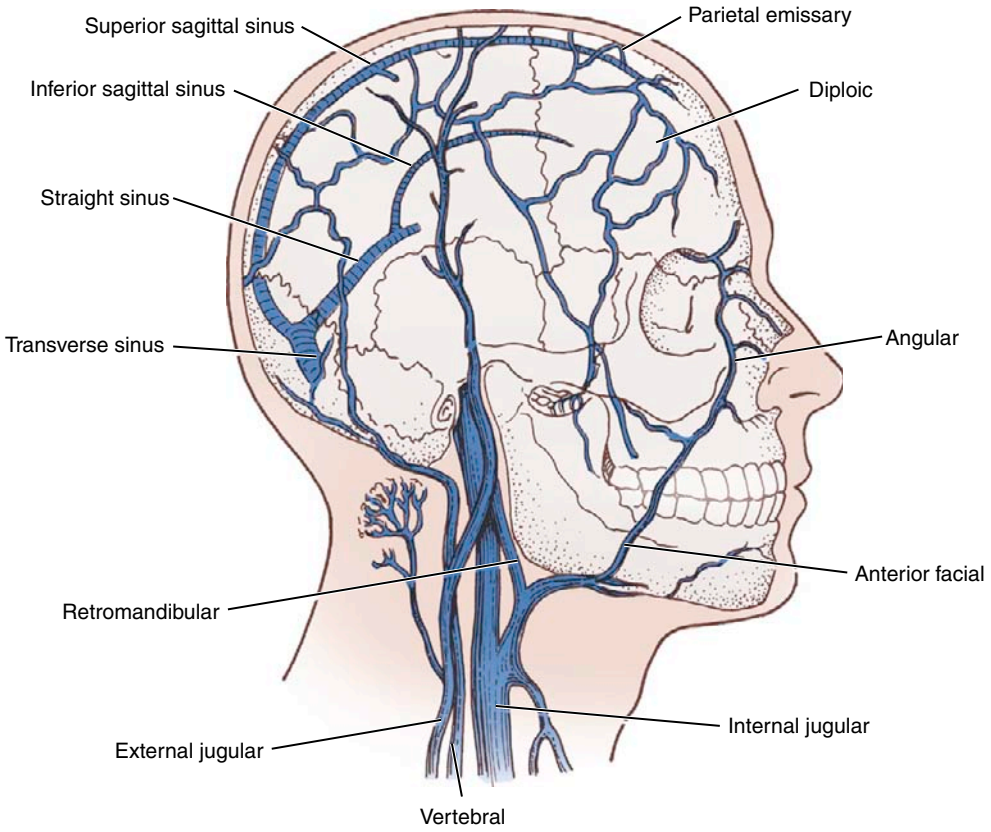


FIGURE 20-15 Semischematic projection of large veins of head. Deep veins and dural sinuses are projected on skull. Note connection (emissary veins) between superficial and deep veins.

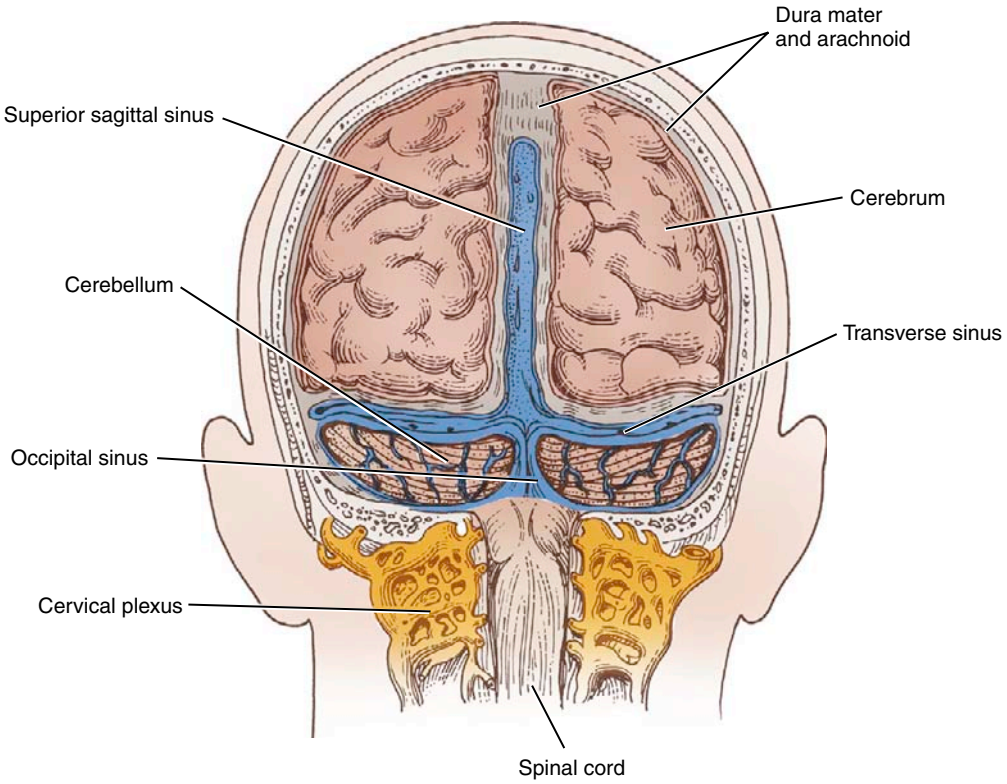


FIGURE 20-16 Venous sinuses shown in relation to brain and skull.

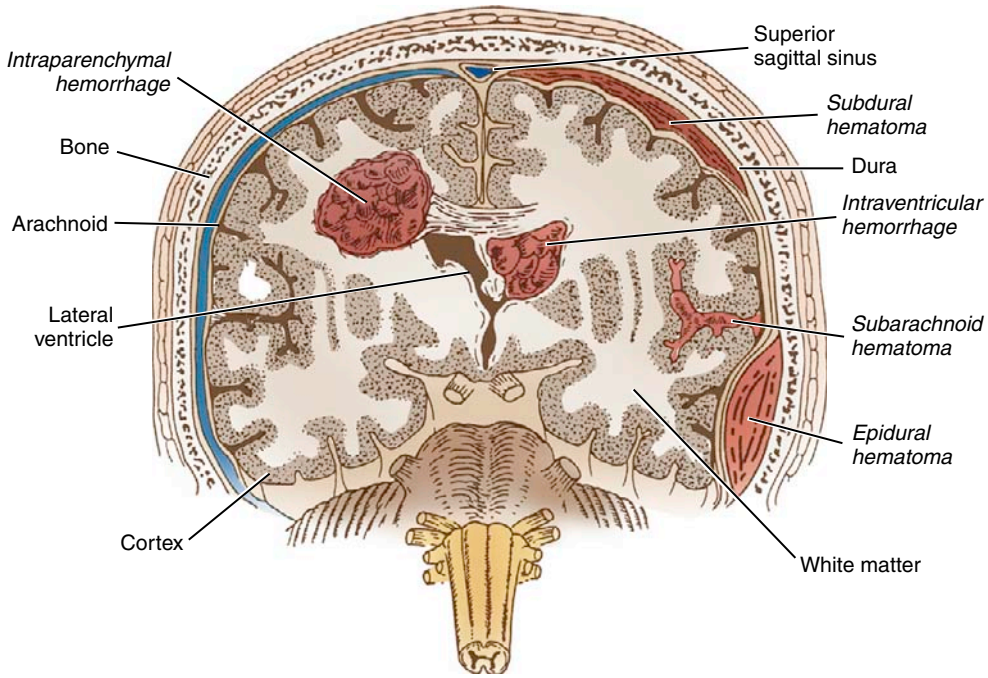


FIGURE 20-17 Types of intracerebral hemorrhage (in italics).

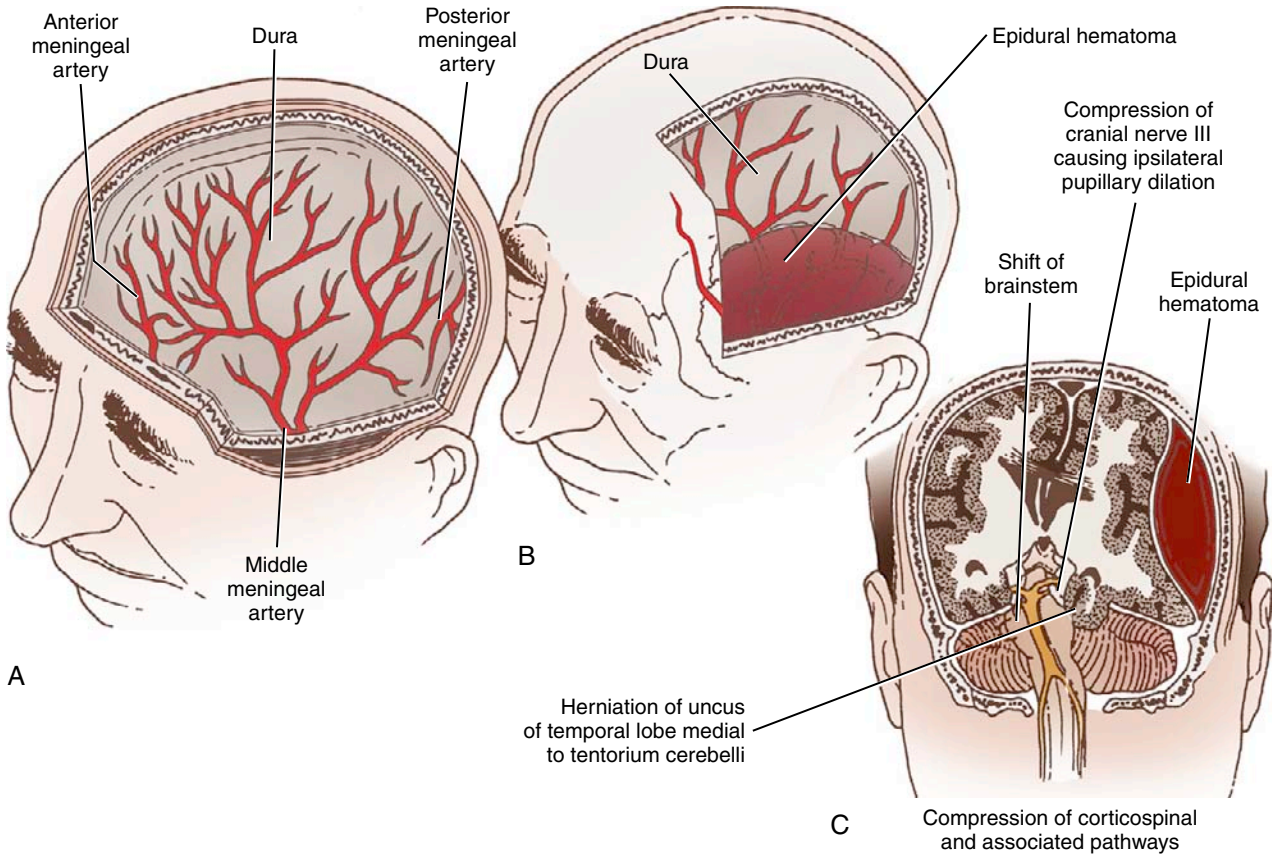


FIGURE 20-18 Epidural hematoma is typically caused by trauma resulting in laceration of the middle meningeal artery. **A**, The middle meningeal artery. The typical traumatic epidural hematoma is caused by a laceration of this vessel. **B** and **C**, A linear fracture of the squamous portion of the temporal bone has torn the middle meningeal artery, which has resulted in an epidural hematoma.

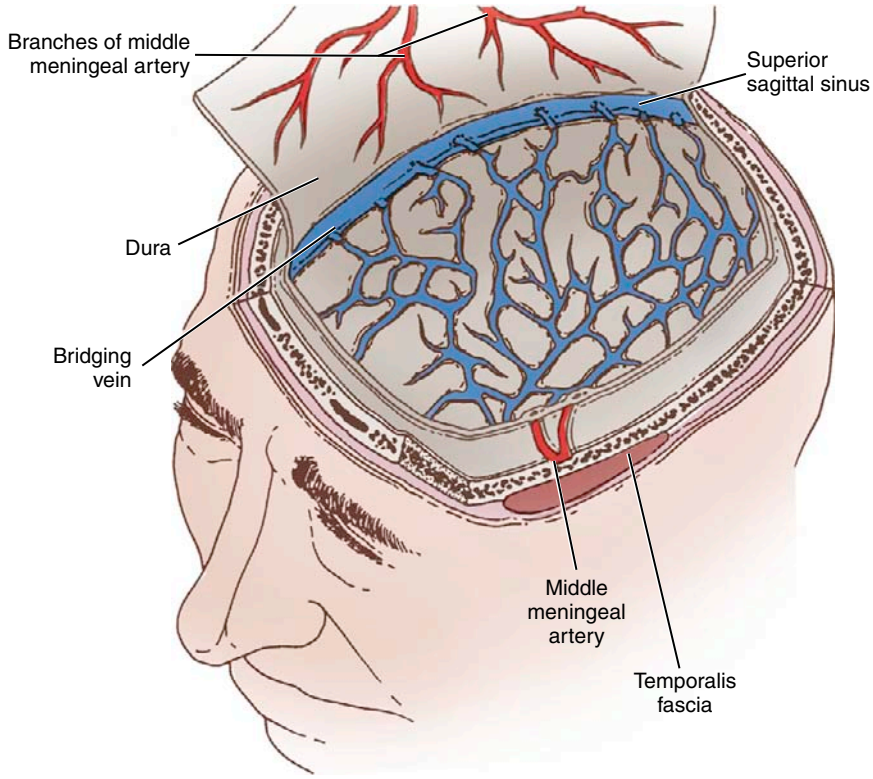


FIGURE 20-19 Veins are shown extending from the surface of the brain to the superior sagittal sinus. Differential movement of the brain within the skull at the time of injury may tear one or more of these veins, leading to the formation of a subdural hematoma.

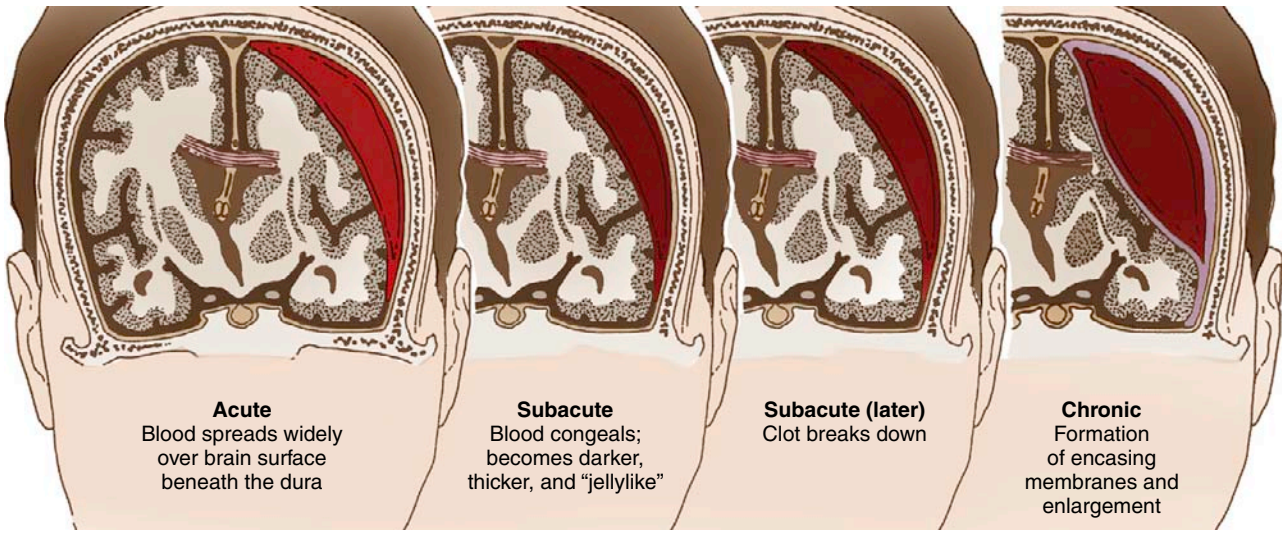


FIGURE 20-20 A subdural hematoma is liquid at first and subsequently clots. It is then reabsorbed or develops into a chronic subdural hematoma as a thick, vascular outer membrane. A thin, inner membrane develops around liquefying blood, starting about 2 weeks after injury. The chronic subdural hematoma enlarges as further bleeding occurs within it.

and olfactory groove. The optic nerves and chiasma are best exposed through a frontal craniotomy along the floor of the anterior fossa or through a frontotemporal approach along the sphenoid ridge. Cranial base approaches using an orbital osteotomy or orbital-zygomatic osteotomies improve access and exposure of the optic system.

Third, Fourth, and Sixth Cranial Nerves. The third, fourth, and sixth cranial nerves are three pairs of nerves—the oculomotor, the trochlear, and the abducens, respectively. They are conveniently considered together because they are the motor nerves to the muscles of the eyes. They are affected by many toxic, inflammatory, vascular, and neoplastic lesions. The third

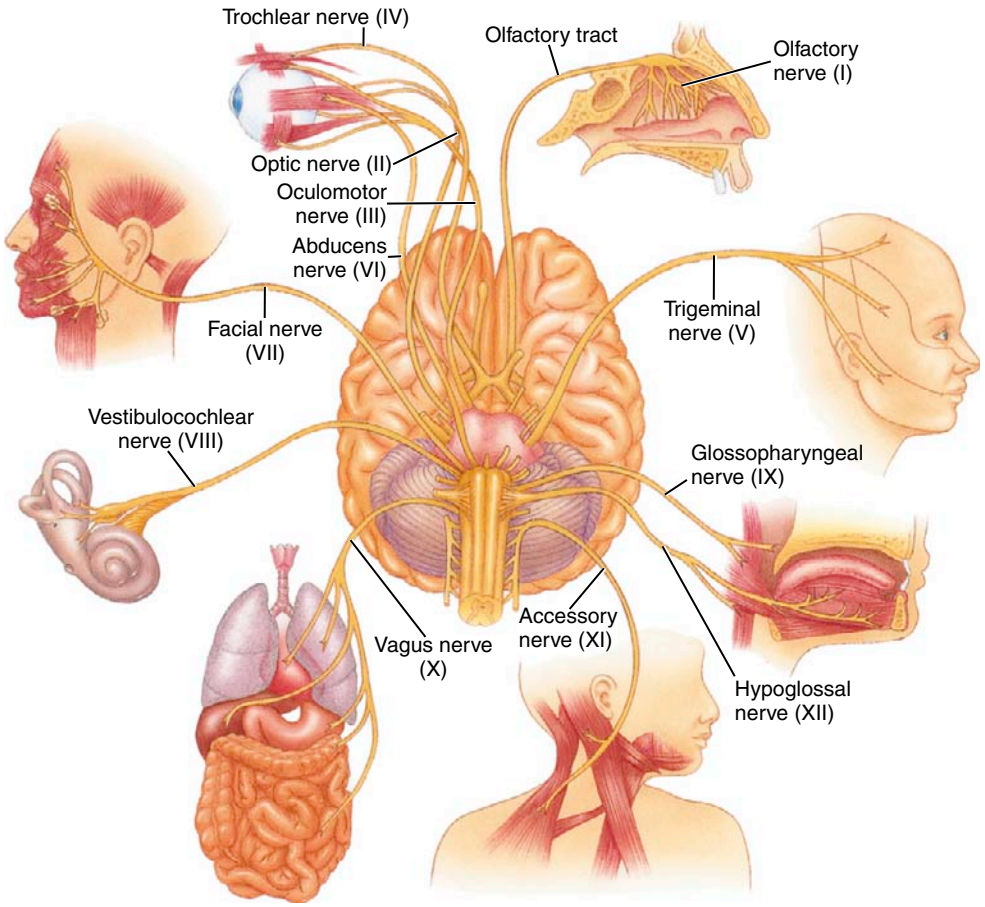


FIGURE 20-21 Ventral surface of brain showing attachment of cranial nerves.

nerve may be affected by aneurysms of the posterior communicating artery, and pressure against this nerve accounts for pupillary dilation when temporal lobe (uncal) herniation, resulting from increased ICP, is present.

Fifth Cranial Nerve. The trigeminal nerve has two functions: (1) sensory supply to the forehead, eyes, meninges, face, jaw, teeth, hard palate, buccal mucosa, tongue, nose, nasal mucosa, and maxillary sinus; and (2) motor innervation of the muscles of mastication. The sensory fibers that arise from cells in the trigeminal ganglion travel along the medial wall of the middle cranial fossa and then extend peripherally in three divisions: ophthalmic, maxillary, and mandibular. Behind the ganglion the fibers enter the brainstem by way of the sensory root. The motor root, which originates from cells in the brainstem, follows the course of the larger sensory component (Figure 20-22).

Trigeminal neuralgia (tic douloureux) is characterized by excruciating, piercing paroxysms of pain, affecting one or more of the major peripheral divisions. The recurrent attacks are usually instigated by stimulation of trigger zones present about the face, nares, lips, and teeth. This condition, believed to be caused by a high incidence of vascular compression on the root entry zone of the nerve leading to demyelination, tends to occur unilaterally and in older persons. Medical treatment is frequently unsuccessful in the long term. Types of neurosurgical procedures currently recommended for trigeminal neuralgia include percutaneous rhizotomy using glycerol, radiofrequency, or balloon compression; radiosurgery; and microvascular decompression (Research Highlight). Microvascular decompression requires a suboccipital craniotomy and is the most invasive of the techniques. However, it is the least destructive and probably the most durable treatment.

Seventh Cranial Nerve. The facial nerve supplies the musculature of the face and the sensation of taste for the anterior two thirds of the tongue. It originates in the brainstem, passes through the skull with the eighth nerve by way of the internal acoustic meatus, continues along the facial canal, and exits just posterior to the parotid gland. The nerve may be damaged by vestibular schwannomas (e.g., acoustic neuromas), fractures at the base of the skull, mastoid infections, and surgical procedures in the vicinity of the parotid gland.

Bell's palsy, a facial lower motor neuron paralysis, can affect the seventh nerve. It may last for a few weeks to a few months, but recovery usually takes place. When permanent interruption of the nerve occurs, useful operations for restoration of function include spinal accessory-facial anastomosis and hypoglossal-facial anastomosis. These operations are performed high in the neck behind the parotid gland by use of the operating microscope.

Eighth Cranial Nerve. The acoustic nerve has two parts, both sensory—the cochlear for hearing and the vestibular for balance. The former receives stimuli from the organ of Corti and the latter from the semicircular canals. The major surgical

RESEARCH HIGHLIGHT

Gamma Knife Therapy for Trigeminal Neuralgia

Trigeminal neuralgia is an extremely painful and debilitating condition characterized by unilateral intense pain in the ear, eye, lips, nose, scalp, forehead, teeth, or jaw. A variety of treatments, including microvascular surgical decompression, are offered to patients. These treatments have varying degrees of success and recurrence of the pain is an unfortunate phenomenon. Patients who have persistent or recurrent symptoms despite intervention represent approximately 10% to 30% of patients who undergo microvascular decompression (MVD), 20% to 50% of those who undergo a percutaneous destructive procedure, and 30% to 40% of those who undergo Gamma Knife radiosurgery. The Gamma Knife creates a lesion at the root entry of the trigeminal nerve, resulting in degeneration of the axons and ability to transmit impulses.

Researchers investigated the use of the Gamma Knife as a salvage procedure in patients who had recurrent or persistent pain after surgical treatment and/or failure of medical management. A total of 79 patients underwent salvage Gamma Knife radiosurgery as a treatment for their trigeminal pain. Pain outcome and quality-of-life indicators were measured 1 month after treatment during the patient follow-up visit and periodically after that via surveys and chart analysis.

The median follow-up period measured after the Gamma Knife therapy was 5.3 years. Analysis of the data showed that at 5 years, 20% of patients were pain free and 50% had pain relief; 41% of the group studied required a subsequent procedure.

Researchers concluded that while salvage Gamma Knife therapy for refractive trigeminal neuralgia is an effective and safe treatment, additional research is indicated to gain further understanding about the mechanism of action responsible for recurrent trigeminal dysfunction.

Modified from Little AS et al: Salvage gamma knife stereotactic radiosurgery for surgically refractive trigeminal neuralgia, *Int J Radiat Oncol Biol Phys* 74(2):522-527, 2009.

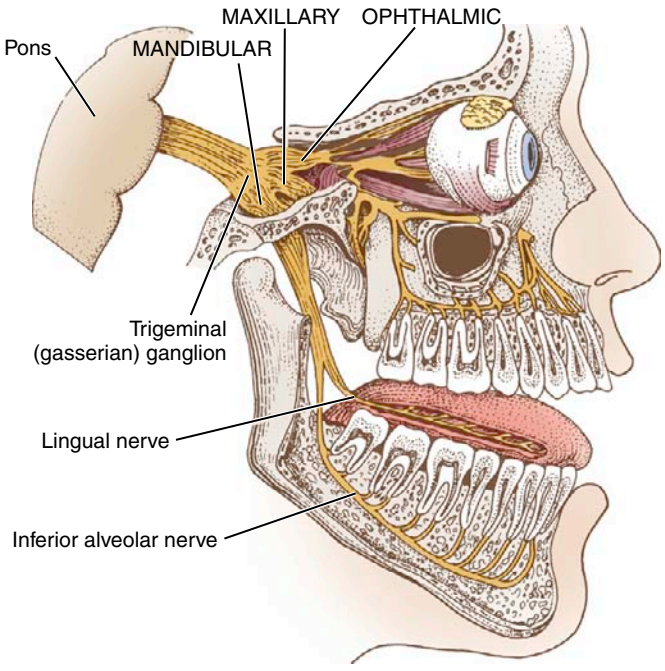


FIGURE 20-22 Trigeminal (fifth cranial) nerve and its three main divisions.

lesion of the eighth nerve is vestibular schwannoma (acoustic neuroma), a histologically benign tumor growing from the nerve sheath at its entrance into the internal auditory meatus. This tumor arises deep in the angle between the cerebellum and pons (cerebellopontine angle). Symptoms may include unilateral deafness, tinnitus, unilateral impairment of cerebellar function, numbness of the face from involvement of the fifth cranial nerve, and, late in the course, papilledema caused by increased ICP. The operative approach is usually through a retrosigmoid craniotomy, exposing the edges of the transverse and sigmoid sinuses. The surgeon must take great care to prevent injury to the pons and to preserve the facial nerve. Attempts are made to preserve the acoustic nerve with smaller tumors when hearing preservation is an option.

Meniere's disease is an affliction of the eighth nerve characterized by a recurrent and usually progressive group of symptoms including dizziness and a sensation of fullness or pressure in the ears. When medical measures fail to alleviate the problem, sectioning of the eighth nerve may be a surgical option.

Ninth Cranial Nerve. The glossopharyngeal nerve supplies the sense of taste to the posterior third of the tongue, supplies sensation to the tonsils and pharyngeal region, partially innervates the pharyngeal muscles, and primarily innervates the carotid sinus. Stimulation of the baroreceptors of the carotid sinus causes slowing of the heart, vasodilation, and decreased blood pressure. Its sensory component can be sectioned to treat a hypersensitive carotid sinus, or it can be sectioned in conjunction with the fifth nerve to treat painful malignancies of the face, mouth, and pharynx. The ninth nerve lies near the eighth nerve in the posterior fossa and is exposed in a similar way.

Tenth Cranial Nerve. The vagus nerve has many motor and sensory functions, primarily including innervation of pharyngeal and laryngeal musculature, control of heart rate, and regulation of acid secretion of the stomach. In neck surgery, the surgeon carefully avoids injury to the recurrent laryngeal branch because its injury results in vocal cord paralysis. In gastric surgery, the surgeon could sever the vagus nerve at the lower end of the esophagus to treat a peptic ulcer. The neurosurgeon is also concerned with preventing damage to the vagus nerve during posterior fossa surgery.

Eleventh Cranial Nerve. The spinal accessory nerve is a motor nerve to the sternocleidomastoid and trapezius muscles. To restore mobility to the face, it may be anastomosed to the peripheral end of a damaged facial nerve.

Twelfth Cranial Nerve. The hypoglossal nerve innervates the musculature of the tongue. Its neurosurgical interest is similar to that of the spinal accessory nerve.

Table 20-2 gives the function, origin, structures innervated, and assessment of the cranial nerves.

SPINE, SPINAL CORD, AND ADJACENT STRUCTURES

Vertebral Column

The primary roles of the spine are maintaining stability, protecting the neural elements, and allowing range of motion. The vertebral column has four distinct curves: cervical lordosis

TABLE 20-2

Understanding Cranial Nerves

Cranial Nerve	Function	Origin	Structures Innervated	Assessment
I Olfactory	Sensory	Olfactory bulbs below frontal lobes	Olfactory mucous membranes	Ability to identify familiar odors
II Optic	Sensory	Diencephalon	Retina of eye	Visual acuity Visual fields
III Oculomotor	Motor	Midbrain	Medial, superior, and inferior rectus muscles of eye Inferior oblique eye muscles Sphincter of iris	Extraocular movements Pupillary reaction to light and accommodation
IV Trochlear	Motor	Midbrain	Superior oblique muscle of eye	Extraocular movements
V Trigeminal	Mixed	Pons	*Sensory:* pain, touch, and temperature sensations in cheeks, jaw, and chin; corneal reflex *Motor:* muscles of mastication	Sensation in forehead, cheeks, jaw, and chin Mastication
VI Abducens	Motor	Pons	Lateral rectus muscle of eye	Extraocular movement
VII Facial	Mixed	Pons	*Sensory:* anterior two thirds of tongue *Motor:* muscles of face, forehead, and eye	Taste for anterior two thirds of tongue Movement of facial muscles (smile) Facial symmetry
VIII Acoustic	Sensory	Pons	Cochlear organ of Corti Vestibule and semicircular canals	Hearing acuity Balance
IX Glossopharyngeal	Mixed	Medulla	*Sensory:* posterior third of tongue *Motor:* muscles of pharynx	Taste for posterior third of tongue Movement of pharynx Gag reflex
X Vagus	Mixed	Medulla	*Sensory:* skin of external ear and mucous membranes *Motor:* muscles of larynx, pharynx, and esophagus; thoracic and abdominal viscera	Swallowing Movement of pharynx Gag reflex Cough
XI Spinal accessory	Motor	Medulla	Sternocleidomastoid and trapezius muscles	Shoulder shrug Turn head
XII Hypoglossal	Motor	Medulla	Tongue	Movement and strength of tongue

(a backward bend), thoracic kyphosis (a forward bend), lumbar lordosis, and sacral kyphosis. The spinal column consists of 33 vertebrae: 7 cervical, 12 thoracic, 5 lumbar, 5 sacral (fused as 1 section), and 1 coccygeal, which may have 1 to 3 fused sections (Figure 20-23).

The first cervical vertebra, or atlas, supports the skull. The second cervical vertebra, or axis, can be identified by its odontoid process, a vertical projection extending into the foramen of the atlas like a stick in a hoop. It rests against the anterior tubercle of the first cervical vertebra. Ligaments hold the two together but allow considerable rotational movement. The other cervical, thoracic, and lumbar vertebrae are more alike in structure. Each has a body, an oval block of bone situated anteriorly. An intervertebral disk, a fibrocartilaginous elastic cushion, separates one body from another (Figures 20-24 and 20-25). The spinal cord lies in a canal formed by the vertebral bodies, pedicles, and laminae. Articular surfaces or facets project from the pedicles and form joints with the facets of the vertebrae above and below. Transverse processes extend laterally and serve as hitching posts for muscles and ligaments. Spinous processes extend posteriorly and can be palpated in most people. The vertebrae are held together by multiple ligaments and muscles (see Figure 20-25). Motion of the spine occurs at the articular facets and through the elastic intervertebral disks. The intervertebral disks bond the adjacent surfaces of the vertebral bodies. Each disk consists of a fibrous outer annulus that contains the inner nucleus pulposus.

Spinal Cord

The spinal cord is protected by the bony framework of the spinal column. The dura mater is separated from its bony surroundings by a layer of epidural fat. Beneath the dura mater is the arachnoid, a continuation of the same structure in the head. The subarachnoid space contains CSF. A thin layer of pia mater adheres to the cord, and CSF also circulates from the fourth ventricle into the central canal of the cord.

The spinal cord is a downward prolongation of the brainstem, starting at the upper border of the atlas and ending at the upper border of the second lumbar vertebra (Figure 20-26). The cord is oval in cross section. It is slightly flattened in the anteroposterior diameter. A cross section looks like a gray H

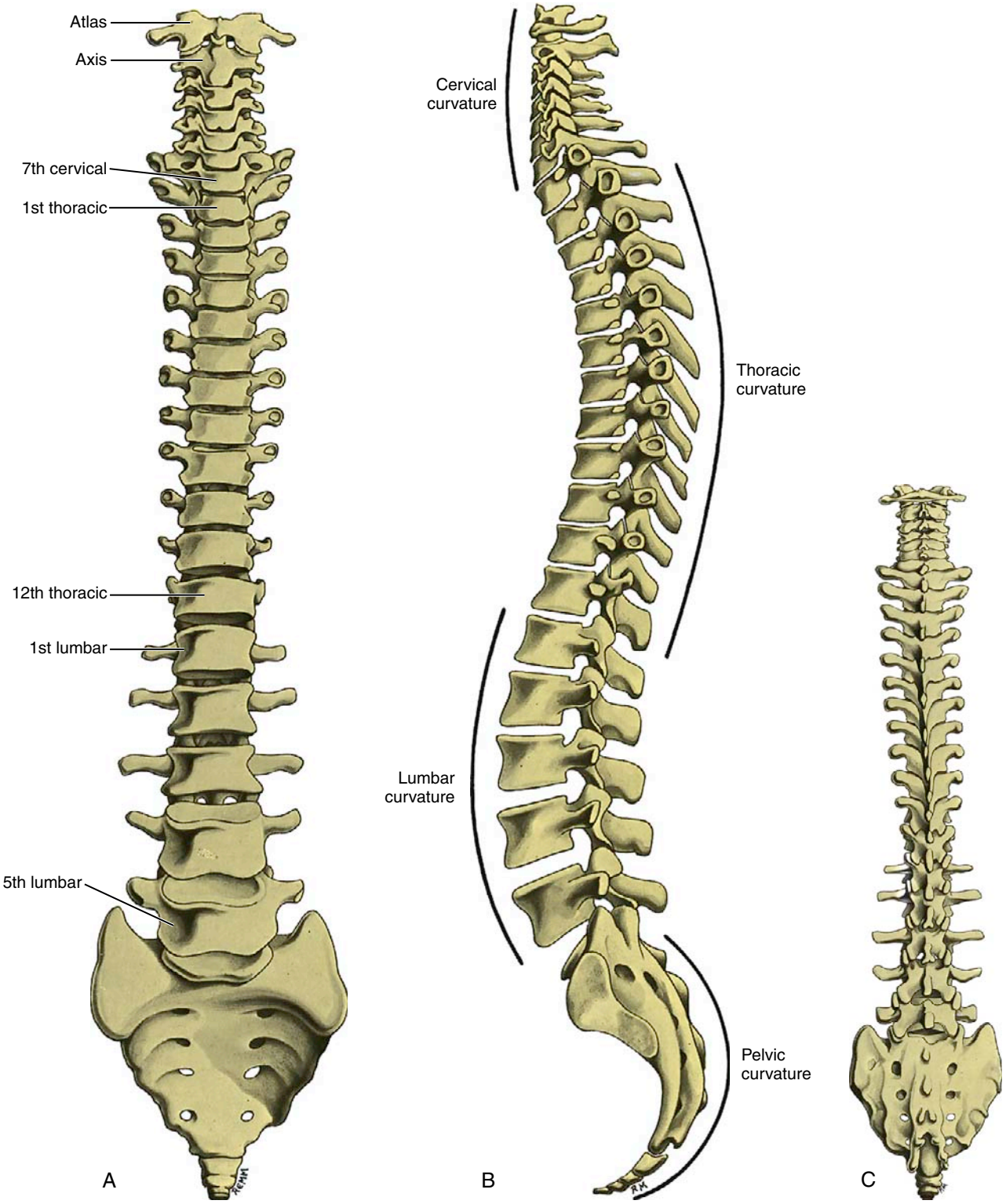


FIGURE 20-23 The vertebral column: **A**, anterior aspect; **B**, lateral aspect; **C**, posterior aspect.

surrounded by a white mantle split in the midline, anteriorly and posteriorly, by sulci (Figure 20-27).

The peripheral white matter carries long, myelinated motor and sensory tracts. The central gray matter consists of nerve cell bodies and short, unmyelinated fibers (see Figures 20-26 and 20-27). The principal long pathways are the laterally placed pyramidal tracts, carrying impulses down from the cerebral cortex to the motor neurons of the cord; the dorsal ascending columns, mediating sensations of touch and proprioception; and the anterolaterally placed spinothalamic tracts, carrying pain and temperature sensations to the thalamus—the sensory receiving station of the brain (Figure 20-28).

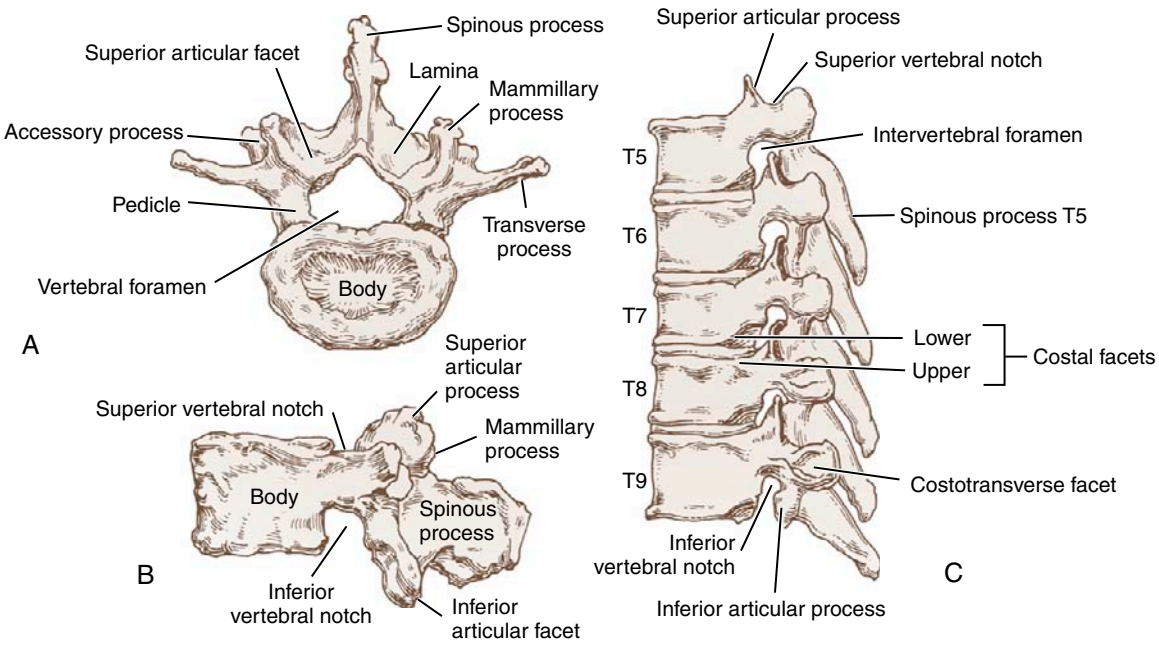


FIGURE 20-24 **A**, Fourth lumbar vertebra from above. **B**, Fourth lumbar vertebra from side. **C**, Fifth to ninth thoracic vertebrae, showing relationships of various parts.

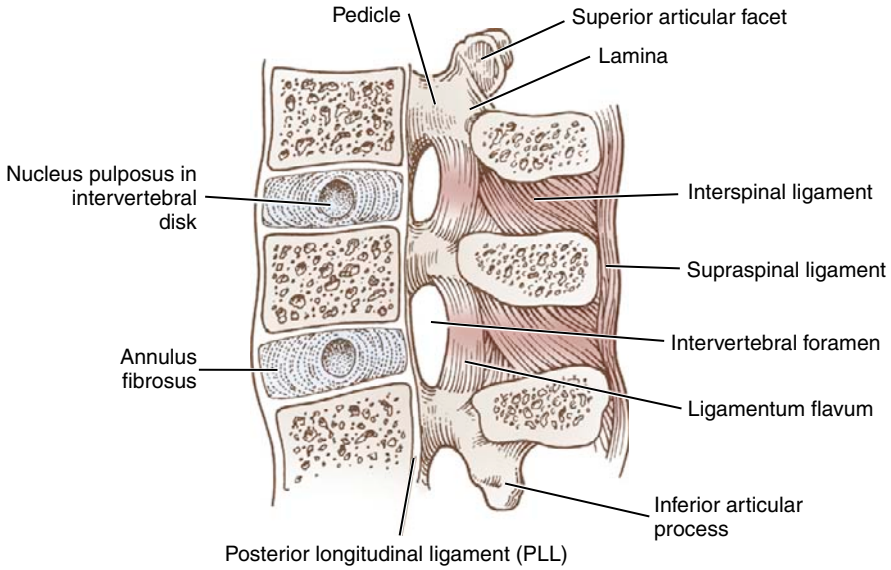


FIGURE 20-25 Median section through three lumbar vertebrae, showing intervertebral disks (nuclei pulposi).

Spinal Nerves

At each vertebral level is a pair of spinal nerves, each consisting of an anterior and a posterior root (see Figure 20-27). The anterior, or motor, root contains cell bodies that lie in the anterior horn of the spinal gray matter. The posterior, or sensory, root contains cell bodies that lie in the spinal ganglia located in the intervertebral foramina, the opening through which the nerves exit from the spinal canal and emerge from the cord. The course of the cervical nerves is horizontal, but at each lower level they assume an increasingly oblique and downward direction. In the lumbar region, the course of the nerves is nearly vertical, forming the cauda equina (see Figure 20-26).

The normal segmental sensory distribution is valuable in the anatomic localization of sensory disorders (Figure 20-29).

Dermatomes are bands of skin innervated by a sensory root of a single spinal nerve. Knowledge of these dermatomes aids the practitioner in locating neurologic lesions (Figure 20-30).

Spinal Vasculature

The vasculature of the spinal cord and vertebral column is a rich, delicate network. The arterial blood supply to the spinal cord arises from the vertebral arteries as the anterior spinal artery and the posterior spinal arteries. These vessels branch and anastomose on both sides of the cord and within the

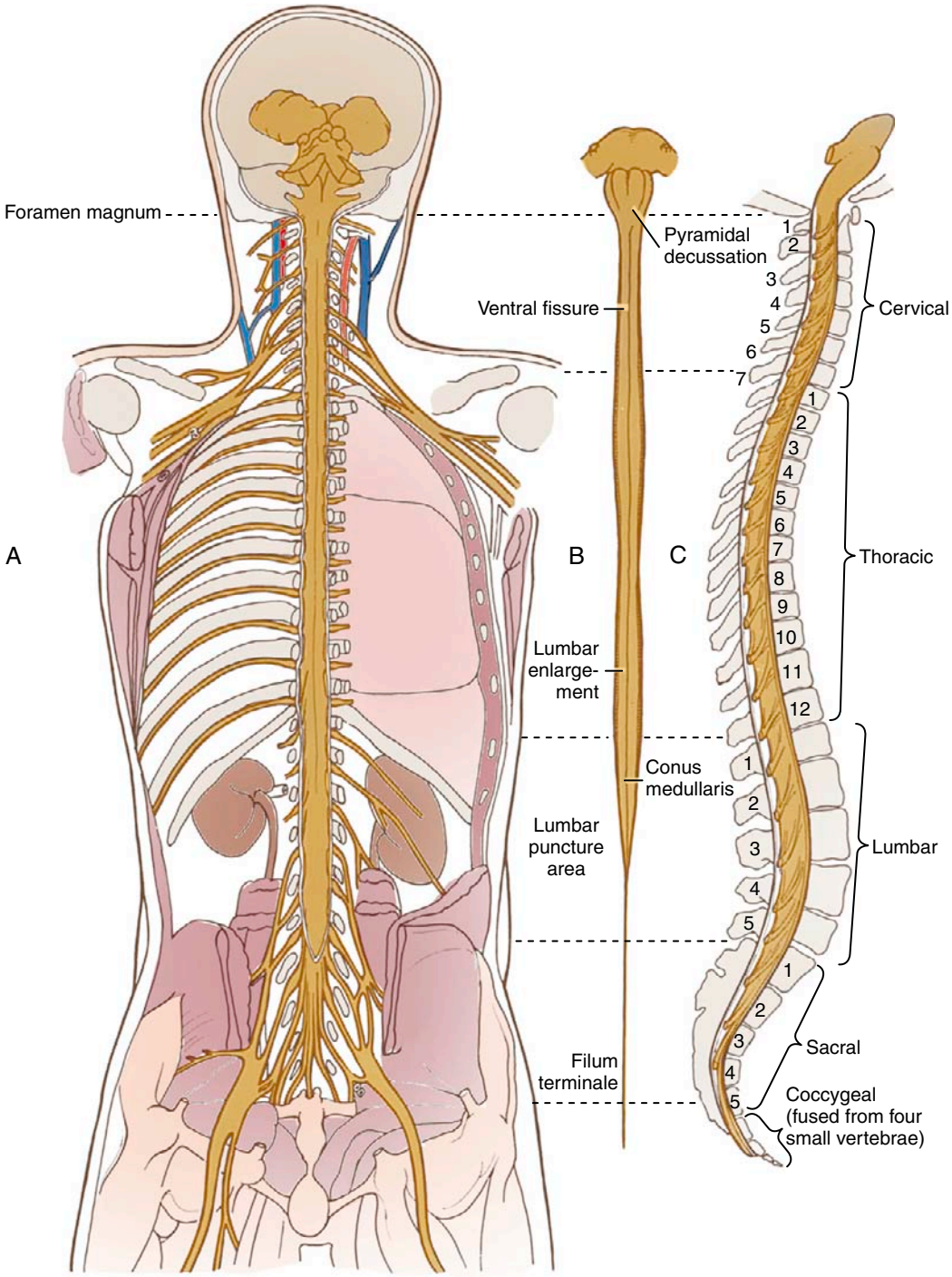


FIGURE 20-26 Posterior view of brainstem and spinal cord. **A**, Torso dissected from back is shown. Dura mater has been opened and cord exposed. Levels concerned can be easily determined by referring to ribs on left side of thorax. Cord proper terminates opposite body of second lumbar vertebra (**B**) as conus medullaris. **B**, Ventral surface of cord stripped of dura mater and arachnoid. It is symmetric in structure, two halves of which are separated by ventral fissure. This fissure stops at foramen magnum. Caudally, pia mater leaves conus medullaris as glistening thread, or filum terminale. **C**, Cord is exposed from lateral side. Dura mater has been opened. Because cord is shorter than canal and spinal nerves exit through intervertebral foramina, one at a time, lowest portion of canal is occupied only by a bundlelike accumulation of nerve roots—cauda equina. Caudal end of dural sac, enclosing spinal cord and cauda equina, lies somewhere between bodies of first and third sacral vertebrae. Size and position of the three views correspond, and elimination of major vertebral levels is indicated by transverse lines for all three figures.

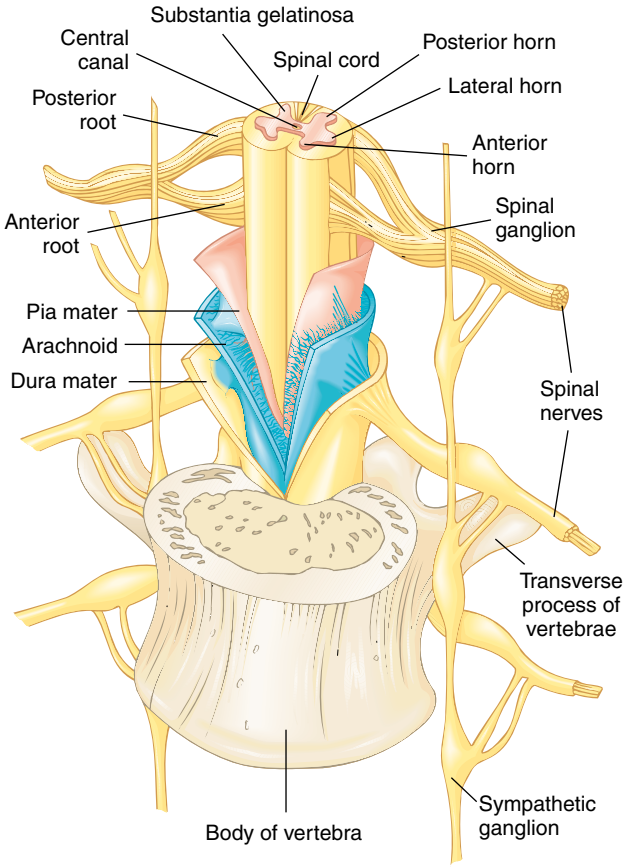


FIGURE 20-27 Spinal cord, showing meninges, formation of spinal nerves, and relationships to vertebra and to sympathetic trunk and ganglia.

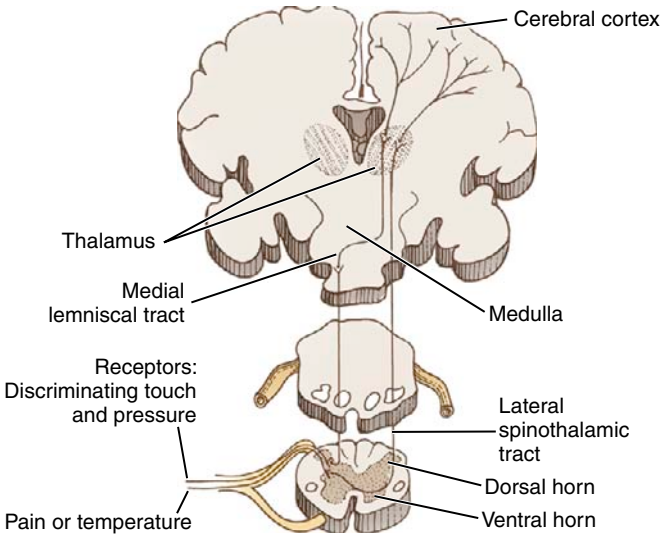


FIGURE 20-28 Lateral spinothalamic and medial lemniscal neural tracts.

substance of the cord. They also branch into anterior and posterior radicular arteries that form spinal rami as they accompany the spinal nerve roots through the intervertebral foramina.

A series of venous plexuses surround and innervate the spinal cord at each level in the vertebral canal. They anastomose with each other and form the intervertebral veins as they pass through the intervertebral foramina with the spinal nerves to join the intercostal, lumbar, and sacral veins. The lateral longitudinal veins near the foramen magnum empty into the inferior petrosal sinus and cerebellar veins. The venous network innervates the bony structures and musculature as well as the spinal cord and nerve roots. The perioperative nurse considers the possibility of venous bleeding during spinal surgery when planning care.

Pathologic Lesions of the Spinal Cord and Adjacent Structures

Surgery is performed to correct congenital malformations, traumatic injuries, tumors, abscesses, herniated and degenerative intervertebral disks, and intractable pain.

Meningocele. The most common congenital lesion encountered is a lumbar meningocele, or myelomeningocele—a failure of the union of the vertebral arches during fetal development. The fluid-filled, thin-walled sac often contains neural elements. This fetal anomaly is often diagnosed prenatally and is often seen with other CNS abnormalities, which include hydrocephalus, gyral abnormalities, and Chiari's malformation of the hindbrain. Refer to Chapter 25 for a discussion of the surgical treatment of meningocele.

Trauma. Trauma to the spine is most commonly caused by motor vehicle crashes and falls. The most common types of vertebral column injuries are fractures, subluxation (dislocation) injuries, and disk herniation, resulting in neurologic injury in 15% of trauma patients (Mendel et al, 2005). The cervical spine is the most vulnerable to injury. Spinal cord injury (SCI) occurs in males three to four times more often than females, usually between the ages of 15 and 30 years (Perrin and McBroom, 2005). Standardized trauma care and transport, early diagnosis, and closed reduction with surgical stabilization as necessary are part of spinal care focused on minimizing cord trauma and maximizing cord recovery. Spinal decompression, stabilization, and traction are all common interventions performed in trauma centers.

Spine and Spinal Cord Tumors. The most frequently occurring tumors of the spine are metastatic, and the spine is the most common site for skeletal metastasis. Although it is estimated that between 5% and 10% of cancer patients develop *symptomatic* spinal metastasis, it is estimated that as many as 30% to 90% of cancer patients actually develop skeletal metastasis (Donthineni, 2009). Pain is the earliest and most prominent symptom, followed by weakness. Secondary spinal tumors most often originate from carcinomas of the lung, breast, prostate blood. Approximately 17% of patients with other primary tumors may experience cord compression as a result of spinal metastases. Metastases to the spine have a predilection toward the thoracic spine, followed by the lumbar and cervical areas (Donthineni, 2009). Treatment goals for metastatic tumors of the spine are pain relief and preservation or restoration of neurologic function. Options include radiation, surgery, or a combination of these. Surgery involves both decompression of the spinal cord and nerve roots and stabilization of the spinal column.

Spinal tumors are classified according to location as *extradural* (outside the dura mater) or *intradural* (inside the dura mater). Intradural tumors may be either *extramedullary*

SURGICAL INTERVENTIONS

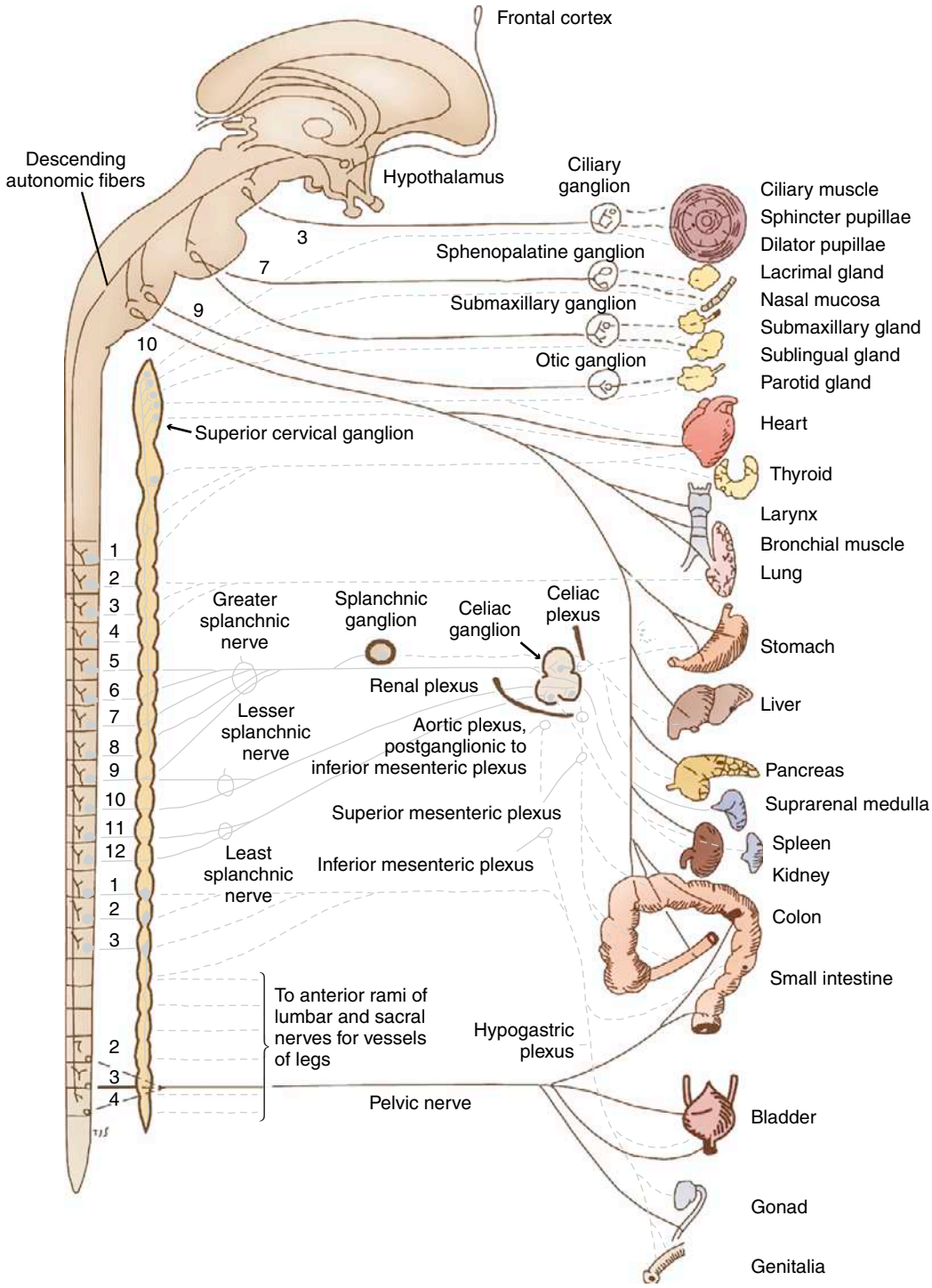


FIGURE 20-29 Sympathetic division of the autonomic nervous system.

(outside the cord) or *intramedullary* (within the cord). Although metastatic tumors may be found in each category, they are usually extradural. Spinal cord tumors account for approximately 15% of CNS tumors (Greenberg, 2005). Most primary CNS tumors are benign.

Extradural tumors arise outside the spinal cord in vertebral bodies or epidural tissues. They account for 50% to 60% of spinal cord neoplasms and include sarcomas and carcinomas, which may be metastatic from adjacent structures in or around the vertebrae (Harrop, 2005). Other extradural lesions include

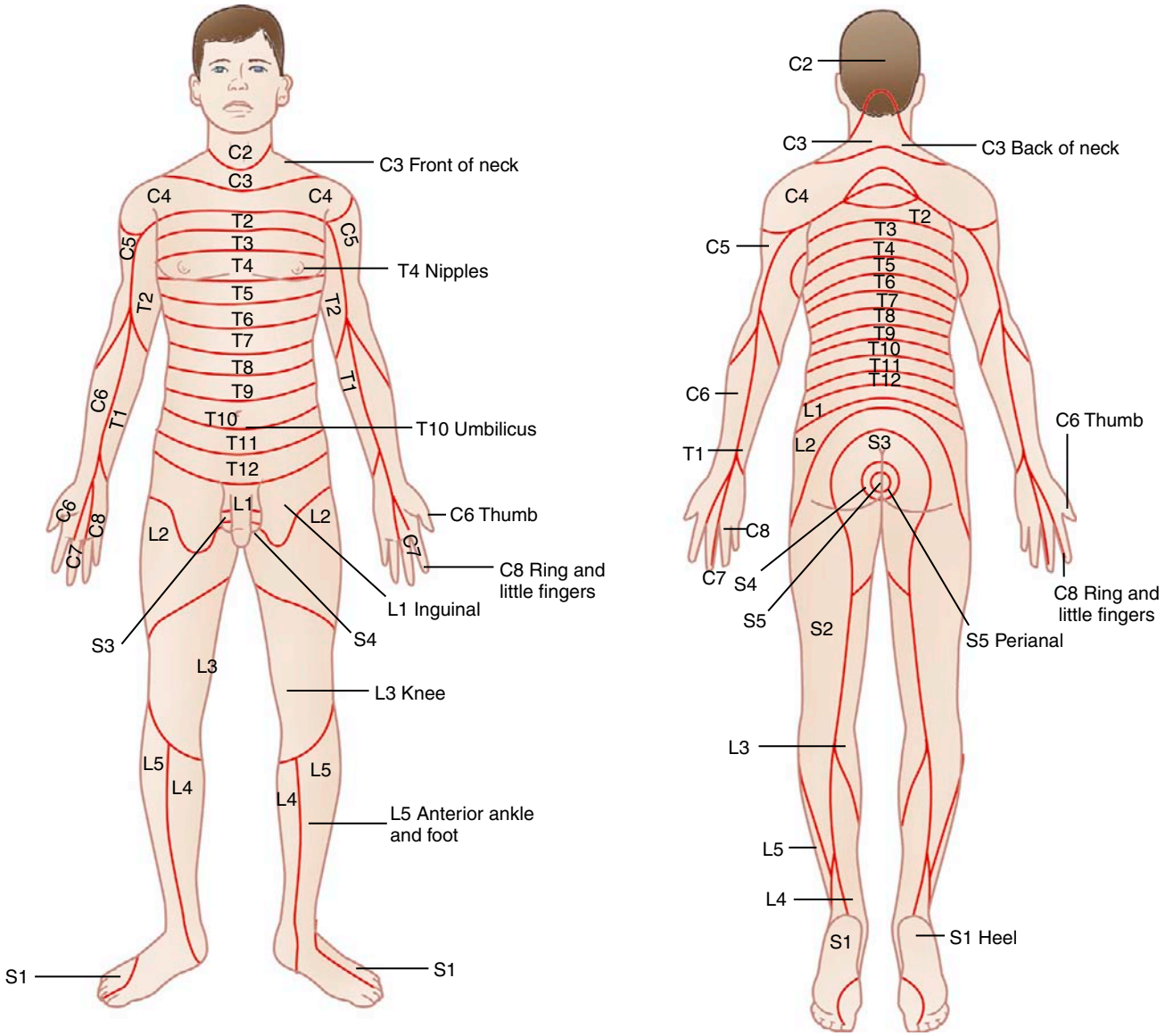


FIGURE 20-30 Dermatomes innervated by posterior nerve roots and their correlation on the body; both anterior and posterior views are shown. *C,* Cervical; *T,* thoracic; *L,* lumbar; *S,* sacral.

lymphomas, lipomas, neurofibromas, chondromas, angiomas, abscesses, and granulomas.

Most intradural tumors are extramedullary and benign and, if diagnosed early before severe neurologic deficits occur, offer an excellent prognosis. They manifest their presence by pain of a radicular nature and various motor and sensory disabilities below their segmental locations. Intradural extramedullary tumors represent 35% to 45% of spinal cord tumors (Harrop, 2005). They are usually benign and originate from the dura mater and arachnoid surrounding the cord and from the root sheaths of spinal nerves. Schwannomas (neuromas) are especially common in the thoracocervical area and may be part of generalized neurofibromatosis. Meningiomas also commonly occur in intradural extramedullary locations. Less frequently, lipomas or other types of tumors are found. Approximately 2% to 7% of spinal cord tumors are intradural intramedullary tumors (Harrop, 2005). These tumors infiltrate the cord tissue and are much more difficult to remove than are extramedullary tumors. Of the intramedullary tumors, the most common are ependymomas and astrocytomas.

Cord tumors frequently produce spinal fluid blockage and can be pinpointed accurately with MRI. Intraspinal injection of contrast material (myelography) is another option for diagnosis. Often, a standard laminectomy is used for exposure and removal.

Spinal Epidural Abscess. Spinal epidural abscess can develop from vertebral osteomyelitis, from infection originating at a distant source and transferred by the blood, or from direct inoculation caused by spinal surgery, LP, or epidural administration of anesthetic. Patients who are immunosuppressed are especially at risk for epidural abscesses. Clinical presentation involves spinal and radicular pain and muscle weakness that can progress to paralysis. Epidural abscess is most easily

diagnosed by MRI and typically treated with surgical decompression, culture, and irrigation, along with 4 to 8 weeks of IV antibiotic therapy.

Intervertebral Disk Disease. Intervertebral disk disease is the most frequently encountered neurosurgical problem. The axial skeleton bears both the body's weight and externally applied axial forces while maintaining mobility. Intervertebral disks serve as mechanical buffers that absorb axial loading, bending, and sheer forces. Bipedal posture further stresses the intervertebral disks, leading to degenerative disk disorders. Disk rupture occurs with radial fissuring of the annulus. The nucleus pulposus then escapes, extending to the margin of the annulus and posterior longitudinal ligament. Once the nucleus pulposus protrudes beyond the perimeter of the disk space into the epidural space, it results in nerve root compression and radiculopathy (pain produced by pressure or traction on the nerve roots) (Figures 20-31 and 20-32). Most disk protrusions occur at the L4-L5 and L5-S1 interspaces. Interventions include a medical trial of treatment with steroids and analgesics/narcotics, muscle relaxation, rest, epidural steroid injections, and, in failed cases, laminotomy or laminectomy with diskectomy. In far-lateral disk herniations, percutaneous lumbar diskectomy is often an alternative to laminotomy. This minimally invasive technique gains access to the disk space posterolaterally, using local anesthetic. The disk space is entered by way of a cannula. An aspiration probe may be used to remove the disk matter, or direct removal can be done microscopically or endoscopically.

Intractable Pain. Certain painful spinal lesions, usually of a malignant nature, can be controlled by use of epidural opiates, by use of fentanyl patches, or by temporary or permanent use of a medication pump. Another pain control measure is to divide the pain fibers supplying the affected area. This may be accomplished by sectioning the sensory roots intraspinally (posterior rhizotomy) or by incising the spinothalamic tracts that carry pain and temperature impulses (anterolateral cordotomy). Alternatively, spinal cord stimulation of the affected area can be achieved with the placement of electrodes in the epidural space. A laminectomy for exposure is necessary to perform these surgical procedures.

Peripheral Nerves. The PNS consists of those structures containing nerve fibers or axons that connect the CNS with motor and sensory, somatic and visceral, end-organs. The PNS includes the cranial nerves (III to XII), the spinal nerves, the autonomic nerves, and the ganglia.

The 31 pairs of spinal nerves are each numbered for the level of the spinal column at which they emerge: cervical, C1 through C8; thoracic, T1 through T12; lumbar, L1 through L5; sacral, S1 through S5; and coccygeal, 1. The first pair of cervical spine nerves emerges between C1 and the occipital bone. The eighth cervical nerves emerge from the intervertebral foramina between C7 and T1. The first thoracic nerves emerge between T1 and T2.

In the cervical and lumbosacral regions the spinal nerves regroup in a plexiform manner before they form the peripheral nerves of the upper and lower extremities. Those in the thoracic region form cutaneous and intercostal nerves. The principal nerves of the upper plexus include the musculocutaneous, median, ulnar, and radial. Those of the lumbosacral plexus include the obturator, femoral, and sciatic.

Each spinal nerve divides into anterior, posterior, and white rami. Rami are primary divisions of a nerve. Anterior and posterior rami contain voluntary fibers; white rami contain autonomic fibers. Posterior rami further branch into nerves innervating the muscles, skin, and posterior surfaces of the head, neck, and trunk. Most anterior rami branch to the skeletal muscles and the skin of the extremities and anterior and lateral surfaces. In the process they form plexuses, such as the brachial and sacral plexuses. Spinal nerves contain sensory dendrites and motor axons; some have somatic axons, and some have axons of preganglionic autonomic motor neurons.

The autonomic (involuntary) nervous system consists of all the efferent nerves through which the cardiovascular apparatus, viscera, glands of internal secretion, and peripheral involuntary muscles are innervated (see Figure 20-29). There is a major anatomic difference between the somatic and autonomic nervous systems. In the somatic nervous system an impulse from the brainstem or spinal cord reaches the end-organ through a single neuron. In the autonomic nervous system an impulse passes through two neurons—the first ending in an autonomic ganglion and the second running from the ganglion

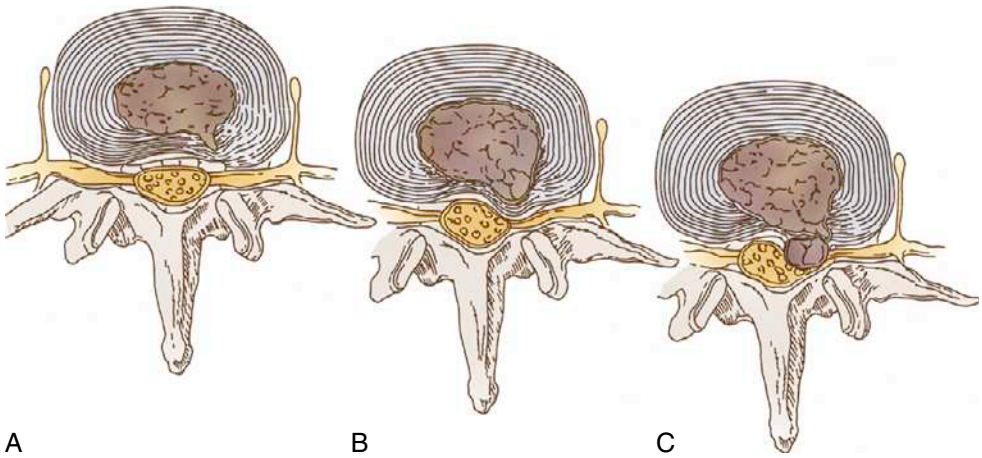


FIGURE 20-31 Stages in the herniation of an intervertebral disk. **A**, Tearing of the rings of the annulus fibrosus. **B**, Protrusion of the disk against the nerve root. **C**, Extrusion of part of the nucleus pulposus, with further nerve root compression.

to the end-organ. Some of the ganglia lie adjacent to the vertebral column to form the sympathetic trunks or chains; others are closely associated with the end-organs.

The preganglionic neurons from the brainstem (which traverse along the cranial nerves) and those from the second, third, and fourth sacral segments to the pelvic viscera end in ganglia in proximity to their end-organs; thus their postganglionic fibers are very short. This is known as the *parasympathetic,* or *craniosacral,* division of the autonomic nervous system. The preganglionic fibers from the thoracic and lumbar spinal cord terminate in the paravertebral ganglia, making up the sympathetic chain, and their postganglionic fibers are relatively long. This is termed the *sympathetic,* or *thoracolumbar,* division of the autonomic nervous system.

The two divisions are distinct anatomically and physiologically. The chemical substance mediating transmission of impulses at most postganglionic sympathetic nerve endings is *norepinephrine,* and the neurotransmitter at all parasympathetic and preganglionic sympathetic neurons is *acetylcholine.*

The majority of organs have dual innervation—part from the craniosacral division and part from the thoracolumbar division. The functions of these two systems are antagonistic. Together they work to maintain homeostasis. In general, the thoracolumbar division functions as an emergency protection mechanism, always ready to combat physical or psychologic stress. The craniosacral division functions to conserve energy when the body is in a state of relaxation.

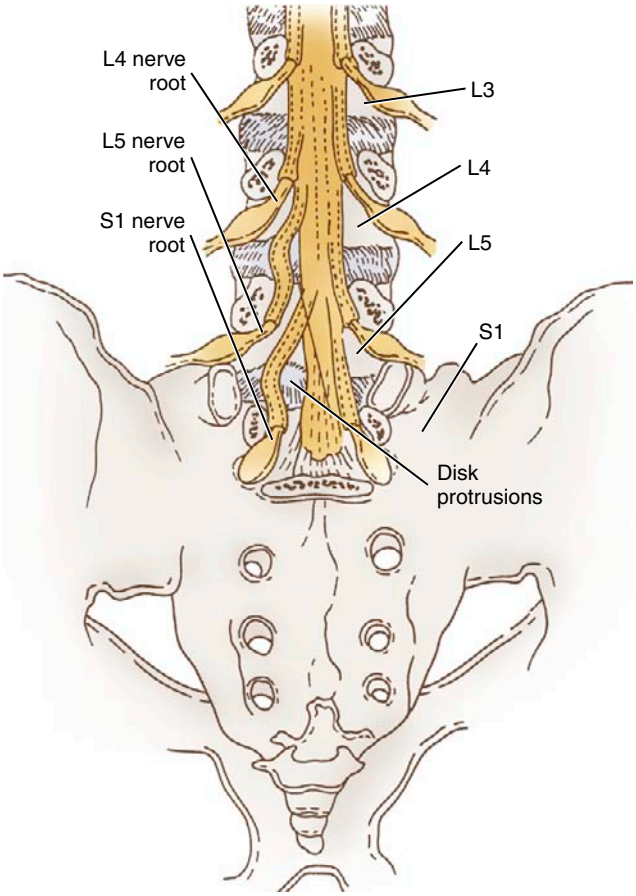


FIGURE 20-32 Posterior view of the lower lumbar spine. A disk protrusion at L4-L5 on the left results in compression of the L5 nerve root where it leaves the dural sac but before it exits from the spinal canal.

Stimuli arising from internal organs or from outside the body traverse visceral and somatic afferent nerve fibers to make reflex connections with preganglionic autonomic neurons in the brainstem and spinal cord. Such stimuli trigger activity of these involuntary systems automatically. When these automatic mechanisms break down or overact, surgery may be indicated. Thoracolumbar sympathectomy was once performed in hypertensive patients as an attempt to decrease blood vessel tone and lower blood pressure. Vagotomy can be performed to decrease acid secretion to the stomach in patients with peptic ulcers. Lumbar sympathectomy is used to relieve vasospastic disorders of the legs. T2 ganglionectomy is done to relieve palmar hyperhydrosis (sweaty palms). See Chapter 22 for a discussion of thoracic ganglionectomy.

Perioperative Nursing Considerations

Assessment

Neurologic Assessment Tools. A familiarity with basic neurologic assessment tools gives the nurse the ability to perform a standardized neurologic assessment that can be compared with the patient's previous assessments and easily communicated to other healthcare professionals. These tools can be used preoperatively to establish a baseline assessment. Postoperatively, they can be used to establish a return to baseline and to assess postoperative neurologic stability. The postoperative condition of a neurosurgical patient can quickly deteriorate, so an adequate baseline assessment is essential (Rapid Response Team box). The Glasgow Coma Scale is commonly used to assess patients with brain injury (Table 20-3). Three indicators of cerebral function—eye opening, verbal communication, and motor response to verbal and noxious stimuli—are assessed; and the appropriate number of points for each is assigned and totaled. The best possible score is 15, and the worst possible score is 3. The Medical Research Council (MRC) Scale for Muscle Strength Grading can be used to assess muscle strength in the upper and lower extremities of spinal cord injury patients or patients who are having spine surgery (Table 20-4).

Preparation for Surgery. Communication among the perioperative team is essential for planning care for the neurosurgical patient in the OR. Information the perioperative nurse needs before the arrival of the patient in the OR includes the following:

- The patient's age, height, weight, level of consciousness, physical disabilities resulting from neuropathologic or other conditions, stability of spine, and communication barriers
- Diagnosis, allergies, medical clearance for surgery, and nothing-by-mouth (NPO) status
- Planned and possible surgical procedures
- Surgical and anesthesia consent signed by the patient or person with power of attorney for medical decisions (if the patient is unable to provide consent)
- Surgical site marked by the surgeon or a representative to designate correct side of head, level of spine, or other surgical site
- Diagnostic and lab studies done and reports needed at the time of operation
- Specific surgical approach and position to be used
- Need for any special equipment, instruments, and supplies

RAPID RESPONSE TEAM

A patient with a neurologic diagnosis may experience irreversible neurologic damage if complications relating to the diagnosis or surgical procedure are not recognized in a timely manner to permit early intervention. In 2008 The Joint Commission established the 16th National Patient Safety Goal; its purpose was to improve the early recognition and response to negative changes in a patient's condition. By January of 2009 all institutions were required to develop and implement a rapid medical response team within their facility (TJC, 2008). Rapid response teams (RRTs) are especially critical for neurosurgical patients because of the rapidity of changes that can occur in the postoperative period. Rapid response teams consist of highly trained personnel that function together to create a pre–code team (Richmond, 2008). The personnel include an ICU nurse, respiratory therapist, medical resident, anesthesia care provider, and sometimes a surgical resident. The RRT can be activated by any bedside clinician, such as registered nurses, residents, and attending physicians, at the earliest sign of patient deterioration. Most criteria for initiating a RRT call are institution specific, but some examples of the criteria include the following:

- Blood pressure: systolic BP below 90 mm Hg or above 180 mm Hg
- Heart rate: below 45 beats/min or above 125 beats/min
- Respiratory rate: below 8/min or above 24/min
- Oxygen saturation: below 90% or increasing oxygen requirements
- Acute change in mental status
- New onset of chest pain
- Staff member concerned about patient and needs a second opinion
- Patient not responding to treatment already underway for recent change in status (Richmond, 2008)

The RRT arrives at the patient's bedside within minutes to plan and implement interventions to stabilize the patient. While stabilization is occurring, the members of the RRT are communicating to the house staff and bedside clinicians the current and future needs of the patient. The RRT can determine if the patient's needs warrant a transfer to an increased level of monitoring such as an ICU. The main objective of the RRT is to provide early detection and treatment for unstable patients thereby avoiding cardiac or respiratory arrest in non-ICU settings (Winters et al, 2006).

RRT EXAMPLE

Mrs. Jones is post-op day 2 from an L4-S1 decompression and fusion for lumbar spinal stenosis. The previous nurse's report states that there were no complications during the procedure and the patient has been hemodynamically stable and neurologically intact postoperatively. The previous nurse's assessment of Mrs. Jones states that she was alert and oriented times 3, she moved all extremities without difficulty and against resistance, and her speech was clear and appropriate. The report also stated that as the day progressed, Mrs. Jones became increasingly drowsy but it was attributed to the patient-controlled analgesia (PCA) pump filled with morphine. The current nurse's assessment determines that Mrs. Jones is difficult to arouse, uncooperative, and having difficulty speaking; she is also not oriented to place or time. All of the current findings contradict the previous nurse's assessment, and the current nurse knows that the patient's health status is rapidly declining. The nurse immediately pages the facility's rapid response team (RRT), who arrives at the patient's bedside within minutes. The RRT performs an assessment and begins immediate interventions to stabilize Mrs. Jones. She is taken for a stat CT scan of the head, which shows cerebral edema. Mrs. Jones did not return to the nursing unit after the CT scan; she was intubated and transferred to an ICU. It was later determined that Mrs. Jones suffered bilateral symmetric cerebellar hemorrhages from a CSF leak that occurred during the initial spinal surgery.

Modified from The Joint Commission: *National Patient Safety Goals 2008,* available at www.jcrinc.com/common/PDFs/fpdfs/pubs/pdfs/JCReqs/JCP-07-07-S1.pdf. Accessed April 14, 2009; Farag E et al: Cerebellar hemorrhage caused by cerebrospinal fluid leak after spine surgery, *Anesth Analg* 100:545-546, 2005; Richmond R: Rapid response teams, Health Policy Newslett 21(2):3, 2008, available at http://jdc.jefferson.edu/hpn/vol21/iss2/3. Accessed April 16, 2009; Winters BD et al: Rapid response teams- walk, don't run, *JAMA* 296:1645-1647, 2006.

- Amount of blood and blood products (fresh frozen plasma, platelets) ordered and available
- Need for radiologic support, neuromonitoring, intraoperative blood salvage unit, and image guidance
- Planned preliminary procedures, such as carotid ligation, lumbar puncture, placement of lines (IV, central venous, arterial), and Foley catheter insertion
- Verification that all necessary personnel, equipment, and supplies are available
- A focused preoperative neurologic examination should be done as a baseline for postoperative assessment; depending on the pathology and surgery, this may include the following:
  - Mental status (level of consciousness, orientation, behavior, ability to follow commands)
  - Vision, pupil response, extraocular eye movements (EOMs), and hearing
  - Examination of sensation and motor strength of extremities
  - Area and intensity of pain

This information allows the perioperative nurse to properly plan and prepare for the surgery and to ensure the well-being of the patient.

Diagnostic Procedures. Most patients will have undergone diagnostic procedures before arriving in the OR. Radiologic and other diagnostic studies are of great significance to the surgical team. The nurse should ensure that any pertinent radiographic images are available in the OR before the procedure begins. The surgeon can refer to these images to locate the pathologic condition, verify the correct surgical site, and plan the appropriate surgical approach and procedure. Diagnostic studies include the following:

1. *Plain x-rays.* X-rays of the spine can be used initially to identify injury to the spinal column. They are referred to intraoperatively to verify that surgery to the spine is being done at the correct level (Figure 20-33).
2. *CT scan.* A CT scan uses x-ray studies, with or without instilled contrast medium, and computer technology to produce a sequential series of positive images of transverse sections of the brain and spinal cord in which differences in tissue density can be detected and deviations from normal identified. This study remains the criterion standard for evaluation of acute head injury and is considered the first-line screening study.

TABLE 20-3

The Glasgow Coma Scale

	Points
EYE OPENING	
Spontaneous	4
To speech	3
To pain	2
None	1
VERBAL COMMUNICATION	
Oriented	5
Confused conversation	4
Inappropriate words	3
Incomprehensible sounds	2
None	1
MOTOR RESPONSE	
Obeys commands	6
Localizes to pain	5
Withdraws to pain	4
Abnormal flexion	3
Abnormal extension	2
None	1

Modified from Hausman KA: Assessment of the nervous system. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, St Louis, 2010, Saunders.

TABLE 20-4

Medical Research Council Scale for Muscle Strength Grading

Grade	Strength
0	No muscle contraction
1	Trace of contraction
2	Active movement with gravity eliminated
3	Active movement against gravity
4	Active movement against gravity and resistance
5	Normal power

From Grant GA, Ellenbogen RG: Clinical evaluation of the nervous system. In Rengachary SS, Ellenbogen RG, editors: *Principles of neurosurgery,* ed 2, St Louis, 2005, Mosby.

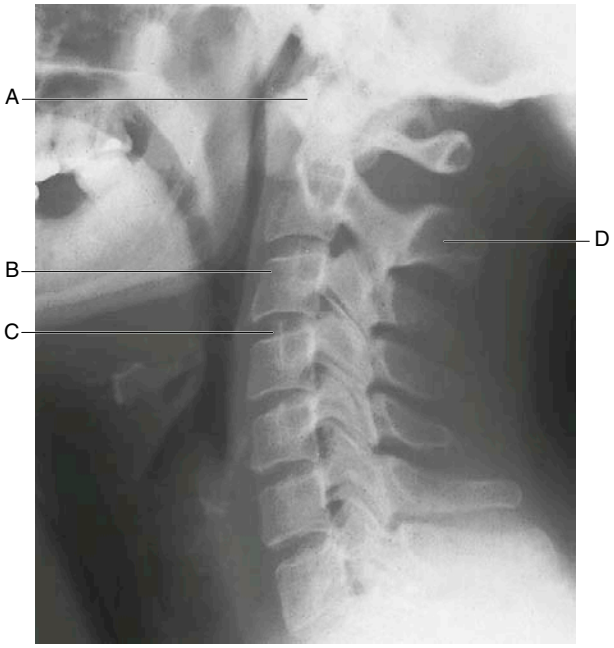


FIGURE 20-33 Lateral x-ray of the cervical spine. **A**, Anterior tubercle of the atlas (C1). **B**, Cervical body. **C**, Intervertebral disk. **D**, Spinous process of the axis (C2).

3. *MRI.* Use of radiofrequency pulses in a powerful magnetic field yields high-resolution images of the human body with no known risk to patients and involves no radiation. Advances in MRI scanning provide enhancement of the scan with the use of gadolinium (contrast medium). A typical MRI study produces views of the brain featured as contiguous slices in three different planes. Axial cuts are from top to bottom. Coronal cuts are from front to back. Sagittal cuts are from side to side. The MRI is the gold standard for the diagnosis of tumors, abscesses, tissue/ligamentous injury, and disk herniation (Figures 20-34 and 20-35).
4. *Stereotactic MRI or CT scan.* Placement of a stereotactic head frame (frame-based system) or fiducials (frameless system) before receiving a CT scan or MRI produces information that is registered into a computer. The goal of stereotactic surgery is to target a point or volume in space precisely by means of a predefined minimally invasive trajectory (Zonenshayn and Rezai, 2005). The frameless system allows the neurosurgeon to see beyond the actual operative field by using an optical tracking device. This handheld device depicts in three planes on a computer screen where the surgeon is working in the brain relative to deeper structures beyond view.
5. *Magnetic resonance angiography (MRA).* MRA is a noninvasive means of studying the cerebral vasculature. An MRA study is capable of detecting carotid stenosis, posttraumatic carotid artery dissection, AVMs, and aneurysms.
6. *Angiography (arteriography).* Injection of contrast medium into the brachial, carotid, vertebral, or femoral arteries is used to study the intracranial blood vessels for size, location, and configuration and to allow diagnosis of space-occupying lesions and vascular abnormalities.
7. *Digital subtraction angiography (DSA).* DSA is a computerized radiologic procedure. An IV rather than arterial injection is required; a contrast medium injection allows examination of selected arterial circulation. By using computer technology DSA provides an alternative to cerebral angiography for high-risk patients.
8. *Three-dimensional CT angiography.* Contrast-enhanced CT brain scan data are used to generate a three-dimensional image of the intracranial vasculature with minimal risk to the patient.
9. *Stereoscopic display of MRA.* Recent advances in MRI permit high-resolution imaging of blood flow. Projection angiograms can be produced to overcome the tomographic nature of conventional MRI scans. These angiograms are similar to plain x-ray films or digital subtraction angiograms in the demonstration of blood vessels, but the three-dimensional information inherent in them is partially lost in single projections. Stereoscopic image pairs allow the clinician to perceive the relative distance of vessels to one another. MRA permits perception of vascular anatomy in three dimensions.

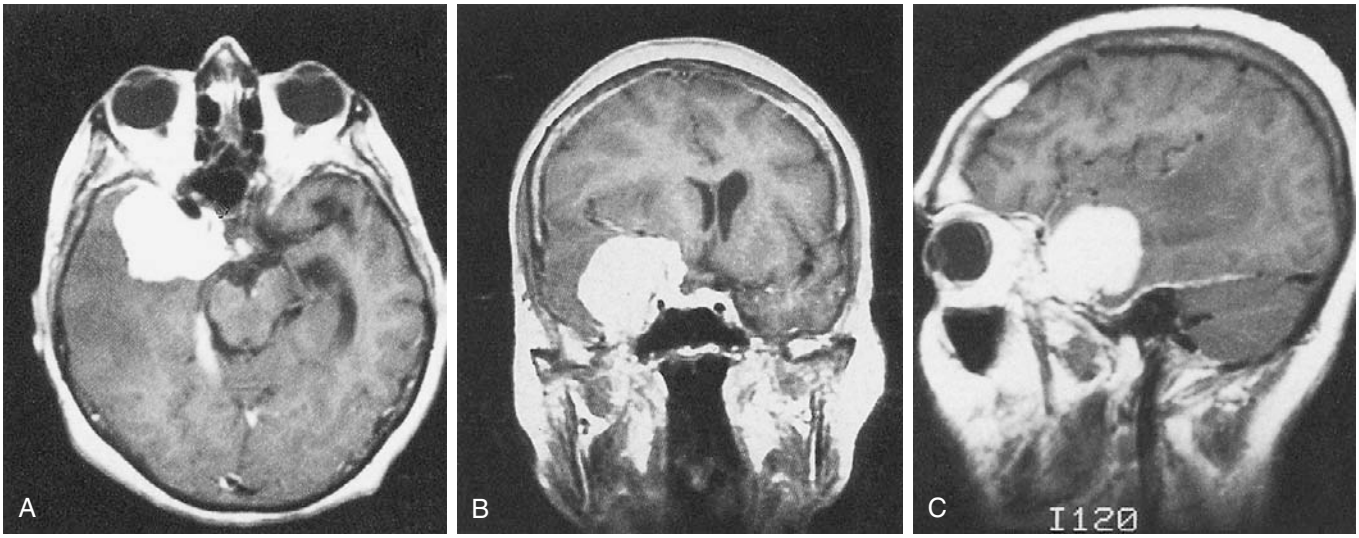


FIGURE 20-34 Gadolinium-enhanced magnetic resonance image (MRI) of a medial sphenoid wing meningioma in (**A**) axial, (**B**) coronal, and (**C**) sagittal planes.

10. *Myelography.* Contrast medium is injected into the spinal subarachnoid space and fluoroscopy is used to view the spinal cord, nerve roots, and spinal column and to demonstrate a defect involving theseareas.
11. *Ultrasound.* Ultrasound is a noninvasive technique that uses high-frequency sound waves and a computer to create images of blood vessels, tissues, and organs. It is often used to assess the blood flow in the carotid artery. This procedure can be done in or out of the surgical suite. It can be used intraoperatively to localize intradural spinal cord tumors.
12. *Electroencephalogram (EEG).* An EEG is a procedure that records the brain's continuous electrical activity by means of electrodes placed on the scalp or intraoperatively on the brain.
13. *Evoked potentials (EPs).* Evoked potentials are procedures that record the brain's electrical response to visual, auditory, and sensory stimuli.
14. *Wada's test (intracarotid amobarbital [Amytal] test).* Wada's test can be used before brain surgery to lateralize language, memory, and the dominant hemisphere. It can help in lateralization of seizure focus and assess the ability of the hemisphere with the lesion to maintain memory when isolated.
15. *Lumbar puncture.* A spinal needle is used to gain access to CSF in the subarachnoid space. Opening and closing pressures are measured to determine if there is increased pressure surrounding the brain and spinal cord. This can help diagnose hydrocephalus or a spinal tumor. CSF is sent to the lab to evaluate for blood, infection, malignancy, and other neurologic diseases. LP is contraindicated when an intracranial mass is known or suspected because it can cause herniation of the brain in the presence of increased ICP.

Nursing Diagnosis

Nursing diagnoses are developed from interpreting and analyzing patient information to determine whether there are specific (actual) or potential (risk for) problems that the perioperative nurse needs to consider in the plan of care. Nursing diagnoses are the basis on which nursing interventions are selected for patients. Neurosurgery patients share common problems that the perioperative nurse should address. Nursing diagnoses

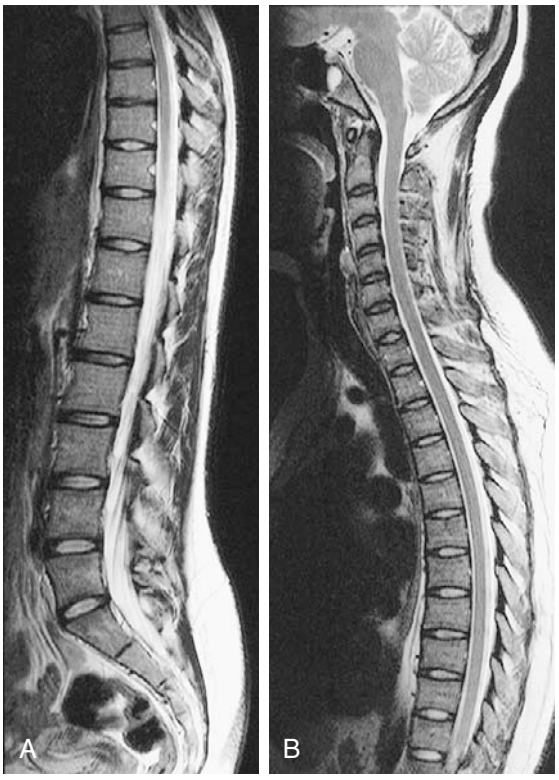


FIGURE 20-35 Sagittal magnetic resonance image (MRI) of (**A**) thoracolumbar spine and (**B**) cervicothoracic spine.

related to the care of patients undergoing neurosurgery might include the following:

- Anxiety related to surgery or surgical outcome
- Deficient Knowledge related to diagnostic tests and surgical procedures
- Risk for Ineffective Breathing Pattern related to location of tumor, surgical position, or effects of general anesthesia
- Risk for Hypothermia
- Risk for Perioperative Positioning Injury

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Anxiety related to surgery or surgical outcome

OUTCOME
The patient's anxiety will be reduced or controlled.

INTERVENTIONS
- Broadly classify intensity of patient's anxiety.
- Determine patient's coping skills.
- Provide listening, reassurance, and information.
- Provide ongoing opportunity for questions or expression of concerns or fears.
- Involve other support systems (e.g., family, friends, social worker, chaplain).
- Assist the patient to use personally effective coping skills.
- Use touch (if welcomed by the patient) and eye contact during communication.

NURSING DIAGNOSIS
Deficient Knowledge related to diagnostic tests and surgical procedures

OUTCOME
The patient and family will verbalize an understanding of the surgical procedure and postoperative plan of care.

INTERVENTIONS
- Determine knowledge level and desire for knowledge.
- Correct misinformation.
- Identify readiness and motivation to learn.
- Provide information regarding tests or surgery.
- Explain perioperative routine, postoperative recovery, and discharge plans.
- Base interventions on patient's needs.

NURSING DIAGNOSIS
Risk for Ineffective Breathing Pattern related to location of tumor, surgical position, or effects of general anesthesia

OUTCOME
The patient will maintain effective breathing patterns.

INTERVENTIONS
- Provide appropriate positioning accessories, and assist in their placement.
- Collaborate with anesthesia provider and surgeon during positioning activities relevant to respiratory effectiveness.
- Determine patient's comfort on OR bed; provide comfort measures as appropriate.
- Maintain open suction line.
- Observe respiratory rate, depth, and character.
- Encourage deep breaths and coughs.
- Communicate with postanesthesia care unit (PACU) regarding respiratory needs.
- Check airway patency frequently during transport to PACU.

NURSING DIAGNOSIS
Risk for Hypothermia

OUTCOME
The patient will remain normothermic.

INTERVENTIONS
- Provide warm ambient OR temperature during surgical intervention.
- Provide warmed intravenous (IV) fluids and blood products.
- Provide body-warming system (e.g., forced warm air) during surgery.
- Keep head covered or wrapped when possible.
- Monitor temperature with anesthesia provider.
- Cover the patient with warm blankets at end of the surgical intervention for transport to PACU.

NURSING DIAGNOSIS
Risk for Perioperative Positioning Injury

OUTCOME
The patient will be free from signs and symptoms of positioning injury.

INTERVENTIONS
- Assess patient's physical limitations before positioning; make accommodations.
- Carefully pad and protect all prominences and sites that are vulnerable to neurovascular injury.
- Check all positioning devices for cleanliness, working order, and freedom from sharp edges.
- Collaborate with OR team in placing positioning devices to maintain patient safety.
- Assess patient at completion of surgery for areas of redness, blanching, or bruising.
- Communicate any findings to PACU nursing staff.
- Document findings and follow-up with patient, as applicable.

Outcome Identification

Outcomes identified for the selected nursing diagnoses could be stated as follows:

- The patient's anxiety will be reduced or controlled.
- The patient or family will verbalize an understanding of the surgical procedure and postoperative plan of care.
- The patient will maintain effective breathing patterns.
- The patient will remain normothermic.
- The patient will be free from signs and symptoms of positioning injury.

Planning

Preparation can significantly reduce anesthesia time and intraoperative time for the patient, as well as physical and psychologic stress for the patient, surgeon, and perioperative nurse. Planning for the patient's care in the OR is based on the results of nursing assessment and the identification of relevant nursing diagnoses. The plan of care then identifies desired outcomes derived from the nursing diagnoses; priorities are set and nursing interventions are designed to assist the patient to reach the desired outcomes. Nursing interventions identified for the patient's plan of care may include reassessment, teaching, counseling, referrals, and specific interventions to assist the patient achieve patient care outcomes. A Sample Plan of Care for a patient undergoing a neurosurgical procedure is given above.

Implementation

The perioperative nurse must determine that all personnel, equipment, instrumentation, and supplies necessary for a successful surgery are available. The nurse uses the information obtained through assessment of the patient and communication with the surgical team to provide individualized patient care. Neurosurgical patients vary in age from the very young

to the very old. They often have special needs because of conditions such as mental status changes, spinal instability, spinal cord injuries, paralysis, other traumatic injuries, and pain. These conditions need to be considered at all times. Neurosurgery patients who seem to be unconscious may actually be aware of their environment and unable to voice their concerns. The perioperative nurse should always talk to the patient and explain what is happening. Showing compassion and attempting to relieve the fears of the patient and his or her family are essential.

Equipment. Neurosurgical procedures require an extensive amount of equipment. The nurse must analyze the arrangement of the equipment in the OR to ensure that the sterile field is not compromised. Electrical equipment should be placed in proximity to electrical outlets, so that cords are out of high-traffic areas. Monitors should be in comfortable view of the surgeon. A microscope needs a clear path to the surgical field. The surgeon and surgical assistants may require specialized surgical chairs or sitting or standing stools to comfortably perform the surgery.

OR BED AND ATTACHMENTS. The nurse uses information about the proposed surgical procedure and desired surgical position to gather the proper OR bed, attachments, and positioning devices before the patient arrives in the OR suite. Perioperative nurses must anticipate needs that may arise during the surgery and prepare for them, considering questions such as the following: Is this the right OR bed in the right position with the right attachments? If fluoroscopy will be used, is the base of the OR bed in a position that will accommodate the C-arm? A specialized OR bed, such as a Jackson table or Andrews table or frame, may be required for posterior spine surgery. Skull clamps, skull pins, and tongs are commonly used for craniotomies and posterior cervical spine surgeries to stabilize the head and neck (Figure 20-36). Occasionally, a patient may come to the OR in a halo that was placed for preoperative stabilization of the cervical spine. At least part of the halo will need to be removed so the surgical site can be accessed. Compatible wrenches must be available to accomplish this.

BASIC EQUIPMENT. Neurosurgical procedures typically require one special neurosurgical overhead instrument table, such as the Mayfield table (Figure 20-37), or two large Mayo trays along with one back table. Other basic equipment includes the following: a sequential compression device, a cooling-heating unit, one or two monopolar electrosurgical units (ESUs), a bipolar ESU, and a wall supply or tank of nitrogen with a special pressure gauge for operating air-powered instruments. Usually two suction units are required. Intraoperative blood salvage is used for most spine surgeries, unless infection or malignancy is suspected.

Neurosurgeons usually wear surgical loupes and a fiberoptic headlight, requiring a light source.

OPERATING MICROSCOPE. An operating microscope may be required for surgery on certain areas of the brain, spinal cord, and peripheral nerves. The operating microscope has revolutionized neurosurgery by providing intense light and up to a 12-fold magnification to areas that previously may have been inoperable or inaccessible. Microsurgery allows for greater surgical precision when operating in close proximity to vital structures and has better surgical results. The perioperative nurse must be able to prepare the microscope for use in neurosurgery, and the surgeon must check it for focal length and focus before scrubbing. Disposable sterile drapes are available for the microscope, as are assistant and observer lenses. Cameras and closed-circuit television monitors are also available for use with the operating microscope.

ENDOSCOPES. Surgeons use endoscopes to perform minimally invasive neurosurgery, such as endoscopic biopsy. The endoscope provides illumination and magnification of structures and an extended viewing angle. Perioperative nurses must be prepared to convert from a neuroendovascular procedure to

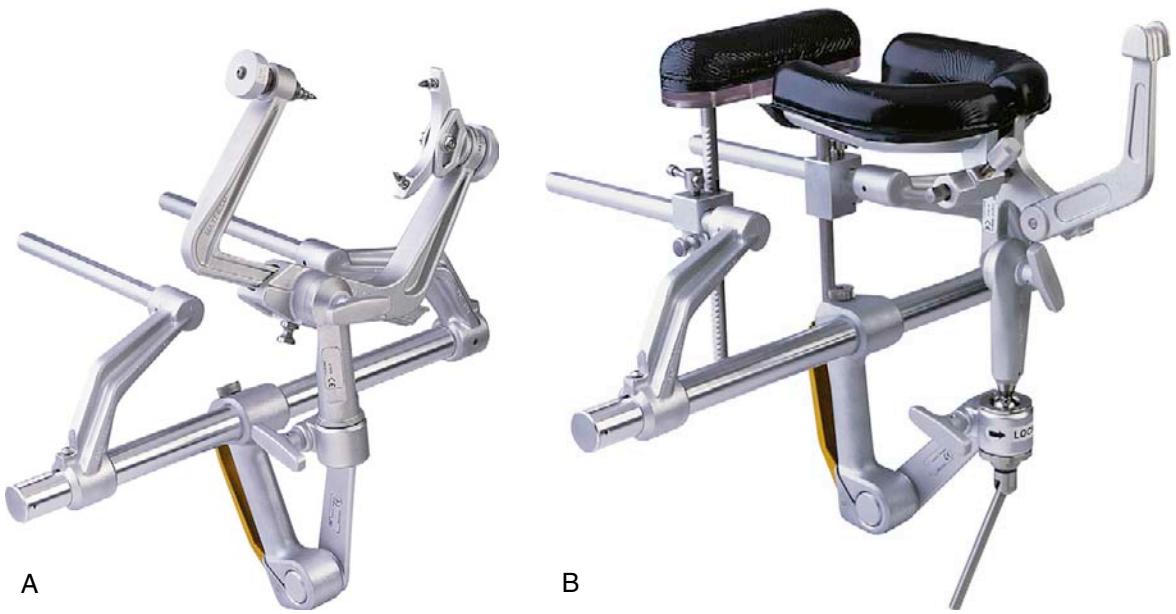


FIGURE 20-36 **A**, Three-pin fixation skull clamp (Mayfield) for stabilizing head during neurosurgical procedures. **B**, Mayfield horseshoe headrest.

an open procedure if it is determined that the surgery cannot be successfully completed endoscopically. An additional use for endoscopes is in open procedures to see areas that are otherwise visually inaccessible.

RADIOLOGIC INTERVENTION. Radiology is commonly used intraoperatively for spine surgery. Typically, a radiology technician will operate the equipment. Lead aprons and thyroid shields must be worn or protective shields must be used by all staff in the OR to protect themselves from radiation exposure. X-rays can be taken to check for proper positioning of the spine and to help the surgeon identify a specific level of the spine. This may be done before incision or after partial exposure of the spinous processes and laminae. In both cases an instrument or needle is used to mark a position on the spine, and an x-ray of the spine is taken. The x-ray enables the surgeon to identify the level of the spine that is marked. The surgeon uses that information to identify the correct surgical level. A postoperative x-ray is also taken to verify that the surgery was done to the correct level of the spine.

With fluoroscopy, also called direct image intensification, a C-arm (covered with a sterile drape) is used to take a continuous x-ray that is portrayed on a monitor. This gives the surgeon the ability to view the spine and to directly view screws as they are being placed during an instrumented fusion. This ensures that spinal instrumentation for fusion is properly positioned in the correct levels. Fluoroscopy is also used for placement of nerve-stimulator electrodes in brain or spinal areas and stereotactic procedures.

STEREOTACTIC AND IMAGE-GUIDED EQUIPMENT. Stereotactic and image-guided equipment is commonly employed for neurosurgery. Either a frame-based (requiring a head-frame skull attachment, see Figure 20-38) or a frameless system (using fiducials) can be used. Both systems use a computer to register points, based on information obtained from a stereotactic MRI or CT scan done preoperatively, to determine the least traumatic approach to the target (tumor, lesion, ventricle). Both systems have accompanying attachments and instruments that must be available. The frameless image-guided system requires a monitor to display views of the brain or spine in three different planes: axial, coronal, and sagittal (Figure 20-39).

FIGURE 20-37 Mayfield overhead instrument table.

ULTRASONIC ASPIRATOR. An ultrasonic aspirator (Cavitron Ultrasonic Surgical Aspirator, CUSA) may be used to emulsify and debulk a tumor with high-frequency sound waves. Various settings allow the surgeon to adjust the instrument to remove firm or calcified lesions, or soft masses. The ultrasonic aspirator provides hemostasis and spares adjacent nerves and vessels as it removes the tumor.

AUDIOVISUAL EQUIPMENT. The use of video cameras, recorders, and television monitors is invaluable to teach staff and enhance understanding of the surgical procedure by perioperative personnel who are otherwise unable to visualize the surgeon's actions directly. By viewing the operative field through the monitor, the experienced scrub person will be able to anticipate the neurosurgeon's next move and will therefore provide better assistance.

INTRAOPERATIVE MONITORING EQUIPMENT. Equipment for intraoperative monitoring, such as EEG, evoked potentials (EPs), ICP, and Dopplers, may also be required.

Instrumentation, Implants, and Supplies. Typically, instrumentation commonly used in neurosurgery is added to basic surgical instrumentation to make neurosurgical-specific trays, such as a basic craniotomy tray or a laminectomy tray. Specialized trays, instruments, or implants can be added based on the surgical procedure.

Powered surgical instruments are commonly used in neurosurgery. Multiple drills, drill bits, and accessories are available. These tools may be powered by air, battery, or electricity and are operated by a hand control or foot pedal. All drills have a safety control that should be engaged at all times the instrument is not in use. The perioperative nurse should monitor the sterile field to ensure that drills and other powered equipment are not left lying on the patient. The use of drills makes bone work easier and reduces operating time. Irrigating the tip of the drill while it is in use prevents overheating of the tissue. By changing drill bits and attachments, different drills can be used to make burr holes, craniotomies, craniectomies, and holes for dural tack-up sutures. They can be used to thin bone for a decompression, to perform decortication for spinal fusion, to harvest hip graft, to shape bone grafts, and to make holes for plating and fixation systems. Examples of specific drills that may be used follow.

The Hall Surgairtome 200 (Figure 20-40) can be used for precision cutting, shaping, and repair of bone. Compressed nitrogen is the power source, as with other air-powered equipment. The Hall Surgairtome 200 can be used to widen the graft area in anterior fusions and to unroof the auditory canal in eighth cranial nerve surgery. For use in less accessible areas, such as the sphenoidal sinus, pituitary fossa, and vertebral bodies, attachments with 20- and 90-degree angles are available. A range of burrs and guards is available.

The craniotome offers a perforator drive for drilling burr holes. Both 12-mm and 7-mm perforators are available in disposable and reusable forms. The perforator driver attachment can be removed and a saw blade and dura guard attached to adapt the instrument for cutting a craniotomy bone flap. A cranioplasty burr and a skull contour burr as well as guards for each type of burr are available.

Another versatile pneumatic tool is the Midas Rex instrument (Figure 20-41). The variety of disposable cutting tools of this foot pedal–controlled instrument and its attachments

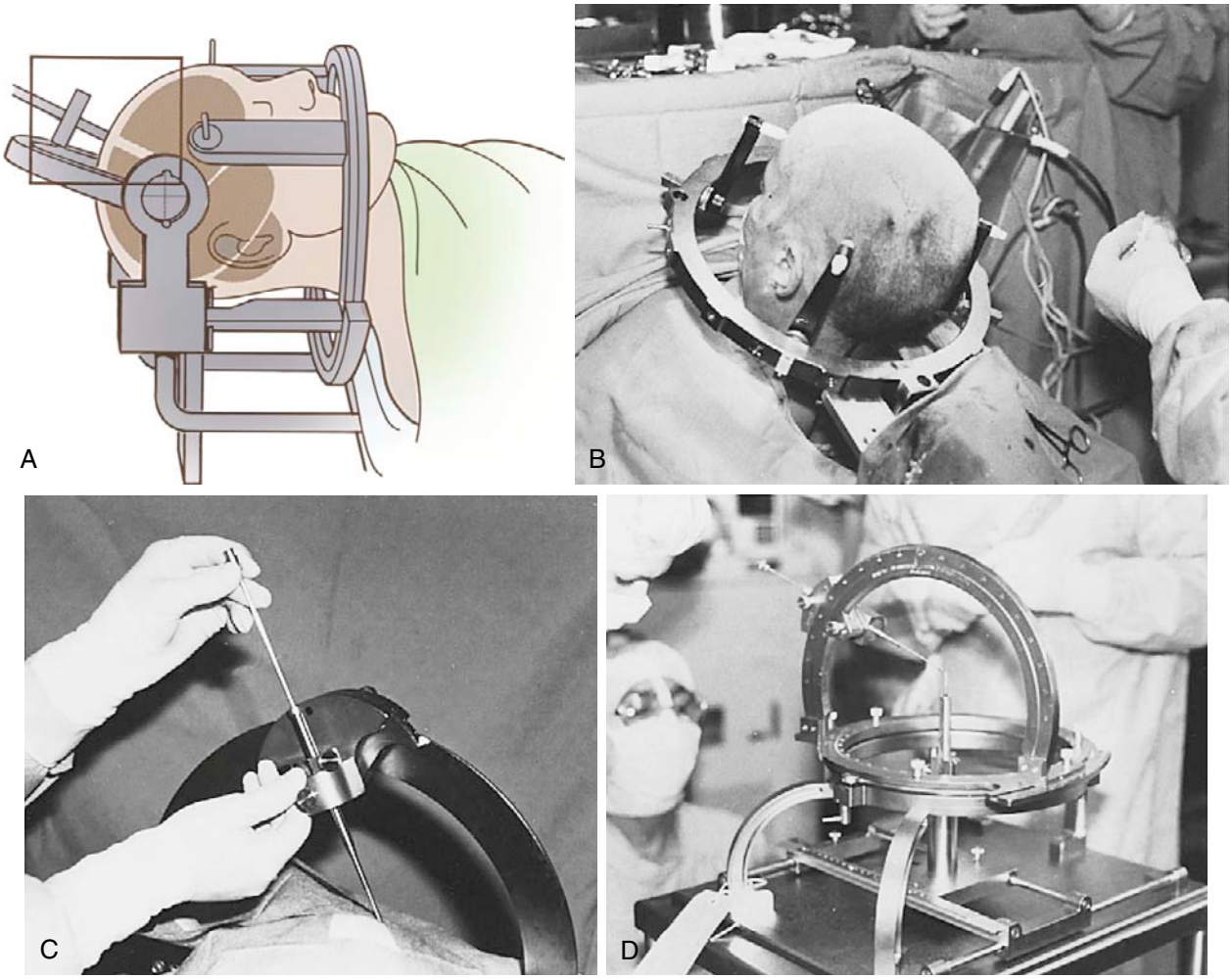


FIGURE 20-38 Stereotactic procedure. Obtaining a biopsy for stereotactic surgery. **A**, Patient fitted with head frame before computed tomography (CT) or magnetic resonance imaging (MRI) scanning. **B**, Awake patient in the sitting position for application of the BRW frame for stereotactic brain biopsy. **C**, Stereotactic surgical procedure with needle insertion for biopsy. **D**, Stereotactic surgical procedure with arc system placed on phantom base to demonstrate and check accuracy of biopsy needle with *xyz* coordinates for precise depth and angle.

provides the neurosurgeon with a versatile bone dissector capable of cutting bone by sawing through it or drilling it away. In addition, large craniotomy flaps can be turned with only a single burr hole. Manufacturers' precautions and instructions must be followed for all powered instruments.

A variety of suction tips, retractors, and retractor systems are required for visualization. A transsphenoidal tray and instruments are required for that specialized approach. Microneurosurgical instruments may be needed for delicate brain or spinal cord surgery. Dural grafts and substitutes may be required to repair the dura. Aneurysm instruments, aneurysm clips, or hemostatic clips may be needed for neurovascular surgery. Titanium plates or wire is used to replace a bone plate after a craniotomy. Spinal instrumentation (plating and fixation systems) may be implanted, and bone grafts and substitutes may be used to promote spinal fusion.

Specific surgeries may require shunts or CSF reservoirs, implantable stimulators or pumps, endoscopes and endoscopic instruments, endovascular instruments, catheters, and coils. These supplies must be available if they are to be placed or implanted during surgery.

The surgical nurse needs to assemble instrumentation with consideration for each individual surgery and according to each individual surgeon's preferences. The instrument list for each procedure and neurosurgeon should be documented, referenced, and frequently updated in collaboration with the surgeon. Specific instruments are mentioned in the surgical procedure descriptions that follow.

Preliminary Procedures. A number of procedures or therapeutic measures are performed before the primary surgery begins. It is important that the perioperative nurse anticipate these procedures, understand why they are done, and be prepared to facilitate them.

ANESTHESIA CONCERNS. The anesthesia provider collaborates with the surgeon and nurses to provide appropriate care to the patient. The anesthesia provider must be aware of and plan for situations in which the neurosurgery patient may

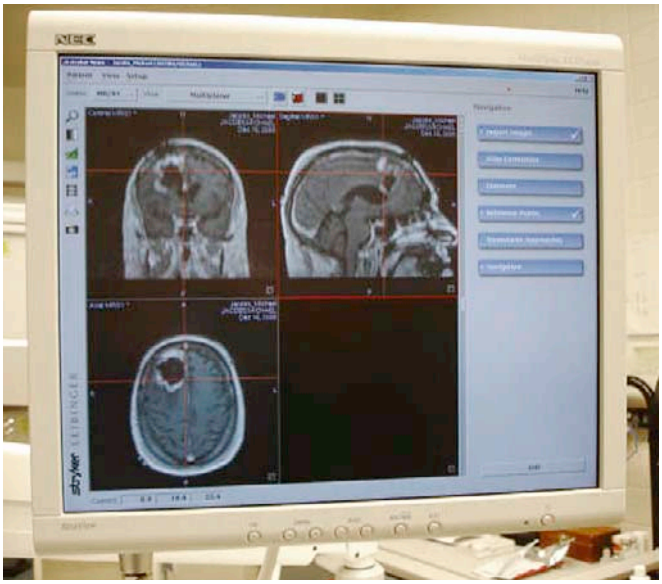


FIGURE 20-39 Frameless stereotactic image-guided navigation monitor showing the brain with tumor in three planes: coronal *(upper left)*, sagittal *(upper right)*, and axial *(lower left)*.

FIGURE 20-40 Hall Surgairtome 200 with attachments.

need to be awake during the surgery for intraoperative assessment. Anesthesia agents must be adjusted if intraoperative monitoring of EPs is to be done. If the cervical spine is unstable or unable to extend, endotracheal intubation may need to be done while the patient is awake. The position of the bed in the OR should be communicated to the anesthesia provider. For

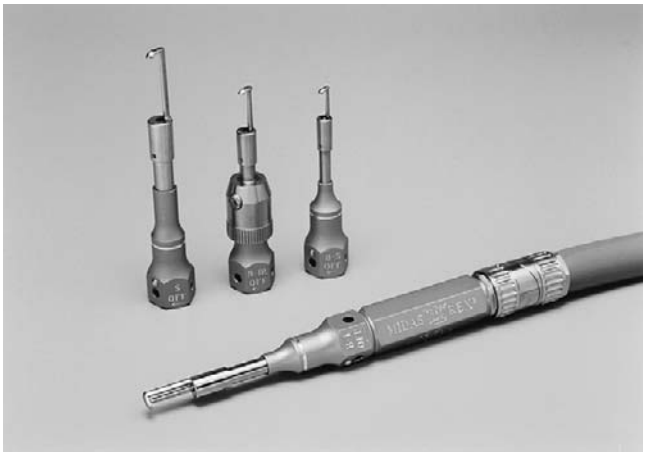


FIGURE 20-41 Midas Rex drill with attachments.

surgery of the head, the bed may be turned 90 or 180 degrees away from the anesthesia machine to provide comfortable access to the surgical site. Anesthesia providers can prepare by having enough length on their tubing to make the turn while maintaining control of the patient's airway.

Anesthesia for neurosurgery requires sufficient IV access. The anesthesia provider may place a central line if peripheral IV lines are insufficient, or if the procedure requires the patient to be positioned in the sitting position. Increased risk of an air embolism during surgery exists when the patient is in a sitting position and when a venous sinus may be breeched. A precordial Doppler ultrasound or a pulmonary artery catheter may be placed to monitor for an air embolus. A catheter in the right atrium can be used to remove an air embolus in the heart. An arterial line may be placed for continuous monitoring of blood pressure and for drawing samples for arterial blood gas (ABG) analysis.

Antibiotic prophylaxis is administered within 30 minutes of incision time and continued at the appropriate dose schedule for at least 24 hours. The preoperative antibiotic dose is the most important dose in the prevention of postoperative infection. Generally, a broad-spectrum cephalosporin is the antibiotic drug of choice, but this depends on the needs of the individual patient. In addition, antibiotics such as bacitracin can be added to the irrigation fluid. Preoperative steroids may be given to minimize inflammation and edema when surgery is done involving the brain or spinal cord. Diuretics may be added for brain relaxation during surgery and to decrease ICP. To prevent seizures antiepileptic drugs are typically given when the cerebral cortex is manipulated. Coagulopathies must be identified and corrected preoperatively.

For all but minor surgeries, a Foley catheter is inserted into the bladder to monitor urinary output during the procedure. It is essential when procedures are expected to be prolonged, when excessive bleeding is anticipated, or when diuretics are to be given intravenously, so that the bladder does not become distended. A Foley catheter is needed by trauma patients for continuous assessment of kidney function.

STEREOTACTIC IMAGE-GUIDED NAVIGATION. To prepare for surgery on the brain, fiducials are placed on bony landmarks or points around the skull before a preoperative MRI or CT scan. Afterward, the fiducials are left in place for entry into the OR. After the patient is anesthetized and positioned,

a skull clamp is placed and an image-guided navigation arm is attached to the skull clamp. This provides a fixed point of reference. The arm should be out of the way of the surgical team to ensure that it will not be inadvertently bumped and moved from its fixed point during surgery, thus disrupting the navigation system and potentially making it useless. The location of the fiducials is registered into the computer, allowing the computer to align the preoperative images (of the CT scan or MRI) to the patient's head. The monitor then shows the location of the navigation probe (which is maneuvered by the surgeon) and its trajectory on all three planes (axial, coronal, and sagittal) of the CT or MRI (see Figure 20-39). This enables the neurosurgeon to plan the approach to the target area and to navigate the surgical area using the navigation probe. After the registration process is complete, the fiducials can be removed so that the area can be prepped for surgery. A sterile sleeve is placed over the navigation arm when draping. The navigation system is used to find the target (tumor, lesion, ventricle) using the least traumatic trajectory. It also helps to ensure that the desired amount of tissue is removed. The image-guided navigation system can also be used for spine surgery.

NEUROMONITORING. An EEG can be used intraoperatively to view and record electrical activity by way of electrodes placed on the scalp or directly on the brain. It can be used to identify the location of seizure foci on the brain for possible resection (Research Highlight). Nonconvulsive use of EEG monitors is employed to monitor for burst suppression during carotid endarterectomy. Burst suppression refers to a decrease in brain activity on the EEG monitor and may be related to hypoxemia-related hypoperfusion.

EPs record the brain's electrical response to visual, auditory, and sensory stimuli. They may be used intraoperatively to monitor hearing during resection of acoustic neuromas or to monitor SSEPs (somatosensory evoked potentials) during some spine surgery. SSEPs may also be used to localize the primary sensory cortex in anesthetized patients. SSEPs involve placing needles in significant muscles of the patient and recording a baseline reading before the surgical incision. A significant change in EPs can indicate surgical invasion of the spinal cord, peripheral nerves, brainstem, or midbrain. To avoid permanent injury to the patient, the patient's position may need to be adjusted, or the surgeon may need to adjust retractors or instrumentation, alter a surgical approach, or decide that a subtotal tumor resection is necessary.

Transcranial Doppler (TCD) ultrasound may be used during carotid endarterectomy surgery. TCD provides information relevant to the major causes of perioperative cerebrovascular morbidity, including intraoperative and postoperative emboli, hypoperfusion during cross-clamping, intraoperative or postoperative thrombosis, and postoperative hyperperfusion syndrome. Using information received from TCD, the surgeon can alter the surgical or treatment plan in an attempt to avoid these complications (Whiten and Gunning, 2009).

LUMBAR AND VENTRICULAR DRAINS. The neurosurgeon may place a lumbar drain in the subarachnoid space of the lumbar spine to allow for CSF removal and intraoperative brain relaxation during aneurysm or tumor exposure. It may also be placed to prevent (or postoperatively, to treat) a CSF leak, which is most likely to occur after posterior fossa or transsphenoidal procedures. Alternatively, surgeons may place a ventricular catheter through a burr hole into a ventricle of the brain. In addition to providing the ability to drain CSF, a ventriculostomy provides the most accurate method of monitoring ICP. A transducer-tipped catheter system is a less accurate but less invasive method for monitoring. It does not allow for CSF drainage. With both the lumbar drain and the ventricular catheter, the nurse must ensure that stopcocks and clamps are properly positioned to avoid overdrainage of CSF, which could result in brain herniation. A separate surgical prep and setup are required for placement of these ICP devices.

Positioning. Many of the basic body positions described in Chapter 5 and their modifications are used in neurosurgery. The perioperative nurse must collaborate with the surgeon before

RESEARCH HIGHLIGHT

Results of Surgical Interventions for Epilepsy

This study sought to evaluate the success of epilepsy surgery in patients who required placement of invasive intracranial (IE) electrodes to localize the seizure source. This is a subset of overall patients who might undergo epilepsy surgery, since many patients can have their seizure source localized from surface electroencephalographic monitoring in conjunction with other standard testing (including magnetic resonance imaging and neuropsychologic evaluation).

A retrospective review was undertaken of all patients at one institution who had IE monitoring over a 5-year period. The IE electrodes were placed through skull burr holes. Resective surgery was offered to the patient if a localizable and resectable source for the seizures was clearly identified. Univariate and multivariate analyses were performed to determine those variables that might predispose the patient to being seizure-free and off medication 1 year after the surgery.

In the 172 patients with placement of IE electrodes, 130 elected to have resective surgery. Reasons for not having surgery were multifocal sources for seizures, unlocalizable source, patient decision, and unresectable source. Surgical procedures performed were temporal lobectomy (47%), focal cortical resection (40%), and supplementary motor area (SMA) resection (10%). At 1 year 47% of patients were seizure free, and at 4 years 44% continued to be seizure free. In the univariate analysis, temporal resections were more likely to be seizure free (53%) compared to non–temporal resections (41%). In addition, seizure-free patients were more likely to be younger (21% of patients over 40 years of age were seizure free whereas 58% of patients under 40 were seizure free). The multivariate analysis suggested that temporal lobectomy, SMA resection, and younger age lead to a higher chance of being seizure free.

IE monitoring is not required for all patients with epilepsy being considered for surgical resection. This study suggests that there are certain patient factors and surgical choices that can predict a more successful outcome when IE monitoring is performed.

From MacDougall KW et al: Outcome of epilepsy surgery in patients investigated with subdural electrodes, *Epilepsy Res,* 2009, doi:10.1016/j.eplepsyres.2009.03.014.

the procedure to ensure the appropriate OR bed, attachments, and supportive positioning devices are available. Positioning devices that may be needed include a headrest, pillows, blankets, gel pads, a safety belt, tape, a shoulder roll (supine), an axillary roll (lateral), a beanbag (lateral), and chest rolls (prone).

Specialized neurosurgical headrests and skull clamps are commonly used for craniotomies and posterior cervical spine surgeries to support and stabilize the head and neck. They can be used with any body position. The basic unit of the neurosurgical headrest attaches to the frame of the OR bed after the standard OR bed headpiece has been removed. An articulated arm allows fine adjustments to the position of the head. A horseshoe-shaped headrest may be used. Alternatively, head clamps, skull pins, and tongs that are attached to the neurosurgical headrest bed attachment and provide maximum stability may be required (see Figure 20-36).

Most skull clamps have three sterile pins that are placed in the skull clamp and covered with antibiotic or povidone-iodine ointment. The surgeon or surgeon's assistant places the skull clamps on the patient's head after anesthetic is administered. The surgeon must place the skull clamp strategically in the skull to provide access to the surgical site and to avoid the frontal sinuses, the superficial temporal arteries, and the eyes. The pins on the clamp partially penetrate the outer table of the skull. If the prone position is used, the surgeon will place the skull clamp while the patient is supine. The surgeon supports the patient's head during the position change and adjusts the final head position after the patient is placed prone (Patient Safety).

After positional adjustments to the patient's body are complete, the skull clamp (and patient's head) is locked into the articulating arm of the headrest by someone other than the person who is supporting the head. The apparatus is tightened from distal to proximal and double-checked for security. Once the patient's head is locked into place, no positional adjustments can be made to the patient's body without first releasing the head. Not doing so could cause injury to the patient's cervical spine. If necessary, an image-guided navigation arm can be attached to certain skull clamps, and the positions of the fiducials are registered into the system before the patient is prepped.

The skull clamp is detached from the basic headrest by loosening the arm from distal to proximal. Finally, while the head is being supported by another person, the skull clamp is loosened, allowing the pins to be released from the skull. Ointment can be applied to the pin sites. Bleeding may occur at the pin sites after the skull clamp is removed. It usually stops with digital pressure, but occasionally a stitch may be required.

The position of the patient's arms must also be considered. For cranial surgery, usually at least one arm is tucked so that

PATIENT SAFETY

Preventing Injury When Using an Intraoperative Head Fixation System

Specialized bed attachments in conjunction with a skull clamp create a mechanical support system that is often used in head and neck surgery when rigid cranial stabilization is desired. Features of this device include the base unit (which attaches to the OR bed), cross bars, a swivel adaptor (reticulating arm), and the skull clamp. Only properly trained OR staff should be permitted to operate these devices. Mounting instructions for the bed attachment vary by OR bed. The nurse must verify that the bed attachment is properly secured before the start of patient positioning.

SAFE APPLICATION OF THE SKULL CLAMP

Once the anesthesia provider has determined that the patient is ready for positioning, the designated member of the OR team will pin the patient's head with the skull clamp. The clamp consists of two skull pins in the rocker arm and one skull pin in the extension arm. When properly placed, the pins in the rocker arm are equidistant from the centerline of the patient's head and the single pin in the extension arm is exactly at the centerline. Improper positioning of the skull pins may cause serious injury to the patient. Special attention should be paid to avoiding the areas of the frontal sinus, temporal fossa, blood vessels, and nerves. The person securing the skull clamp must ensure that the pins are at an angle of 90 degrees, the necessary pounds of clamping force are applied, and the rocker arm is in the "CLOSED" position.

SAFE POSITIONING

After the head is safely pinned, the patient can be positioned for surgery. It is important that open communication exists between all members in the OR suite. Every member of the OR team plays a key role in the positioning process, and without good communication critical steps may be missed. Airway management is vital, and the anesthesia provider must have control of the patient's airway at all times. All movements of the patient's head and body must first be cleared by the anesthesia provider. There must be at least three people responsible for positioning the head. One member of the anesthesia team monitors the airway, one member of the surgical team holds the patient's head within the skull clamp, and one member secures the reticulating arm of the bed attachment to the skull clamp. All the components of the bed attachment have a starburst locking mechanism, and it is critical all teeth are engaged and locked securely. It is the responsibility of the team member holding the patient's head to do the final check to ensure all locking mechanisms are engaged properly. There should be no movement detected in any component of the system if secured properly. If even one component of the system is not properly engaged, the patient could possibly be injured.

POSTOPERATIVE MONITORING

Once the procedure is complete and it is time to remove the patient from the fixation system, the same safety measures go into effect. The anesthesia provider maintains control of the patient's airway while one member of the surgical team holds the patient's head within the skull clamp, and a second member of the surgical team releases all the locking mechanisms of the reticulating arm. At this time either the standard headpiece of the OR bed can be reattached or the patient can be moved to the postoperative bed or stretcher. When the skull clamp is released, the surgeon confirms that all three pins are extracted from the patient's head and secured. If bleeding is observed from the pin site, the surgeon may apply pressure to control the oozing, or may use a monofilament suture to close the hole.

Modified from Integra product information, available at www.integra-ls.com/products/. Accessed May 5, 2009; PMI Pro Med Instruments instruction manual, revised September 12, 2008.

the Mayo stand can be positioned over the patient. For cervical spine surgery, both arms are tucked so that the surgical site can be accessed from both sides of the table. When the arms are tucked, the elbows are padded to protect the ulnar nerve, the palms face inward, and the wrist is maintained in a neutral position (Denholm, 2009). A drape secures the arms. It should be tucked snuggly under the patient, not under the mattress. This prevents the arm from shifting downward intraoperatively and resting against the OR bed rail.

For thoracic and lumbar spine surgery, armboards can usually be placed out of the way of the surgeon and radiology equipment. Armboards are maintained at less than a 90-degree angle to prevent brachial plexus stretch.

As always, the nurse identifies any potential hazards and takes precautions to prevent them. Sequential compression devices are applied before induction of anesthesia to prevent deep vein thrombosis (DVT) unless they are contraindicated because of a known DVT. Pressure points must be identified and relieved. Joints must be maintained in functional alignment with no pressure or tension on superficial nerves and vessels. A warming/cooling blanket is applied for temperature control. An occlusive dressing applied over the eyes protects them from chemical burns and corneal abrasions that may occur from solutions used to prep the head. Keeping the head positioned above the heart minimizes bleeding when operating on the head.

Supine position or some modification of it can be used for approaches to the frontal, parietal, and temporal lobes; the anterior cervical spine; and the anterior lumbar spine. Lateral position can be used for an approach to the cerebellopontine angle in the posterior fossa, for anterior thoracic and lumbar spine surgery, and for posterior spine surgery. It can be used for lumbar sympathectomies and for placements of nerve stimulators and pumps.

Prone position and modifications of it can be used for access to the posterior spine and for suboccipital and posterior fossa craniotomies. A laminectomy frame or chest rolls are commonly used for prone position. The Jackson table permits access of the C-arm for intraoperative fluoroscopy of the spine. The Andrews table or frame can be used for a modified knee-chest position, which is useful for posterior lumbar spine surgery. The patient's hips and knees are flexed so that the lower body is supported primarily by the knees. The Hicks spinal surgery frame may be used to support this position and allow the abdomen to hang free. The chest is supported on a chest roll. Advantages of this position include decreased bleeding because of the collapse of epidural veins, better exposure resulting from hyperflexion of the spine, absence of pressure on the vena cava, and increased ease of ventilation. Operating time is usually reduced when this position is used. Disadvantages of the knee-chest position include the difficulty of maintaining physical stability on the OR bed, the increased possibility of patient hypotension, and the pooling of blood in the lower extremities.

Fowler's (sitting) position is used for some craniotomies involving a posterior or occipital approach. Advantages of this position include optimum visibility of the operative field and decreased blood loss because of the lowered arterial and venous pressures. Disadvantages are the potential for orthostatic hypotension and air embolism. In the sitting position the venous pressure in the head and neck may be negative, predisposing the patient to air embolism (Risk Reduction Strategies). Other potential problems with this position include neck flexion with airway compromise and difficulty in achieving and maintaining functional alignment. Please refer to Chapter 5 for more information on the previously mentioned positions.

Skin Preparation. Prevention of infection is a primary concern in neurosurgery. An antiseptic skin prep is performed by the perioperative nurse, surgeon, resident, or surgical assistant. General principles and precautions cited in Chapter 3 apply to neurosurgical preps. Although studies have shown that shaving the surgical site can contribute to the possibility of infection, usually some hair removal is necessary when operating on the head and posterior cervical spine.

Hair removal from the head causes a disturbance in body image and can be upsetting to patients. A discussion and often a compromise regarding hair removal should take place between the surgeon and patient before the surgery, and an understanding should be reached as to how much hair will be removed. Hair that is removed is the property of the patient. It should be placed in a container, labeled with the patient's name, and kept with the patient after surgery.

Hair removal should be done as close to the time of skin incision as possible to decrease the possibility of surgical site infection. Whenever possible, minimal hair removal is recommended. It is possible to shave a 1- to 2-cm wide area along the length of some craniotomy incisions after the hair is parted at the incision site. After the minimal shave, the hair can be combed away from the incision and held back with prepping solution or antimicrobial ointment. However, other craniotomies require more extensive hair removal. Electric hair clippers are preferred to razors because they are less irritating and less likely to nick the skin, which would predispose the area to infection. After hair removal, the nurse should inspect the patient's skin carefully for any signs of inflammation or infection. If any such signs are noted, they should be reported to the surgeon immediately. The head and hair surrounding the planned incision can be prepped, even though the hair will be draped out of the operative field.

For surgery on the cervical spine it is possible to secure long hair on top of the head and remove neck hair with clippers to a level even with the top of the ears or to the occipital protuberance. Postoperatively, patients with long hair can comb it down over the shaved area until the hair regrows. Patients undergoing thoracic or lumbar spine surgery may not need to be shaved. If a bone graft from the hip will be taken for spinal fusion, that area must be prepped as well as the spinal incision area.

Many neurosurgeons mark the incision line with a marking pen or a marking solution and wooden stick. If a marking solution is used, indigo carmine, gentian violet, or brilliant green is recommended. Methylene blue should never be found in a neurosurgical OR because it produces an inflammatory reaction in CNS tissue. Because the markings tend to wash off during the prep, some surgeons may scratch the scalp along the planned incision with a sharp sterile needle. This increases the risk of infection and should only be done if there is danger of harming the patient by varying from the planned line of incision.

Draping. According to the recommendations of The Joint Commission, the surgical team takes a "time out" during the prepping and draping procedures to be sure that everyone is in agreement that the correct surgery is being done to the correct patient in the correct location. The surgical consent is read aloud by the circulating nurse. In neurosurgical procedures, the right or left side of the head and the level of the spine must be specified. The

RISK REDUCTION STRATEGIES

Preventing and Managing Venous Air Embolism in the Sitting Position

The use of the sitting position is more common in neurosurgical procedures than in other specialties because of its excellent surgical access, improved ventilation, and improved drainage of blood and cerebrospinal fluid from the head and neck, thereby decreasing intracranial pressure. However, patients undergoing posterior fossa, cervical, or supratentorial procedures in the sitting position are at risk for venous air embolism (VAE). VAE is a potentially serious intraoperative condition that may result in significant morbidity and mortality. The incidence of VAE in neurologic procedures performed in the sitting position is 10% to 80% and has a mortality of approximately 1%.

The perioperative nurse partners with the anesthesia provider, neurosurgeon, and scrub person to provide safety for patients during seated neurosurgical procedures. The nurse must be knowledgeable about the factors that contribute to VAE to plan effective and safe patient care.

Common sources of VAE are the major cerebral venous sinuses, in particular, the transverse, the sigmoid, and the posterior half of the sagittal sinus, all of which may be noncollapsible because of their dural attachments. Air may also enter through the emissary veins, particularly from the suboccipital musculature, the diploic space of the skull, and the cervical epidural veins. VAE is possible any time there is a negative pressure gradient between the operative site and the right atrial pressure.

PREVENTIVE MEASURES

The nurse should anticipate assisting the anesthesia provider with the placement of a pulmonary artery pressure (PAP) catheter, precordial Doppler, and a multiorifice central venous line. The pulmonary artery catheter allows the anesthesia care provider to monitor heart pressures. The right atrial central venous catheter is used to measure right arterial pressure, administer vasoactive medication if needed, and provide a route to aspirate air from the right atrium. Depending on availability, transesophageal echocardiography (TEE) may be used to detect VAE. The nurse should collaborate with the anesthesia provider and neurosurgeon to configure the OR to accommodate the TEE equipment. According to the surgeon's preference, the nurse should ensure the patient is wearing compression stockings, sequential compression devices, or elastic Ace bandage wraps on the lower extremities to promote venous return and prevent venous stasis. With the help of the anesthesia care provider, the nurse can place the patient in an antishock suit with separate inflatable chambers for the legs and abdomen, which may not be inflated until a venous air embolism has been detected.

DETECTION OF VENOUS AIR EMBOLISM

The anesthesia provider will monitor the PAP, Doppler, end-tidal CO_2 levels and TEE (if used). Generally, transient decreases in arterial pressure and end-tidal CO_2 levels, which are not otherwise related to anesthetic administration or surgical condition, indicate the presence of VAE. The audible tone of the precordial Doppler changes, and turbulence, or "washing-machine" sounds, may indicate early VAE. If VAE is detected or suspected, the nurse must be prepared to assist the surgeon and anesthesia provider to rapidly treat the patient.

MANAGING VENOUS AIR EMBOLISM

Once VAE has been diagnosed, a critical component of treatment is to prevent further air entrainment. The nurse should ensure saline-soaked dressings are available on the sterile field so the surgeon can immediately cover the surgical site. The surgeon should then assess and eliminate any entry site to prevent additional air entry. The anesthesia provider is responsible for attempting to aspirate the air by way of the multiorifice right atrial catheter and may administer ephedrine, dobutamine, or norepinephrine to provide inotropic support to the right ventricle. A repositioning to the left lateral decubitus position (right side up) may be indicated to prevent the air in the atrium from moving to the ventricle and causing an air lock. If the patient's position cannot be changed because of the positioning apparatus, the tilt of the OR bed can be adjusted to lower the source of air entry and decrease the negative air pressure gradient. The antishock suit may be inflated, thus increasing right atrial pressure and decreasing the pressure gradient between the right atrium and an entraining vein.

Modified from Goodkin R, Mesiwala A: General principles of operative positioning. In Winn RH, editor: *Youman's neurological surgery,* vol 1, ed 6, Philadelphia, 2009, Saunders; Mirski MA et al: Diagnosis and treatment of vascular air embolism, *Anesthesiology* 106(1):164-177, 2007; Leslie K et al: Venous air embolism and the sitting position: a case series, *J Clin Neurosci* 13(4):419-422, 2006; St-Arnaud D, Paquin MJ: Safe positioning for neurosurgical patients, *AORN J* 87(6):1156-1172, 2008.

surgical team should also check that the marking (initials) made to the surgical site in the holding area are in the operative field.

Draping for some neurosurgery procedures is complex and requires the cooperation of the surgeon, assistant, and scrub nurse. Four or more towels are placed around the operative site. They may be secured by disposable skin staples, small towel clips, or silk sutures on a cutting needle.

Draping for a craniotomy is challenging. If a minimal shave was done, an adhesive drape with staples placed around the shaved area near the incision can help to keep hair out of the incision. Towels can be contoured to the prepped area of the head and held in place with staples, leaving the operative site exposed. A craniotomy drape can then be placed over the towels. A sterile drainage bag below the incision will help to catch irrigation and blood and drain it into a suction canister. If a stereotactic head frame is used, be sure that the drapes do not interfere with the head frame attachments.

Prepping a hip graft incision site may need to be done with spinal fusion surgery. Two areas may need to be prepped and squared off with towels, which can be held in place with an adhesive drape. A partially unfolded three-fourths drape can be placed between the two planned incision sites before the universal or laparotomy drape is placed. A clamp can be placed over the prepped hip area to positively identify it. The drape can be cut over the prepped area, being sure not to cut an area of the drape that covers a nonsterile area. A second adhesive drape can hold the cut drape in place. Please refer to Chapter 3 for general draping procedures.

Hemostasis and Visualization. A few minutes before making the incision, the surgeon may inject the incision site with a local anesthetic agent, such as lidocaine or bupivacaine. Lidocaine has a more rapid onset and shorter duration of action than bupivacaine. Along with decreasing the effect of the stimulus of

the skin incision, infiltration of the solution will apply pressure within the tissues and decrease bleeding at the time of incision. Using a local anesthetic that also contains epinephrine will constrict blood vessels to further minimize bleeding.

Meticulous hemostasis is particularly important in neurosurgery. Many methods are incorporated to limit blood loss. A major consideration is control of hemorrhage from the highly vascular scalp. Skin edges along the wound are compressed with gauze sponges and fingers during the initial incision. Usually, this is followed by application of disposable scalp clips (Figure 20-42). An automatic clip gun may be used to apply clips to include the galea and skin edge. The clips limit bleeding by applying pressure to the scalp edges. They remain in place until closure. Placement of self-retaining retractors also helps to control bleeding of the scalp.

Retraction is required for visualization. Self-retaining retractors such as cerebellar or Gelpi retractors can be used to retract skin, subcutaneous tissue, muscle, or the scalp. Suture can be used to retract the scalp or the dura of the brain or spinal cord. Blunt, malleable retractors are used on brain tissue. Table-mounted self-retaining retractor systems such as the Greenberg help the surgeon to see deep into the brain and may be used with a microscope.

Electrosurgery is routine for neurosurgical procedures. Perioperative nurses must understand the uses and hazards of the ESU and be familiar with the safety measures. Electrocoagulation current seals the blood vessels. To be effective, the electrocoagulating current must contact the vessel in a dry field. For this reason, suctioning is necessary to remove blood as the contact is made between the instrument carrying the current and the bleeding point. A monopolar current is used to cut and coagulate tissue. It can be applied to forceps, a metal suction tip, or another instrument, which acts as a conducting tool. Monopolar electrosurgery is safe to use on the epidermis, dermis, galea, periosteum, muscle, and bone. It is used extensively for exposure of the posterior spine.

Bipolar ESUs provide a completely isolated output with negligible leakage of current between the tips of the forceps, permitting use of electrocoagulating current in proximity to structures where ordinary monopolar electrocoagulation would be hazardous (Figure 20-43). It is safe to use the bipolar ESU to control bleeding on the dura of the brain and spinal cord and near vital nerves and vessels. It can be used to maintain hemostasis and to dissect tissue in the brain. Lactated Ringer's or normal saline solution irrigation is often used during bipolar electrocoagulation to minimize tissue heating, shrinkage, drying, and adherence to the forceps. Some bipolar units have built-in irrigating systems. The use of the bipolar electrocoagulation technique allows hemostasis of almost any size vessel encountered. Vessels as large as the superficial temporal artery, as well as those too small for suture or clip ligation, may be coagulated with bipolar units.

Suction is necessary to evacuate blood, CSF, and irrigation solution from the surgical site. Metal suction tips in multiple sizes, such as the Sachs, Frazier, and Adson, are used not only because they keep the wound dry but also because they can conduct electrocoagulation current from a monopolar unit to the bleeding point. Suction applied directly on normal neural tissue may be harmful and is avoided. Instead, a cottonoid patty may be placed between the suction tip and neural tissue for protection. Suction can be used to aspirate necrotic or traumatized brain tissue or soft brain tumors after a sample has been obtained for pathologic examination. It is also useful in evacuating abscess cavities, removing fluid from a ventricle or the subarachnoid space, holding a solid tumor during its removal, and applying compression to a bleeding vessel.

Bone wax is a hemostatic material that should be available for all cranial and spinal cord operations. Bone wax may be applied with the surgeon's fingertip or with the tip of an instrument such as a Freer or Penfield elevator. The surgeon firmly rubs or packs the wax into the bleeding surfaces of bone. Bone wax is commonly used in burr holes, along the edges of a craniotomy, and on the cut edges of the spine.

FIGURE 20-42 Automatic clip gun, with disposable scalp clips and cartridge.

FIGURE 20-43 Malis bipolar coagulator and bipolar cutter, with irrigation module.

Gauze sponges are used to control bleeding before the skull or spinal canal is entered; however, they are coarse and can injure fragile tissues such as the brain and spinal cord. Instead, compressed, absorbent patties made of rayon or cotton (cottonoids) are used to control bleeding beneath the skull and around the spinal cord. Patties are also placed over delicate neural tissue for protection. It is far less traumatic to suction on a patty than directly on the tissue. Patties are available in a variety of sizes, both squares and strips, ranging from ¼ inch to 6 inches long and from ¼ inch to 1 inch wide (Figure 20-44). A supply of various sizes is typically moistened with irrigation solution or thrombin and offered to the surgeon on a waterproof surface. Patties have x-ray–detectable markers and strings attached and are included in the standard sponge count.

Cotton balls moistened with irrigation solution or thrombin may be used as a temporary pack or tamponade in a bleeding tumor bed after a tumor has been removed. The gentle pressure of the cotton balls along with time and patience on the part of the surgeon may stop bleeding not controllable by other means. Cotton balls also have x-ray–detectable strings and are included in the sponge count.

A variety of hemostatic clips are available and used by neurosurgeons to occlude both superficial and deep vessels. Unlike clips that were used in the past, hemoclips and Ligaclips are made of an alloy that is compatible with the MRI scanner. The scrub person removes the clips from a special cartridge with the appropriate applicator and passes them to the surgeon for application to a vessel. Such clips enable the surgeon to occlude vessels in areas difficult to reach by other means and to ligate superficial vessels of the brain before cutting them and without destroying any surrounding tissues. Clips are available in a variety of sizes. Numerous types of special clips are used for permanent or temporary occlusion of vessels or an aneurysm neck in the surgical treatment of an intracranial aneurysm (Figure 20-45).

Neurosurgeons almost routinely use certain hemostatic agents in addition to mechanical hemostasis (Surgical Pharmacology). An absorbable gelatin sponge (Gelfoam) can be applied to an oozing surface, either dry or saturated with

SURGICAL PHARMACOLOGY

Hemostatic Agents

Achieving hemostasis in delicate areas can be a challenge for the neurosurgeon. In addition to using meticulous technique to prevent bleeding, topical agents are routinely used as an adjunct to hemostasis. The perioperative nurse must be familiar with the agents used in this setting.

Agent	Dosage Form	Mechanism of Action	Side Effects	Nursing Considerations
Topical thrombin	Powder for reconstitution; packaged with diluent and spray pump, or diluent and spray tip syringe, with diluent only	Catalyzes conversion of fibrinogen to fibrin	May cause fever or allergic-type reactions	Product is for external use only; must be refrigerated.
Gelatin matrix (FloSeal)	Gelatin matrix granules and topical thrombin packaged as a kit with syringes and mixing bowl	Matrix particles form a composite clot that seals bleeding site; thrombin component converts fibrinogen in patient's blood to fibrin	Anemia, atrial fibrillation, infection	Product reaches maximum expansion at approximately 10 min. Excess product should be removed with gentle irrigation.
Absorbable gelatin sponge (Gelfoam)	Film, powder, and topical forms	Absorbs and holds blood and fluid within its interstices; exerts physical hemostatic effect	Local infection and abscess formation	Should not be used in closure of skin incisions because it may interfere with healing of skin edges. Often moistened with saline or topical thrombin before use.
Collagen hemostat (Avitene, Helistat, Instat)	Pads, powder, sheets, sponges	When in contact with a bleeding surface, attracts platelets that aggregate into thrombi, initiating formation of a physiologic platelet plug	Adhesion formation, allergic reaction, foreign-body reaction, inflammation, potentiation of infection	Apply dry. Excess material should be removed.
Oxidized regenerated cellulose (Surgicel)	Fibrous, knitted, or sheer weave fabric	Allows platelets and aggregates of thrombin and particulate blood elements to cling and form a coagulum that can act as a patch	Encapsulation of fluid, foreign-body reactions	Store at room temperature.

Modified from LexiComp Online, available at www.crlonline.com/crlsql/servlet/crlonline. Accessed June 22, 2009; FloSeal package insert product information, available at www.baxter.com/products/biopharmaceuticals/downloads/FloSeal_PI.pdf. Accessed June 22, 2009; Gelfoam package insert product information, available at www.pfizer.com/files/products/uspi_gelfoam_sponge.pdf. Accessed June 22, 2009.

FIGURE 20-44 Cottonoid strips and patties.

FIGURE 20-45 Standard aneurysm clips and appliers.

irrigation solution or topical thrombin. Larger pieces can be cut into a variety of sizes of strips and squares. Gelfoam is often followed by a patty, which enables the surgeon to maneuver and compress it once it is in the surgical site. Gelfoam is absorbable and can be left in the body.

Oxidized regenerated cellulose is available in two forms: a rayonlike gauze (Surgicel) and a cottonlike form (Fibrillar). These are also absorbable hemostatic agents that are used to control bleeding from oozing surfaces, vessels, and sinuses in the brain. These hemostatic substances are presented in various sizes and shapes and are offered to the surgeon dry. The hemostatic material adheres to the bleeding area with gentle pressure.

Thrombin is a drug that can be topically applied to bleeding surfaces to achieve hemostasis. Typically, Gelfoam or patties are saturated with thrombin and placed on the oozing surface.

Irrigating the wound helps the surgeon identify active bleeding points and may facilitate hemostasis. A syringe with an angiocatheter tip may be used to deliver irrigation for microsurgery. Many neurosurgeons irrigate surgical wounds with an antibiotic solution before wound closure. The antibiotic is mixed with irrigation solution according to the surgeon's preference so that it is ready for use when needed.

Suture. Required suture will vary according to the surgery, the condition of the wound and patient, and the surgeon's preference. Suture can be used for retraction of the scalp for a craniotomy flap. Dura of the brain and spinal cord may be retracted, tacked up, and closed with braided nylon suture. In general, high tensile strength is needed for closure of the galea of the scalp and the fascia and subcutaneous tissue of the back. Braided, absorbable suture can be used in interrupted stitches to close these layers. Skin may be closed with subcuticular absorbable suture, with either a continuous or an interrupted suturing technique using a monofilament, nonabsorbable suture material such as nylon; alternatively, skin can be closed with staples. Whatever technique is used for skin closure, skin edges should be everted. A drain may be secured to the skin with a nonabsorbable suture such as nylon. In an environment of infection, monofilament, nonabsorbable suture is preferred.

Dressings. Applying dressings to wounds on the head is challenging, especially if a minimal shave was done. For larger incisions in particular, a head wrap can be the best alternative. It keeps a nonadherent dressing in place over the incision site and provides compression to prevent the formation of a postoperative hematoma. A smaller dressing can sometimes be held in place with a transparent dressing or tape. Applying a liquid adhesive, such as Mastisol, to the skin before application of the dressing can help to hold it in place.

Evaluation

After the surgical procedure is completed, the patient is transported to the intensive care unit (ICU) or postanesthesia care unit (PACU). A report along with intraoperative

documentation is given to the nurse receiving the patient. The identified outcomes from the established nursing diagnoses and interventions are evaluated on an ongoing basis throughout the perioperative period, and adjustments to the plan are made as necessary. Before leaving the OR, the nurse assesses the patient's postoperative skin integrity and performs a postoperative neurologic assessment for comparison with the preoperative assessment. In addition, the patient's outcomes from the identified nursing diagnoses are evaluated. If the outcomes were met, they may be communicated as follows:

- The patient expressed feeling less anxious, coped with perioperative routines adequately, and verbalized an understanding of the planned procedure or procedures.
- The patient or family verbalized knowledge of diagnostic and surgical procedures and had realistic expectations of tests, routines, and postoperative care.
- The patient maintained effective breathing patterns; ventilation was maintained, arterial blood gases were within normal limits, and breath sounds were bilateral.
- The patient will continue to maintain a normal body temperature or undergo rewarming.
- The patient exhibited no signs and symptoms of pressure injury; sensation and motion were the same as preoperative functional levels; and respiratory status and blood pressure were maintained within expected parameters.

Patient and Family Education and Discharge Planning

Patient and family education is the key to helping the patient return to his or her optimal quality of life. As soon as the need for surgery is identified, a multidimensional education program should begin and include the patient's family. Teaching should address the psychosocial as well as the physiologic aspects of the patient's life. The plan should offer opportunities for the patient to develop new skills, coping mechanisms, and behaviors to adapt to aspects of temporary or permanent neurologic deficit.

Neurosurgery patients may experience a variety of deficits involving vision, hearing, swallowing, speech, motor, sensation, and mental status. Depending on the patient's pathologic condition and surgery, other physicians may observe the patient postoperatively along with the neurosurgeon. Neurologists, ophthalmologists, endocrinologists, cardiologists, radiologists, oncologists, and infectious disease physicians may be involved with managing the medical care of neurosurgery patients. Rehabilitation, physical, occupational, and speech therapists are instrumental in the recovery of neurosurgery patients. They also teach the patients and their families how to cope with temporary and lifelong deficits and how to improve their quality of life. Some patients may benefit from time spent in a rehabilitation facility before returning home. Patients with severe alterations in neurologic function may require long-term care.

The nurse plays an important role in teaching patients and family members how to look for and recognize potential postoperative complications, such as changes in mental status or behavior, progressive weakness, seizure activity, increasing pain, and signs and symptoms of infection. Routine discharge instructions should include information about newly prescribed medications and their potential side effects in addition to treatment options for postoperative and chronic pain (Patient and Family Education). The nurse should also ensure the patient has instructions for the use of cervical collars, braces for spinal stability, and wound dressing changes when applicable.

PATIENT AND FAMILY EDUCATION

Discharge Planning for Postoperative Posterior Thoracic or Lumbar Spinal Fusion

When discharging patients, ensure that all postoperative instructions are clear and legible, including proper phone numbers for the surgeon and nurse. The nurse should reinforce all written instructions, and ask the patient and caregivers to verbalize and demonstrate a clear understanding of the instructions.

HOME CARE

- Stress the importance of follow-up care. Advise patients when to schedule a follow-up appointment with the surgeon, and when to begin physical therapy.
- Review the signs or symptoms of infection that warrant immediate notification to the surgeon. They include a temperature of 101° F or greater; increased swelling, redness, or tenderness around the incision site; and any drainage originating from the incision.
- Instruct the patient to seek immediate medical attention if they experience the onset of a sudden and/or severe headache, weakness of the extremities, or any changes in bowel or bladder function.

WOUND CARE

- Ensure that patients and caregivers are instructed on proper cleaning, inspecting, and dressing of the wound. Assure them that a small amount of swelling is normal and should continually decrease. Instruct patients to avoid soaking the wound, to shower only when cleared by the surgeon, and to discontinue the use of any lotions or oils on or near the incision site.
- Educate patients on the risk factors that contribute to delayed wound healing such as smoking, obesity, advanced age, diabetes, chronic steroid use, and malnutrition.

ACTIVITY

- Walking and climbing stairs are typically encouraged. Activity tolerance is generally patient specific and should be personalized as necessary.
- Patients will have activity restrictions which typically include the following: prolonged travel or driving; sitting for periods longer than 30 minutes at a time; occupational limitations; strenuous exercise; lifting more than 10 pounds; and bending or twisting at the waist.

PATIENT AND FAMILY EDUCATION

Discharge Planning for Postoperative Posterior Thoracic or Lumbar Spinal Fusion—cont'd

PAIN MANAGEMENT

- Discuss how much pain, soreness, and stiffness are expected and the importance of contacting the surgeon if the pain is excessive. Over several months, back and leg pain should decrease, depending on the severity of pain preoperatively.
- Review all prescriptions and proper dosing. Discuss which over-the-counter medications, such as acetaminophen, are appropriate. Advise patients that the use of aspirin and NSAIDs, such as ibuprofen, may not be indicated for several weeks because they can cause bleeding.
- Offer pain-reducing activities such as exercise, and relaxation techniques.

DIET

- Proper nutrition promotes wound healing.
- Fluids, fruits, and fiber can help prevent constipation.

SPECIAL INSTRUCTIONS AND FOLLOW-UP CARE

- Provide instructions for use of any braces or supports. Generally, a brace should be worn at all times, except when showering and sleeping, until told otherwise by the surgeon.
- Advise patients to resume all preoperative medications unless otherwise noted.
- Provide prescriptions for new x-rays, CT scans, and MRIs according to the physician's orders.
- Discuss smoking cessation when appropriate. Stress the connection between smoking and delayed would healing, and offer resources for smoking cessation.

Available at www.spineuniverse.com/treatments/surgery/lumbar/discharge-instructions-lumbar-fusion-surgery. Accessed Feb 1, 2010.

The entire healthcare team is responsible for planning an easy transition from the acute care center to the patient's home or to a skilled nursing or rehabilitation facility. The patient and family need to be involved in every aspect of the neurosurgery patient's care and should be encouraged to ask questions and voice their concerns and opinions.

Surgical Interventions

MINIMALLY INVASIVE AND SPECIALIZED NEUROSURGERY TECHNIQUES

Microneurosurgery

Adaptation of the operating microscope for neurosurgery has resulted in improvement of many neurosurgical procedures and made new procedures possible. For years, neurosurgeons have worn magnifying loupes to see small structures. Loupes usually have a magnification of 2× or 3.5×. The microscope has a variety of magnifications ranging from 6× to 40×, providing flexibility and precision. The co-axial illumination overcomes the difficulties of lighting neurosurgical wounds (History box).

Use of the microscope restricts the surgeon's field of vision and mobility; therefore the surgical technologist and surgical assistant must be proficient. The operative field, unless video monitoring is available, cannot be seen. Surgical personnel must understand the surgical procedure and the corresponding anatomy, know the names and uses of all microinstruments, and be proficient at passing the instruments to the surgeon without delay that are ready for use. Each time the surgeon must look away and then back to the surgical field, open wound time and anesthesia time are increased while the surgeon becomes reoriented to the field. Therefore the assistance the scrub nurse gives the surgeon saves time and directly benefits the patient.

Microsurgical instruments have been modified and adapted to the requirements of neurosurgery. These instruments often possess the following characteristics: bayonet shape, so that the surgeon's hand remains outside the line of vision and the beam of the microscope light; finely sprung and fluted grip; long length for access to deep structures; and slender and delicate tips that occupy as little space as possible. Microneurosurgical instruments are expensive and delicate. Instructions for handling, cleaning, sterilizing, and storing these instruments should be followed. An instrument that is sprung, bent, dulled, hooked, or in any way damaged must never be handed to a surgeon for use but must be repaired or replaced. Instruments must be kept free from blood and tissue during use because the microscope also magnifies debris on the instruments, occluding the structure the surgeon is about to approach. Very fine microsutures are available.

Microsurgical techniques have been applied to cranial, spinal, and peripheral nerve operations. Some procedures in which microsurgery is of value are explorations of the posterior fossa, especially for tumors of the fourth ventricle or cerebellopontine angle, and removal of small acoustic neuromas, with resulting preservation of the facial nerve. Small-vessel endarterectomy, cerebral arterial bypass, cerebral aneurysm clipping, and excision of AVMs are performed using the microscope for visualization of the surgical site. Microsurgery also has advantages in the treatment of tumors and AVMs of the spinal cord.

Neuroendoscopy

Neuroendoscopy is a rapidly evolving field of minimally invasive surgery. The endoscope provides illumination and magnification of structures and an extended viewing angle. Brain retraction and manipulation are reduced in endoscopic surgery, resulting in decreased tissue damage (Teo and Mobbs, 2005). The surgical team must be prepared to convert from a neuroendovascular procedure to an open procedure if it is determined that the surgery cannot be successfully completed endoscopically.

Indications for neuroendoscopic surgery are many. Endoscopic tumor removal or CSF diversion through endoscopic fenestration, such as a third ventriculostomy, can be done for

HISTORY

Evolution of Surgical Magnification

From 1813 to 1825 English, French, and German opticians attempted to coordinate two monoculars into a single instrument, finally providing the modern binocular, used then as opera glasses. Abbe and Zeiss, circa 1870 to 1880, improved opera glasses with the invention of the binocular roof prism, which enabled greater enlargement of the image without having to deal with the increased length of the optical tube.

In 1886 Westien, a German instrument maker, developed the first surgical loupes for a zoologist interested in performing more accurate dissections. Later, Westien developed binocular loupes for an ophthalmologist. He further adapted magnifying loupes from a stationary device to an instrument to be worn on the head, offering a power of 5× to 6× magnification. These proved impractical because of their weight.

The first teleloupes were developed in 1912. They were the prototype of current surgical loupes, offering a light weight and a magnification of 2×. Their initial popularity was appreciated by ophthalmologists, and in 1948 Riechert, initially an ophthalmologist who later became a neurosurgeon, advocated their use during neurosurgical procedures. It is believed that neurosurgeons' use of surgical loupes was more widespread, but they had not published this fact.

Operating microscopes borrowed the technology of optical systems developed for surgical loupes and underwent further development of their optical and mechanical systems between 1921 and 1952. Monocular scopes, first fixed near the head of the patient, evolved to binocular scopes that attached to the OR bed and later became freestanding floor mounts. The delayed application of the operating microscope in general surgery has been related to the technical deficiencies of the early microscopes, in that they were unstable and immobile and had limited illumination.

In 1952 Littman succeeded in developing a sophisticated, maneuverable microscope for surgical requirements that maintained sharp focus and had a co-axial light system. This prototype was known as the *OPMI 1* and drew the attention of otologic surgeons, ophthalmologic surgeons, and neurosurgeons. The operating microscope has made it possible for neurosurgeons to perform delicate, minimally invasive surgery in anatomic regions requiring magnification and illumination.

Modified from Carl Zeiss: *Technical milestones,* available at www.zeiss.com/C12567A100537AB9/Contents-Frame/63125BAC5434D55DC1256DB900446D61. Accessed June 22, 2009.

the treatment of hydrocephalus and can eliminate the need for a shunt. Interventricular tumors may be removed endoscopically. In addition, the endoscope can be used to assess adequacy of tumor removal and to identify tumor portions left behind or adherent to vital structures. Stereotactic and image-guided surgery is often used with neuroendoscopy successfully. The endoscope is commonly used in the transsphenoidal approach for pituitary and sellar tumor resection (possibly in collaboration with an otolaryngology surgeon), for microvascular decompression, and for endoscopic biopsy of a lesion. The potential rewards of neuroendoscopy include improved postoperative results, shorter hospitalization times, and fewer postoperative complications (Teo and Mobbs, 2005).

Endovascular Procedures

There are several neurovascular disorders that are amenable to an endovascular procedure. This approach is considered minimally invasive, and is therefore a reasonable option for patients who are not candidates for open surgical procedures because of age, health status, medical condition, or location of the lesion. Interventional neuroradiology uses fluoroscopy to gain access to the intracranial circulation by way of a percutaneous transfemoral catheter.

The endovascular approach to the treatment of both ruptured and unruptured cerebral aneurysms is endosaccular occlusion (Evidence for Practice). This is an excellent technique for aneurysms that are complex, have a neck that is too short for clipping, or are difficult to reach via traditional craniotomy. A flexible platinum coil is fed through the transfemoral catheter and is coiled within the body of the aneurysm, conforming to the aneurysm's shape. The coil is then detached from the catheter. The coil blocks blood flow to the site, thereby preventing rupture or rerupture, both of which can be fatal.

Although surgical excision is still the standard treatment for intracranial arteriovenous malformation (AVM), surgical morbidity may be decreased by utilizing endovascular embolization preoperatively in select cases. A specialized microcatheter is guided directly into the AVM via angiography. The abnormal blood vessels in the AVM are occluded from the inside by means of embolization. There are several materials used to cause embolization, including fibered titanium coils, polyvinyl alcohol particles, and fast-drying biologically inert glues. The AVM may effectively be devascularized and reduced in size through endovascular embolization, and when combined with microsurgery or stereotactic radiosurgery, the AVM may be completely eradicated. Endovascular embolization as the sole treatment of intracranial AVMs is unacceptable, because of unknown long-term occlusion rates and low rates of complete occlusion. In the case of dural arteriovenous fistulas, which comprise 10% to 15% of all intracranial AVMs, endovascular techniques may be curative without the need for further intervention.

Endovascular embolization is also advantageous when employed as a preoperative treatment for select intracranial tumor resections. Highly vascular tumors, as well as tumors that are inopportunely positioned, can be devascularized using techniques similar to those used in the treatment of AVMs, thus decreasing blood loss and risk of hemorrhage during resection.

Carotid artery angioplasty and stenting are the endovascular procedures used to treat carotid artery stenosis. A balloon-tipped catheter is advanced to the location of the offending plaque within the carotid artery and is inflated to press against the plaque. Consequently, the plaque is flattened against the vessel lumen and blood flow is reestablished. A metal-mesh tube is then advanced to the same location to act as a scaffold to prevent reocclusion. Stents may be bare metal, or they may be coated with thrombolytic agents.

Intracranial stenosis has been deemed a high-risk disease in need of alternative therapies. Endovascular intracranial angioplasty and stenting are options, although neither has yet to be

EVIDENCE FOR PRACTICE

Surgical/Endovascular Treatment of Ruptured Aneurysms

The Stroke Council of the American Heart Association (AMA) has formulated recommendations for the surgical/endovascular treatment of ruptured aneurysms. These guidelines are intended to serve as a framework for the treatment of ruptured aneurysms.

- Endovascular coil occlusion of the aneurysm is appropriate if the aneurysm is deemed treatable by either endovascular coiling or surgical clipping.
- Reasonable consideration of the individual characteristics of the patient and aneurysm must be used in deciding the best means of repair.
- The patient should be managed in a surgery center offering both techniques.
- Either procedure should be performed to reduce the risk of rebleeding after the initial aneurysmal subarachnoid hemorrhage (SAH).

CLIPPING

The surgeon performs a craniotomy (opening of a portion of the skull) and separates the aneurysm from the surrounding tissue. A small titanium clip, whose features are similar to those of a clothespin, is then placed across the base of the aneurysm. Once the clip is secured, blood can no longer enter or exit the aneurysm sac. By using a needle to drain the remaining blood out of the aneurysm, the sac should empty and eventually collapse. The procedure is ideally performed within 72 hours of diagnosis. It is important to note that following rupture, there is a 40% chance of death and 80% chance of disability. Early detection and treatment offer the best chances of survival.

COILING

Also known as endovascular therapy, coiling is a less invasive treatment option. Especially for those patients who are in poor health, surgical intervention may pose a greater threat than the aneurysm itself. Coiling has proven to be a safe alternative to the traditional treatment of a craniotomy. This procedure does not involve opening of the skull, and is performed from inside the blood vessel. A catheter is inserted into the patient's groin, and is guided up toward the brain under fluoroscopy. A wire is then threaded into the catheter and directed into the aneurysm. Once inside the aneurysm, the wire twists into small coils and continues filling the aneurysm sac until eventually the aneurysm is occluded (Zuccarello and Ringer, 2009).

Previous studies, such as the International Subarachnoid Aneurysm Trial (ISAT) in 2002, found that patients who were initial candidates for both types of procedures had better outcomes 1 year after endovascular coiling as opposed to surgical clipping. Since that time, few studies have emerged to either support these findings or challenge them. It is essential that research continues to determine which course of treatment is the most beneficial.

Modified from Bederson BJ et al: Guidelines for the management of aneurysmal subarachnoid hemorrhage: a statement for healthcare professionals from a special writing group of the Stroke Council, *Stroke* 40:994-1025, 2009; Zuccarello M, Ringer A: Aneurysm clipping, *Mayfield Neuro,* 2009, available at http://mayfieldneuro.com/PE-Clipping.htm. Accessed May 31, 2009.

evaluated in a controlled clinical trial. Successful use of balloon angioplasty has been documented in mostly academic, high-volume centers, performed by highly skilled and experienced physicians. While the results are encouraging, the technically demanding nature of the procedures carries substantial risk. The Wingspan stent has been approved by the U.S. Food and Drug Administration (FDA) to treat symptomatic patients with intracranial stenosis greater than 50% that is refractory to medical therapies. The stent is implanted using the Wingspan technique. Following balloon angioplasty, a self-expanding nitinol stent is placed across the atherosclerotic lesion in the brain. While the Wingspan system appears to be a viable treatment option, a high rate of restenosis has been reported, and its value is not yet firmly established (American Association of Neurological Surgeons [AANS], 2009).

Intraarterial thrombolysis for the treatment of acute ischemic stroke is a consideration for patients who have missed the 3-hour window for therapeutic intravenous thrombolysis. The endovascular route is used to deliver a high concentration of a thrombolytic agent directly to the site of the offending thrombus in combination with mechanical clot extraction. Intraarterial thrombolysis is still being studied for its long-term value. It is currently recommended for selected patients with major ischemic stroke of less than 6-hours duration caused by occlusion to the middle cerebral artery, and who have contraindications to intravenous thrombolysis, such as recent surgery (Doherty and Way, 2006).

Mechanical clot extraction is an endovascular technique that may be used alone or in conjunction with intraarterial thrombolysis. Success rates are improved when both modalities are used. There are several retrieval devices approved by the FDA for extraction of thrombi from occluded intracranial arteries. A typical retrieval device consists of a coil that is delivered to the thrombus site via endovascular microcatheter and screwed into the clot like a corkscrew to extract the clot. The coils are available in different shapes and configurations to accommodate the specific thrombus. Mechanical clot extraction shows its best utility for cerebral arteries demonstrating large or irregularly shaped clot burdens (Meyers et al, 2009).

Stereotactic Radiosurgery

In stereotactic radiosurgery, stereotactic localization is coupled with delivery of ionizing radiation to destroy a lesion in the brain. Radiosurgery is technically noninvasive and has a low associated morbidity. The use of radiosurgery has increased, and success of treatment has improved with advancements in neuroimaging (CT and MRI) and computer technology. The goal of radiosurgery is to obliterate a relatively small intracranial target with a high irradiation dose while sparing adjacent and distant tissues. Stereotactic imaging and target localization using CT, MRI, or angiography must be fully integrated with the radiation delivery device to achieve pinpoint localization of the target (Pollock and Brown, 2005). Radiosurgical instruments include the Gamma Knife, the Novalis, and the CyberKnife.

Radiosurgery can be used to treat AVMs, tumors, and trigeminal neuralgia. Best results are achieved for lesions smaller than 35 mm. Larger lesions or lesions involving or near cranial nerves can be successfully treated with a fractionated approach where the radiation is precisely delivered in small

daily fractions. This technique, called fractionated stereotactic radiotherapy (FSR), has been particularly useful for preserving vision and hearing. Patients with larger lesions often have symptoms of mass effect that are generally not improved with radiosurgery. Radiosurgery and FSR techniques have successfully sterilized a variety of intracranial lesions often with far less morbidity than a surgical approach.

Stereotactic Procedures

The goal of stereotactic surgery is to target a point or volume in space by way of a predefined minimally invasive trajectory (Zonenshayn and Rezai, 2005). This is accomplished with coordinate systems that provide a constant frame of reference. Radiographic modalities (CT, MRI) are used to navigate three dimensionally and locate and destroy target structures. Predetermined anatomic landmarks are used as guides.

Originally, special head-fixation devices were developed for stereotactic brain surgery (see Figure 20-38). Over the past decade frameless systems have surpassed frame-based techniques in popularity and versatility. These systems employ fiducial markers that either affix temporarily to the skin or are implanted into the outer table of the skull, thereby eliminating the need to mount a frame on the patient's head. These markers are visible on the imaging modality being used. By registering the physical location of the fiducials on the patient's skull, the corresponding points on the image can be aligned with the operating space (Zonenshayn and Rezai, 2005).

Both frame-based and frameless stereotactic systems use radiography, fluoroscopy, CT scans, or MRI to permit accurate placement of a probe directed at the target area. The preoperative images are aligned to the patient's head during surgery so that the surgeon has a better idea of the target area.

The many common applications for cranial stereotactic surgery include craniotomies, transsphenoidal approaches, endoscopic surgery, needle biopsies, and therapeutic aspiration. It is also used for catheter placement and third ventriculostomy surgery. Spinal stereotactic surgery is used for screw placement and spinal cord lesions. Common target areas for the stereotactic approach include tumors, infectious lesions, vascular malformations, the basal ganglia, the thalamus, and anterolateral spinal tracts. Target areas can undergo biopsy, be destroyed by chemical or mechanical means, or be electrically stimulated. Stereotactic procedures are also done to place electrodes in various regions of the brain to determine the site of origin of seizures.

Procedural Considerations. As in most image-guided surgery (IGS), carts with a monitor and the computer, along with accessory equipment and supplies, are required. A variety of stereotactic frame systems are available. The nurse must be familiar with the system in place at his or her institution. Frameless stereotactic surgery triggered a new era in surgical navigation and information delivery. This technology provides three-dimensional visualization of anatomic features with real-time localization information (see Figure 20-39).

Operative Procedure

1. The patient's head is placed into a halo head frame with a stereotactic cage before the surgery (framed stereotaxy). Alternatively, fiducials are placed on the patient's skull (frameless stereotaxy).
2. The patient is then taken for a CT or MRI scan of the brain. The target is identified, and computer coordinates are determined and recorded.
3. The nurse brings the patient to the OR with the frame or fiducials left in place. The stereotactic coordinates are registered or entered into the computer, and the procedure is performed through a burr hole. The stereotactic probe is guided by the computer, directing the surgical approach and trajectory (see Figure 20-38).
4. Hollow cannulae, coagulating electrodes, cryosurgical probes, wire loops, and other lesion-producing or biopsy instruments may be introduced for the destruction of areas in the brain. Temporary and permanent nerve-stimulator electrodes are also introduced to augment the pain-control function of the CNS. These instruments are introduced through a burr hole in the skull.

SURGICAL APPROACHES TO THE BRAIN

Burr Holes

A burr hole is the minimum exposure that can be made to gain access to the brain. A small incision is made in the scalp down to the skull. A small self-retaining retractor is placed. The periosteum is retracted using a periosteal elevator. A drill is used to make the appropriate-size burr hole (usually 1 to 2 cm). If necessary, the burr hole can be enlarged using Kerrison rongeurs. The dura is incised, exposing the brain.

Burr holes are necessary for many neurosurgical procedures. They are placed in the skull to remove a localized fluid collection secondary to head trauma that results in an epidural or subdural hematoma. A burr hole can be used to access the intracerebral ventricles for the following reasons: placement of a ventricular catheter to drain obstructed CSF; measurement of ICP; or establishment of a ventricular shunting system. Burr holes are placed for many stereotactic procedures, such as stereotactic biopsy or placement of electrodes. Burr holes are also made before turning the bone flap in preparation for a craniotomy procedure.

Craniotomy

A craniotomy is the removal of a section of the cranium referred to as a bone flap. One or more burr holes are placed, and the dura is dissected away from the cranium. A craniotome with a dura guard attachment is used to excise a section of the cranium, exposing an area of the brain. The surgeon replaces the bone flap to its original location and secures it with wire or titanium plates and screws.

Multiple types of craniotomy incisions are used to expose different parts of the brain. Depending on the location of the pathologic condition, a craniotomy may be frontal, parietal, occipital, temporal, or a combination of two or more of these approaches. The pterional craniotomy is an extremely versatile approach to the anterior and middle fossae. It is useful to access lesions of the frontal or temporal lobes near the sylvian fissure or skull base. A craniotomy may be performed to evacuate intracranial hematomas not accessible through a burr hole, to control bleeding, to debulk or resect tumors, to excise or clip vascular lesions, to aspirate abscess formation, and to decompress cranial nerves.

When turning a scalp flap for a craniotomy, the surgeon may peel the scalp back off the pericranium. The surgeon

elevates the bone flap with the overlying muscles still attached (osteoplastic) or strips the periosteum off the skull before the bone flap (free flap) is turned. The bone plate may be separated from the soft tissues, removed from the skull, and set aside for replacement at the end of the procedure. It is placed in an antibiotic solution and remains on the sterile field. The surgical technologist ensures that the bone flap stays separate from other items on the sterile field and alerts the perioperative nurse and any relief surgical technologists of its location to prevent it from being inadvertently discarded. If the bone is not separated from the soft tissues, it is reflected with the temporal muscle and soft tissues. If intracranial swelling is a major concern or the purpose for the craniotomy, the bone plate may not be replaced. If it is not replaced, it may be frozen in a sterile container according to hospital protocol to be used at a future date.

Craniectomy

Craniectomy is the permanent removal of a section of the cranium using burrs and rongeurs to enlarge one or more burr holes. The surgeon performs a craniectomy to gain access to the underlying structures. This procedure may be required to remove tumors, hematomas, and infection of the bone. A suboccipital craniectomy, done with the patient in prone or lateral position, allows access to the posterior fossa. Titanium mesh may be used to repair the cranial defect. Craniectomy is also indicated as treatment for craniosynostosis in infants and young children. Severe head injury with increased ICP can be treated with a craniectomy to give the brain room to swell.

Transsphenoidal Approach

The transsphenoidal route to the pituitary fossa is a less invasive means of removing tumors than the transcranial route. This can be done with a small incision through the nose or through the gingiva under the upper lip. More recently, an endoscope has been used to assist with access through the sphenoid sinus into the pituitary fossa. Tumors of the parasellar region may also be approached using this technique.

SURGERY OF THE BRAIN AND CRANIUM

Evacuation of Epidural or Subdural Hematoma

After trauma, decompression of the brain, as well as removal and drainage of blood clots and collections of liquefied blood from above or beneath the dura mater, may be required. The need for hematoma evacuation is primarily determined by a declining neurologic status in the patient. Depending on the severity of the injury, evacuation can be accomplished through burr holes or a craniotomy. If elevated ICP is a major concern, the craniotomy plate may be temporarily removed from the skull. This gives the brain more room to swell and may prevent brain herniation and death.

Operative Procedure—Burr Hole Placement for Evacuation of Hematoma

1. A preoperative CT scan is very useful in planning optimal placement of burr holes. The surgeon makes at least two linear or small horseshoe incisions over the site of the lesion. Two or more burr holes are made.
2. If a blood clot or collection of bloody fluid is found outside or beneath the dura mater, the surgeon enlarges the burr hole with a Kerrison rongeur until adequate exposure is obtained.
3. If the hematoma is subdural, the dura is incised.
4. Clot and fluid are evacuated, and hemostasis is accomplished with the ESU or the use of hemostatic clips.
5. The surgeon irrigates through the holes using catheters or bulb syringes. Large amounts of irrigating solution are used until the return appears clear.
6. A drain or catheter may be inserted in the subdural or epidural space for postoperative drainage. Additional burr holes can be made as necessary during the course of the procedure to ensure complete evacuation.

Cranioplasty

Cranioplasty is performed for repair of a skull defect resulting from trauma, malformation, or a surgical procedure. The purpose of cranioplasty is to relieve headache and local tenderness or throbbing, to prevent secondary injury to the underlying brain, and for cosmetic effect.

Procedural Considerations. Repair of a skull defect may be performed acutely in clean cases. In contaminated cases, 6 months should pass before repair is attempted (Connolly et al, 2009). When a bone plate is removed for control of elevated ICP, it can be repaired following resolution of ICP issues. If the patient's bone plate was frozen under sterile conditions, it could be replaced with microplates and screws.

The most common materials used for cranioplasty include titanium mesh and/or methylmethacrylate. Commercially prepared cranioplastic synthetics that supply the needed chemicals and mixing containers have simplified the procedures of shaping and molding the prosthesis. Sometimes heavy wire mesh is cut to the shape of the defect, and the methylmethacrylate is molded over the mesh.

Recent technologic advancements use CT scans to produce a computer-generated duplication of the defect. A properly sized prosthesis can be produced and sterilized before the surgery. After the defect is exposed, minor adjustments in the shape of the prosthesis can be made with a burr to achieve an optimal fit.

Operative Procedure—Cranioplasty Using Computer-Generated Prosthesis

1. Typically, the old incision is reopened.
2. Keeping in mind that there is no bony protection between the scalp and the brain, the surgeon carefully elevates the scalp flap from the underlying scar, dura, and brain.
3. Bone edges are exposed with a curette, and the prosthesis is fitted to the defect using a burr. Debris is irrigated out of the wound.
4. Microplates and screws secure the prosthesis in place.
5. The incision is closed as usual for craniotomy.

Operative Procedure—Cranioplasty Using Cranioplastic Material

1. A scalp flap is turned, and the bony defect is exposed.
2. The edges of the defect are trimmed, and a ledge is formed to seat the prosthesis.
3. After the bone defect has been prepared so that it is slightly saucerized, the methylmethacrylate is mixed by combining one volume of liquid monomer with one volume of the pow-

dered polymer. When this has formed a doughy mass, it is dropped into a sterile polyethylene bag. The soft plastic is then rolled on a flat surface into the desired shape, leaving the thickness to the approximate depth of the skull edges. A sterile test tube, syringe barrel, or other round object can be used, although a stainless-steel roller is preferred because of its weight and ease of use.

4. The soft cranioplastic material in the bag is placed over the skull defect and, through light pressing with the ends of the fingers, is fitted into the missing skull area. Assistants stretch the plastic bag as the surgeon molds the plate into the defect and forms an overlapping bevel edge. This overlapping fringe keeps the plate from falling inside the skull, in the same manner as the skull saucerization.
5. When the heat of the chemical reactions is evident, the surgeon lifts the plate out of the bony wound and removes it from the polyethylene bag. Cool saline should be used on the flap while the exothermic reaction takes place.
6. When the plate is cool enough to handle, the surgeon trims excess material and bone using rongeurs or a saw and places the plate in the cranial defect to check for fit.
7. A craniotome is used to smooth the rough spots and bevel the edges so that the plate will blend gradually with the skull.
8. Mixing and fitting the plate take about 7 minutes, the same time needed for the cranioplastic material to harden. Sutures may be used to hold the plate in place, generally at three or more points.

Ventricular Catheter and Shunt Placement for Hydrocephalus

Hydrocephalus is a condition marked by an excessive accumulation of CSF resulting in dilation of the ventricular system (where CSF is manufactured and circulated) and increased ICP. Conditions that result in the development of hydrocephalus and CSF obstruction in both children and adults include congenital hydrocephalus, spina bifida, tumors, intracranial/intraventricular hemorrhage, aqueductal stenosis, and Chiari's malformations. Hydrocephalus is treated by accessing the lateral ventricles for the insertion of a ventricle shunting system. The most commonly used methods to divert CSF from the ventricles are the externalized ventriculostomy catheter and the internalized VP shunt.

Placement of an externalized ventriculostomy catheter requires that a burr hole be made to access either the right or the left lateral ventricle. The ventricular catheter is passed into the ventricle. Flow of CSF is verified. The distal end of the catheter is tunneled beneath the scalp, posterior to the burr hole, externalized, and secured to the scalp with suture. The externalized end of the catheter is connected to an external drainage system, which allows for controlled CSF drainage and for ICP measurement. This system has allowed for temporary shunting in patients with elevated ICP and hydrocephalus from any cause. It is an invaluable adjunct in the clinical assessment and management of head trauma with increased ICP.

For more permanent control of hydrocephalus, an internalized ventricular shunt is placed. The type of shunt and the site of insertion are determined by the neurosurgeon. Three approaches for ventricular insertion are frontal, parietal, and occipital. Although the most common drainage site for an internalized shunting system is the peritoneum by way of open dissection or percutaneous trocar, there are other options. If drainage in the peritoneum is inappropriate because of infection or adhesions, other possible distal insertion sites include the right atrium, the pleural cavity, and the gallbladder (Wang and Avellino, 2005).

The VP shunt system comprises a ventricular (proximal) catheter, a reservoir, a valve, and a peritoneal (distal) catheter. A unitized shunt has fewer separations and connections. The reservoir, if used, is inserted between the catheter and the valve. Access to the system through the reservoir enables the practitioner to assess the patency of the shunt, to obtain CSF for laboratory analysis, to introduce contrast medium for radiologic studies, and in some specific cases to inject medication into the shunt. The one-way valve system directs flow of CSF out of the ventricular system. Valves are available in a variety of different pressure and flow settings. Nonprogrammable valves and shunts are pressure controlled and open to release flow whenever the actual pressure exceeds the pressure that the valve is designed to open (the opening pressure). Some valves are flow controlled and attempt to maintain a constant flow despite pressure changes. A more recent advance is the programmable valve. Programmable valves and shunts allow adjustments to the opening pressure after the shunt is implanted, avoiding surgical procedures to change valves.

Procedural Considerations—Ventriculoperitoneal Shunt Placement.

The patient is placed in a modified supine position with a shoulder roll. The head is turned to the opposite side and supported on a donut. Hair is removed from the site where the burr hole will be made to behind the ear and down to the neck. The burr hole site must be prepped, along with the neck, chest, and abdomen on the side of the shunt insertion.

The shunt unit should be handled with extreme care. As with all implantable devices, each manufacturer's specific instructions must be followed and care taken to keep the assembly free of lint, powder, or other foreign bodies that could cause a reaction in the patient's tissues. Lubricants are never used. Blood should be kept clear from the lumen of the catheter to prevent clotting and obstruction. The unit is soaked in normal saline and antibiotic solution and primed before implantation. Air trapping in the valve assembly should be avoided. The valve must be properly oriented to facilitate CSF flow from the ventricles to the peritoneum.

The surgeon may use an endoscope or stereotactic image-guided navigation system to locate small ventricles or to fenestrate the septum between ventricles, thus avoiding the necessity to place multiple ventricular catheters. Surgical technique for VP shunt placement is basically the same for adults and children (Figure 20-46).

Operative Procedure—Ventriculoperitoneal Shunt Placement

1. The surgeon makes a horseshoe-shaped incision to the right or left of midline, along the papillary line. Skin and periosteum are elevated.
2. Scalp bleeding is controlled, and the skin flap is retracted.
3. A burr hole is placed, and the dura is coagulated and incised. The surgeon uses the bipolar ESU to electrocoagulate the pia at the catheter insertion site.

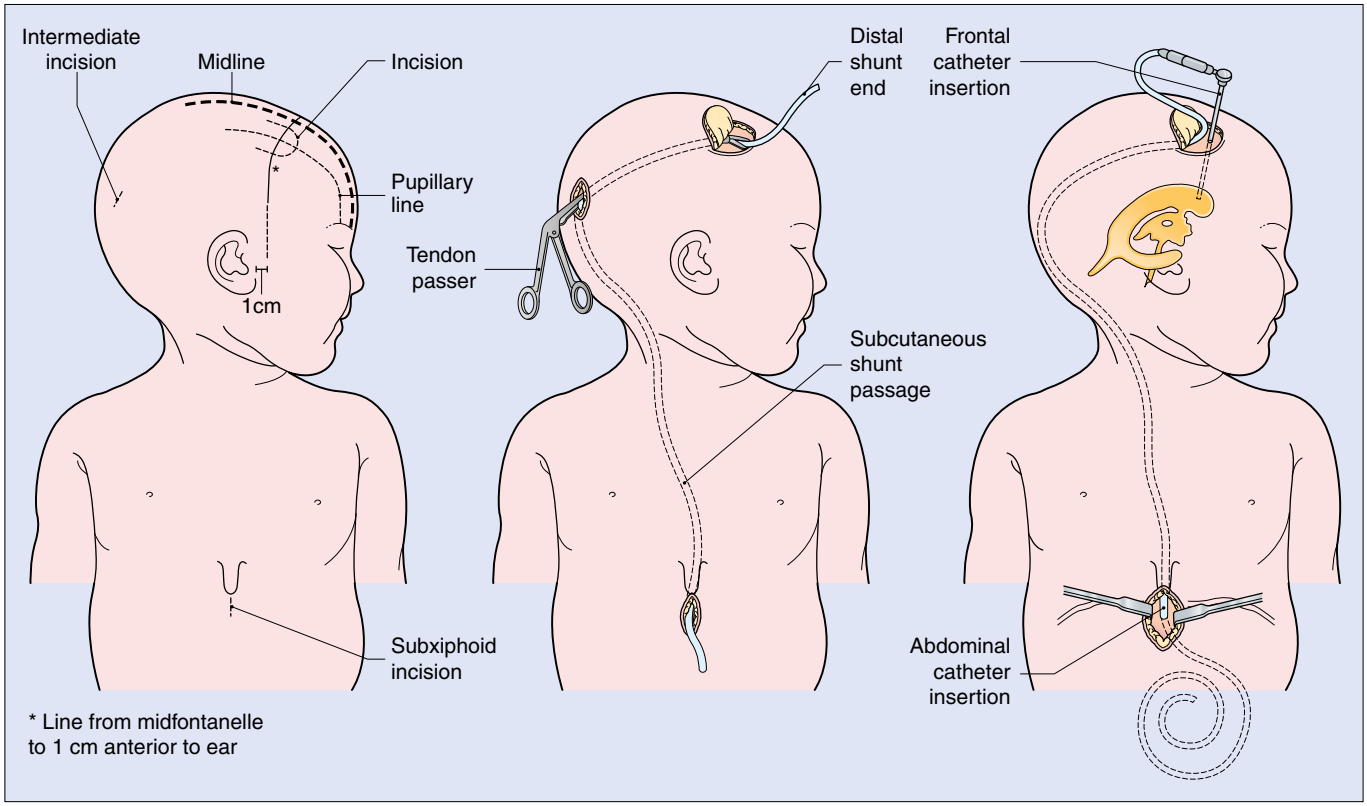


FIGURE 20-46 Placement of a frontal ventriculoperitoneal (VP) shunt. The technique is similar for adult and pediatric patients. The patient is positioned, and coordinates are marked. The shunt is passed subcutaneously. The ventricular catheter and then the peritoneal catheter are inserted.

4. The ventricular catheter with an introducer is inserted perpendicularly into the lateral ventricle approximately 4.5 cm in the infant and 6.5 cm in the adult. When the ventricle is penetrated, the surgeon removes the introducer, verifies the CSF flow, and attaches and secures the reservoir and valve with 2-0 silk ties.
5. A subcutaneous tunnel is created from the burr hole to a neck incision, where the peritoneal catheter is then connected.
6. The surgeon makes a subxiphoid or lateral abdominal incision and exposes the peritoneum.
7. Further tunneling is performed from the neck to the chest and abdomen, avoiding the nipples and umbilicus. The surgeon passes the catheter through the tunneling device to the abdominal incision. After spontaneous distal flow of CSF is verified, the distal end of the peritoneal catheter is passed into the peritoneal cavity, leaving enough length to allow for growth in the child and movement in the adult.
8. The catheter is secured to the peritoneum with a purse-string suture. All incisions are closed, being careful not to puncture the shunt system with a suture needle.

Shunt failure can occur at any time, requiring any single portion of the shunt system or the entire system to be replaced. Obstruction, disconnection, malfunction, and infection are routine causes of shunt failure. Revising a shunt typically involves a troubleshooting process. Therefore it is best to prep and drape the patient to provide access to any and all portions of the shunt system. An infected shunt may be externalized until the infection is treated.

Craniotomy

Procedural Considerations. Craniotomy is a technique for exposure of the brain to surgically treat intracranial disease. There are multiple types of craniotomy incisions. A key element of these operative approaches is patient positioning, which facilitates exposure, allowing complex procedures to be done through small bony windows with limited dural opening and a minimum of cortex exposure. A skull fixation device provides head stability and allows for rotation, flexion, and extension in the final positioning of the head. If frameless stereotactic image-guided navigation is to be used, registration of fiducials must be done. Careful planning of the incision is imperative for adequate exposure. As a rule, flaps that create a vascular pedicle should be avoided and linear or sigmoid (S-shaped) flaps should be used. This is particularly true for patients with malignant brain tumors who will be treated with radiation, steroids, and chemotherapy. A pedicle flap compromises the blood supply to the incision and, with these other treatments, increases the likelihood of wound infection.

Operative Procedure—Craniotomy for Tumor Resection

1. The surgeon infiltrates the incision site using a local anesthetic with epinephrine.
2. The surgeon and the assistant apply digital pressure along the skin edges as the surgeon incises the skin through the galea.

3. Raney scalp clips are applied to skin edges, and/or self-retaining retractors are placed. The ESU is used on the major scalp vessels for hemostasis.
4. The scalp flap is reflected in the subperiosteal plane with periosteal elevators or with the monopolar device to divide muscle attachments. It is retracted up using devices that may include retractors, towel clips, suture, or rubber bands and supported with a scalp roll.
5. Burr holes are placed that expose the dura and are widened using curettes and Kerrison rongeurs. The dura is dissected from the cranium using Woodson, Penfield, or Adson dissectors.
6. The craniotomy is accomplished using a craniotome with footplate attachment as the assistant irrigates to cool the bone. The bone flap is carefully elevated from the dura and placed in irrigating solution on the back table.
7. Bone dust is irrigated away from the wound, and hemostasis is established. Bleeding edges of bone are waxed, and bleeding vessels in the dura are electrocoagulated with the bipolar ESU or occluded with thrombin-soaked Gelfoam and patties. The surgeon places hemostatic agents and patties around the craniotomy edges, and then places dural tacking sutures that will remain permanently to prevent postoperative epidural hematoma formation.
8. After hemostasis is achieved, the surgeon opens the dura with a #11 or #15 blade. A dural suture may be placed in the dura before incising it. This tents the dura, ensuring that the surface of the brain is not inadvertently nicked. A Woodson dissector and blade or Metzenbaum scissors are used to extend the dural incision. Bleeding from transected dural vessels can be prevented by coagulating them with the bipolar ESU before cutting them, or to avoid shrinking of the dura, hemoclips can be placed or vessels can be compressed with a hemostat.
9. A self-retaining retractor system is placed if necessary. Cortical dissection is achieved using the bipolar ESU, microscissors, and suction, and the specific surgical procedure is completed. Samples of tumor are sent for pathologic study if applicable.
10. Hemostasis is established. Irrigation can be used to find bleeding sites in the brain. A resection cavity is lined with Surgicel and filled with irrigation. Valsalva's maneuver can be produced with the ventilator to verify hemostasis.
11. The surgeon closes the dura with a 4-0 suture (braided nylon or silk). Gaps in the dura can be repaired using muscle, pericranium, dural substitute, or pericardium. A central dural tacking suture may be placed, and Gelfoam may be placed over the dura.
12. The bone plate is fitted with titanium plates and screws and reconnected to the cranium, or it may be wired into place depending on the surgeon's preference.
13. Muscle/fascia is reapproximated and galea is closed with interrupted absorbable sutures. Skin is closed with suture or staples.

Operative Procedure—Pterional Craniotomy

1. The skin incision for the pterional craniotomy extends from the zygoma to the midline, curving gently just posterior to the hairline (Figure 20-47).
2. The surgeon and the assistant apply digital pressure over folded sponges on both sides of the incision line. The skin and galea are incised in segments, with the length of each segment being equal to that over which the finger pressure is applied. The tissue edges are held with 6-inch toothed forceps as scalp clips are placed on the flap edges. Any remaining active arterial bleeding is controlled by electrocoagulation. If the incision extends into the temporal area, bleeding in the temporal muscle is managed by electrocoagulation, hemostats, tamponade, or suture ligature. Mayo scissors can be used to incise temporal muscle and fascia.
3. The soft tissue is peeled off the periosteum by sharp or blunt dissection or by electrodissection. The scalp flap is reflected over folded sponges and retracted by use of small towel clips and rubber bands or by muscle hooks on rubber bands. In either case, the traction is maintained by securing the rubber band to the drapes with heavy forceps. The flap may be covered with a moist sponge or Telfa strips and a sterile towel. Bleeding is controlled by electrocoagulation (Figure 20-48).
4. When a free bone flap is planned, the muscle and periosteum are incised. Muscle and periosteum are elevated with the skin-galea flap, reflected, and retracted as a unit, as described previously.
5. The periosteum and muscle are incised with a scalpel or ESU knife except at the inferior margins, which are left intact to preserve the blood supply to the bone flap. The periosteum is stripped from the bone at the incision line with a periosteal elevator. Bone wax is used to control bleeding.
6. The scalp edges and muscle are retracted from the bone incision line by a Sachs or Cushing retractor. Two or more burr holes are made (Figure 20-49). A great deal of heat is generated by the friction of the perforator or burr against the bone. The assistant must irrigate the drilling site to counteract the heat and remove bone dust, which collects as the holes are made. A large-gauge suction tip is used to remove both irrigating solution and debris from the field. As the inner table is perforated and the dura exposed, tamponade

FIGURE 20-47 The skin incision for a pterional craniotomy.

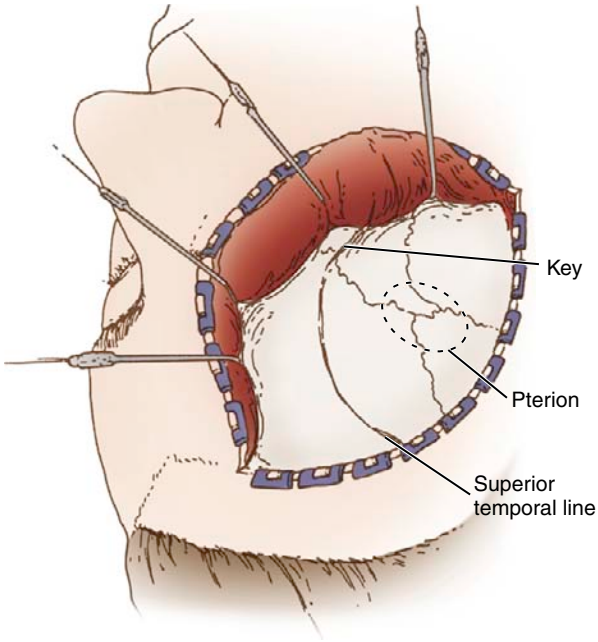


FIGURE 20-48 A commonly employed means of opening the scalp involves incision of the skin, galea, temporalis fascia, and muscle with reflection of the resultant flap in a single layer.

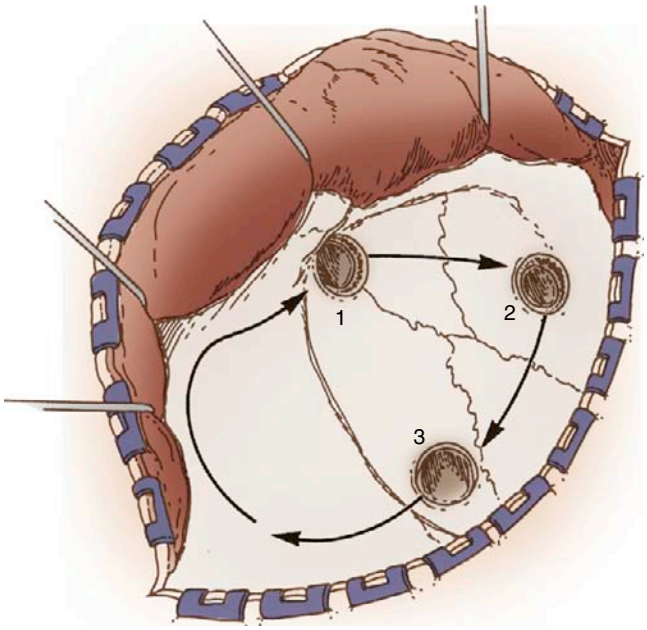


FIGURE 20-49 The pterion craniotomy is performed with power instruments so that three burr holes are placed. The bone is cut as shown, exposing the frontal and temporal dura and the sphenoid ridge.

of the burr hole may be done temporarily with bone wax or a cottonoid strip or patty. Each hole is eventually debrided by a #0 or #00 bone curette or small periosteal elevator. The dura mater is freed at the margins with a #3 Adson elevator, #3 Penfield dissector, or right-angle Frazier elevator or similar instrument. The hole is irrigated and suction applied simultaneously. Active bleeding points in the bone are identified, and bone wax is applied.

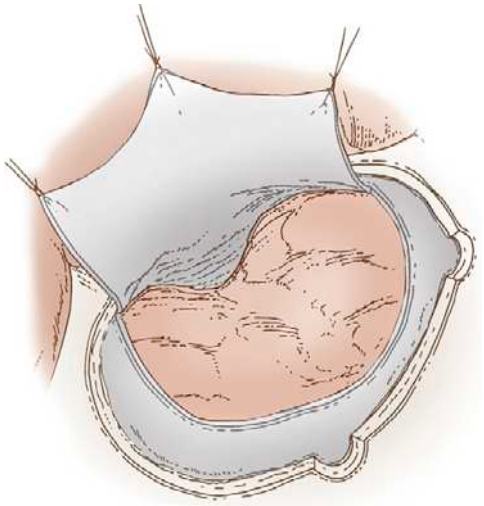


FIGURE 20-50 The dura is opened and reflected back with stay sutures.

7. When all burr holes have been made, the surgeon separates the dura mater from the bone with a dural separator, such as a #3 Penfield dissector. Dural separation is done to prevent tearing of the dura mater, especially over venous sinuses. An air craniotome or Midas Rex drill can be used for cutting the bone flap. Irrigation and suction are required as the bone flap is cut. Soft tissue edges are retracted with Sachs or Cushing retractors.
8. The bone flap with muscle attached is lifted off the dura mater by two periosteal elevators. Bleeding from the bone is controlled with bone wax. The bone flap is covered with a moist sponge, cottonoid material, and then a clean sterile towel and is retracted in the same manner as the scalp flap.
9. The dura mater is irrigated. Moist patties may be inserted between the dura mater and bone and folded back to cover the exposed bone edges. Epidural tack-up sutures are usually placed around the edge of the craniotomy defect to close the epidural dead space. Sterile towels may be placed around the operative site.
10. The surgeon opens the dura (Figure 20-50). A dura hook or a dural stitch may be used to elevate the dura mater from the brain, and a small nick is made in the dura mater with a #15 blade. Alternatively, a small opening may be made in the dura mater without elevating it, after which the dural edges are grasped with two forceps with teeth and are elevated. A narrow, moist cottonoid strip is inserted with smooth forceps (bayonet or Cushing) into the opening to protect the brain as the dura mater is incised and elevated. The dural incision can be made with Metzenbaum scissors, special dura scissors, or a Rayport dura knife. Usually traction sutures are placed at the outer edge of the dura mater and are tagged with small bulldog clamps or mosquito hemostats. Sometimes the tag instruments are attached to the drapes to increase traction and keep tension on them. As the dural veins are approached during dural opening, the surgeon ligates or coagulates them before cutting. Ligation is done with hemostatic clips such as Weck hemoclips, McKenzie clips, or Ligaclips. The brain surface is protected by moist cottonoid strips.

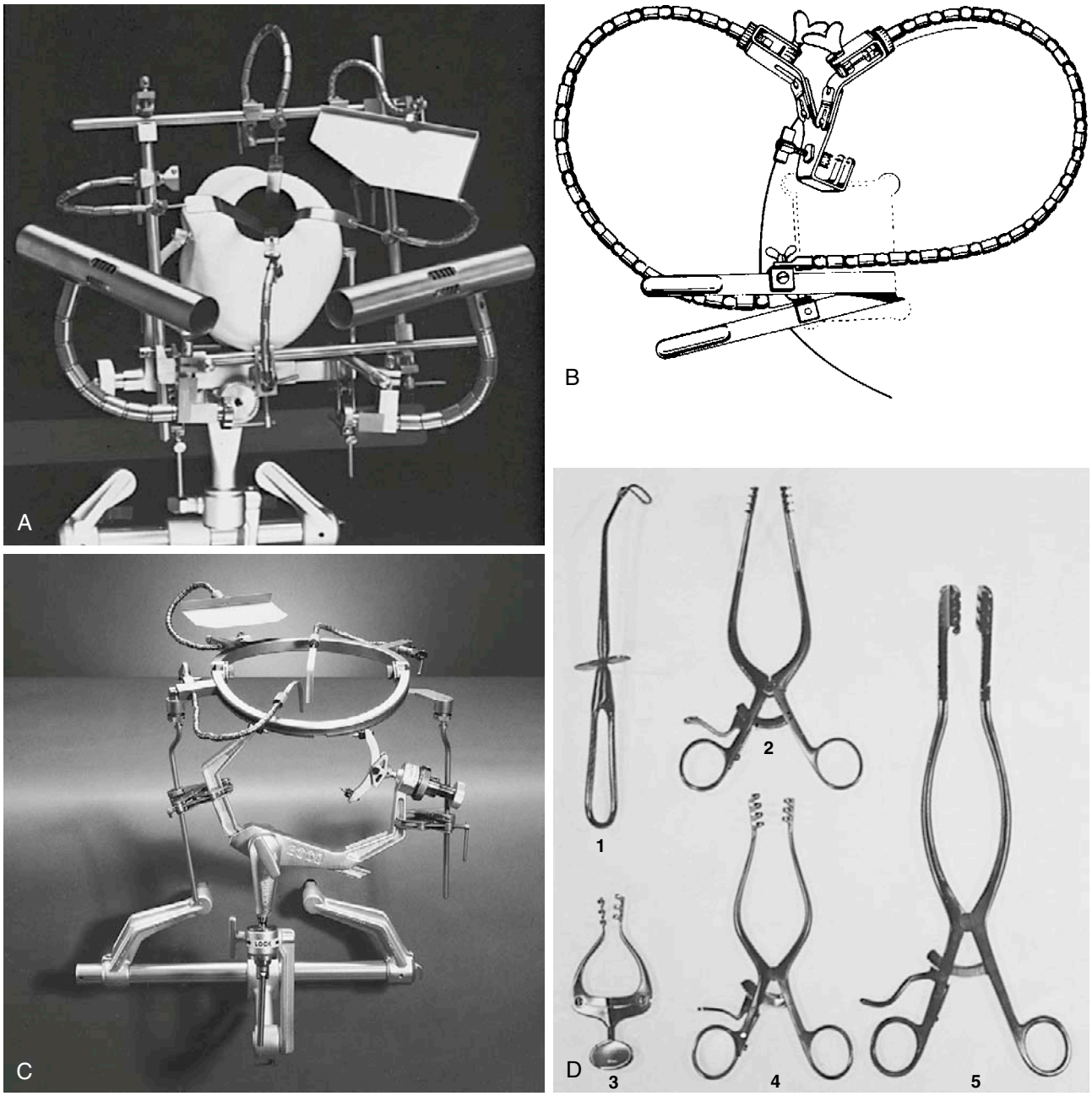


FIGURE 20-51 **A**, Greenberg retractor with blades. **B**, Leyla-Yasargil self-retaining retractor. **C**, Budde halo retractor with attachments. **D**, Retractors: *1*, Cushing subtemporal decompression retractor; *2*, Adson cerebellar retractor; *3*, Jansen mastoid retractor; *4*, Weitlaner retractor; *5*, Beckman laminectomy retractor.

11. The surgeon appropriately places cottonoid strips and brain retractors, both self-retaining (Figure 20-51) and manual, while working toward visualizing the particular pathologic entity.
12. Pituitary rongeurs as well as the CUSA (Cavitron Ultrasonic Surgical Aspirator) may be needed for tumor removal. Also, a selection of dissectors, bayonet and Gerald forceps, and a bipolar ESU are used. Completely filled irrigating syringes and a full range of moist cottonoid patties and strips must be within easy reach of the surgeon and the assistant. After correction of the pathologic condition and control of bleeding, the brain may be irrigated with an antibiotic solution of the surgeon's choice.
13. The dura mater is usually closed by running or interrupted sutures of absorbable suture or black braided nylon. Dural grafts may be used.
14. The bone flap is replaced and fixated with titanium plates and screws.
15. Periosteum and muscle are approximated with 2-0 or 3-0 absorbable suture. The galea is closed with the same sutures. Skin closure can be interrupted or continuous suture or skin staples.

Surgery for Intracranial Aneurysm

An aneurysm is a vascular dilation usually caused by a local defect in the arterial vascular wall, particularly at points of bifurcation. Vessels at risk within the brain involve those of the major circulation within and around the circle of Willis. Aneurysms are believed to arise from a complex set of circumstances involving a congenital anatomic predisposition enhanced by local and systemic factors. Aneurysmal rupture and hemorrhage into the subarachnoid space are frequently the first sign of an aneurysm, resulting in a sudden, severe headache described as "the worst headache ever." Current neurosurgical techniques have made operations on intracranial aneurysms more feasible; however, fewer than 40% of patients with ruptured aneurysm will return to functional life and 30% die before reaching the hospital (Batjer et al, 2005). Hemorrhage and the cascade of ensuing cerebral trauma are the greatest hazard of the condition and of the operation. To minimize this, control of blood pressure as well as vascular supply to the region beyond the limits of the lesion may be required. Occasionally, control of the cerebral circulation at the level of the cervical carotid artery is desired. The artery may be exposed and controlled by means of preplaced ligatures or clamps that can be tightened to occlude the vessel if bleeding occurs at the aneurysm site during the operation. This is a separate preliminary surgical procedure.

Procedural Considerations. Aneurysm clips and appliers of the surgeon's choice must be included with the instrumentation. A variety of aneurysm clips are available, and most are spring loaded. Figure 20-45 illustrates a few of the clips and appliers available. Clips may be classified as temporary or permanent, and both must be available with a minimum of two appliers for each type of clip. Temporary clips are commonly used to control giant aneurysms where it may be necessary to evacuate clot and debris before permanent occlusion can be accomplished (Figure 20-52). Temporary clips may also be used to establish the best position for the permanent clip. Temporary clips should be discarded after use. Permanent clips are used to occlude the neck of the aneurysm. Aneurysm clips should not be compressed between the fingers. Clips should be compressed only by the surgeon when seated in their appliers. Once a clip has been compressed, it should be discarded. Clips that have been compressed may be sprung and may slip, causing complications such as bleeding or compression of another vessel or a nerve.

The full armamentarium of aneurysm-occlusion tools should be available for the surgeon. Besides clips, fast-setting aneuroplastic resinous material, a piece of temporal muscle, ligature carriers, or any other material requested by the surgeon should be in the room and ready to use. Fine silk ligatures and hemostatic clips, with or without bipolar electrocoagulation of the neck of the aneurysm, have also been used successfully.

A basic craniotomy setup is required in addition to the special items mentioned. Supplementary suction must be immediately available on the field to prevent hemorrhage from obscuring the surgeon's vision if the aneurysm dome ruptures during the operation. A blood salvage unit should be available for reprocessing of blood for replacement when significant blood loss is expected.

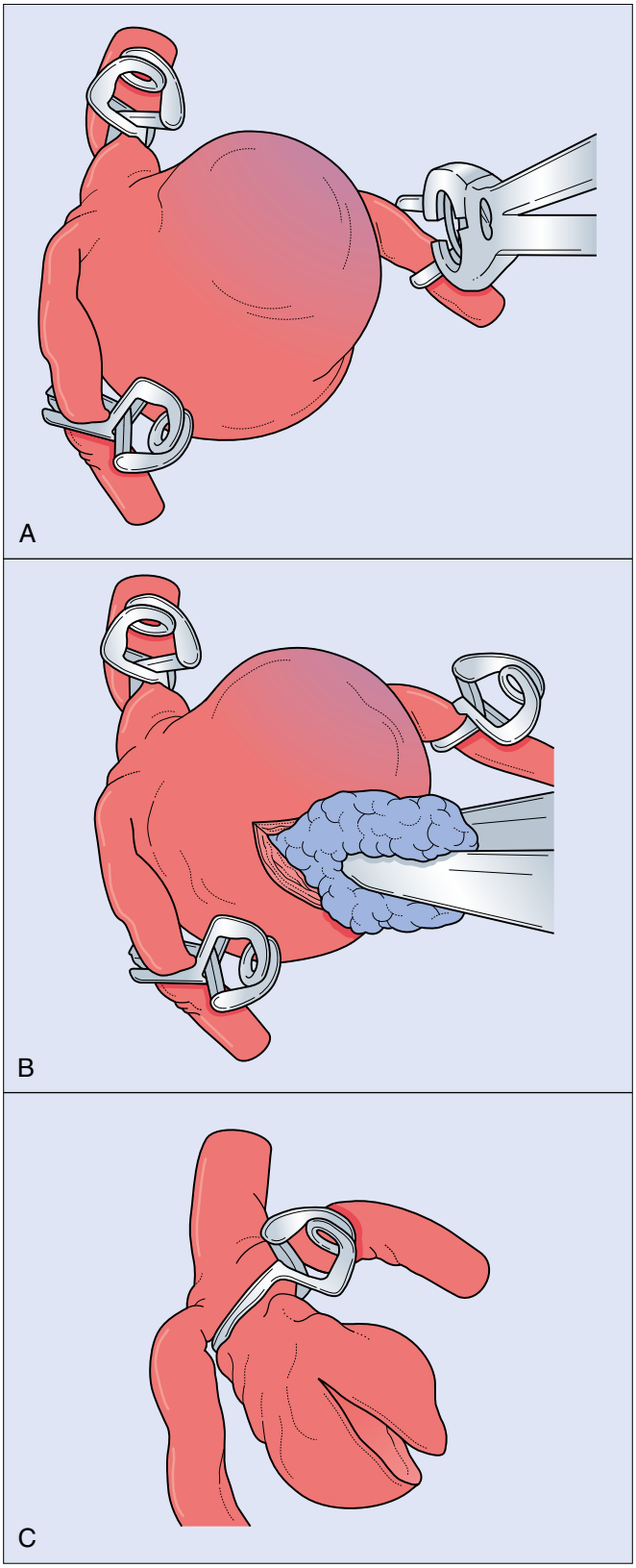


FIGURE 20-52 Temporary arterial occlusion is often necessary in repairing complex large or giant aneurysms. **A**, Temporary clips are placed on the feeder vessels. **B**, The aneurysm sac is opened to allow evacuation of debris and thrombus. **C**, Permanent clip in place.

Interventional radiology now plays an important role in the management of intracranial aneurysms. Intravascular balloon occlusion and coiling of aneurysms by interventional radiologists are now considerations in the treatment of aneurysms that meet the criteria for endoscopic therapy. The coils, composed of a soft platinum alloy, allow conformability to the dome of the aneurysm. A guide catheter is introduced into the femoral artery under fluoroscopy and advanced from the aorta into the vessel specific to the aneurysm. Coils are first introduced to outline the border of the aneurysm, and then smaller coils are added to fill the center of the aneurysm. Gradually, blood flow will be reduced, allowing the aneurysm to thrombose (Khatri et al, 2008). Both the neurosurgeon and the radiologist work closely to diagnose and treat these life-threatening anomalies.

Operative Procedure—Craniotomy for Aneurysm Clipping

1. A frontal, pterional, or bifrontal craniotomy may be done to approach an aneurysm in the area of the circle of Willis. The bifrontal approach requires extra scalp clips and hemostatic forceps. All aneurysm instruments preferred by the surgeon must be included.
2. After the dura mater has been opened, the surgeon places a self-retaining brain retractor and exposes the optic nerve and subarachnoid cisterns. The olfactory nerve may be electrocoagulated and divided with a long scissors for better exposure.
3. The surgical technologist and perioperative nurse position the operating microscope as directed by the surgeon. Microinstruments, including a micropolar bayonet, are used.
4. Bridging veins are coagulated with bipolar electrocoagulating forceps. Irrigation, which may be a part of the bipolar ESU, is necessary during bipolar electrocoagulation.
5. The surgeon uses microdissectors, hooks, elevators, scissors, knives, forceps, a diamond microknife, and an irrigating bipolar ESU to dissect the covering arachnoidal webs.
6. Careful dissection of the arachnoid and clear visualization of the neck of the aneurysm without rupture of the dome are the aims of the surgeon.
7. The surgeon identifies and frees the parent arteries so that they can be occluded with a temporary clip if necessary. Other structures, such as the optic chiasma and optic nerves, are identified.
8. As the surgeon works slowly toward the dome and neck of the aneurysm, the anesthesia provider may lower the patient's blood pressure for easier control of hemorrhage, should the aneurysm rupture. If the neck of the aneurysm can be isolated, the surgeon places a clip across it. Clips such as the Sundt-Kees and Heifetz have Teflon linings and can be used to approach the aneurysm from a 180-degree angle to avoid excessive manipulation and traction of the parent vessel, if the neck is on the underside of the vessel. These clips support the vessel and serve as a clip graft.
9. Following clip placement, the surgeon may check the aneurysm sac by puncturing it with a needle to see if the clip pressure is adequate to stop blood flow to the aneurysm or to aspirate the aneurysmal contents.
10. As soon as the aneurysm has been occluded, the anesthesia provider returns the patient's blood pressure to normal and the surgeon checks the aneurysm site for bleeding. When the surgeon is satisfied that the operative field is dry, wound closure is begun.

Surgery for Arteriovenous Malformation

An AVM consists of thin-walled vascular channels that connect arteries and veins without the usual intervening capillaries. These vascular lesions may be microscopic or massive. AVMs are rare, affecting only about 300,000 people in the United States (National Institute of Neurological Disorders and Stroke [NINDS], 2009). Malformations vary widely in size, area of involvement, and structure. Arteriovenous fistulas may be congenital or may result from trauma or disease. Vascular anomalies may also lead to subarachnoid or intracerebral hemorrhage or may have extensive irritative effects and cause focal or generalized seizures.

Procedural Considerations. AVMs are difficult to treat successfully. Feeding vessels can be clipped with or without partial removal of the lesion. Total removal, when possible, gives best results. Microsurgical techniques have made total removal without devastating injury to surrounding brain tissue and vessels possible in many cases.

Other methods of treating these malformations include stereotactic radiosurgery with the Gamma Knife. Another method is preoperative embolization, which makes dissection much easier. Surgical glue, such as *N*-butyl cyanoacrylate and tantalum powder, is delivered by means of a catheter into the blood vessels before surgery. During the surgery, the glue is removed along with the AVM. Serial embolization may be performed to reduce the size of the AVM and provide symptom relief when the goal of treatment is not complete obliteration (Schumacher and Marshall, 2006).

Operative Procedure—Craniotomy for Arteriovenous Malformation

1. A supratentorial or infratentorial craniotomy is done, depending on the location of the lesion.
2. The surgeon exposes the feeding arteries distant from the malformation, traces toward it, and then occludes the feeders by clipping, electrocoagulation, ligation, or laser beam coagulation.
3. The malformation is dissected out with suction and bayonet forceps. Additional vessels are clipped or coagulated along the way. Usually one or more draining veins are left to be ligated as the last step in the removal. Closure and dressing are as described for craniotomy.

Craniotomy for Suprasellar and Parasellar Tumors (Pituitary Tumor, Craniopharyngioma, Meningioma, Optic Glioma)

Procedural Considerations. The preferred approach for pituitary tumors and some parasellar tumors is the less invasive transsphenoidal approach. However, for large and complex pituitary and parasellar tumors, a craniotomy may be indicated. A craniotomy setup is used with these additional pituitary instruments: Ray curettes (ring, sharp); angulated suction tips, right and left; large and small spinal needles, #22 or #24; curettes, small, #0 through #4-0; and a Luer-Lok syringe, 10 ml.

Operative Procedure—Craniotomy for Pituitary Tumor Resection

1. The surgeon makes either a bifrontal or a unilateral incision into the frontal or frontotemporal region. Most unilateral approaches are carried out from the right side.

2. Wet brain retractors over moist cottonoids are inserted for exposure of the optic chiasma and the pituitary gland. The frontal and often the temporal lobes are retracted. The olfactory nerve may be coagulated and divided with scissors.
3. A DeMartel, Yasargil, or Greenberg self-retaining retractor is placed to maintain exposure. Aneurysm clips and applicators should be available to control unexpected bleeding from major vessels. The microscope may be moved into place.
4. The surgeon uses the bipolar ESU for hemostasis around the tumor capsule and incises it with a #11 blade on a long knife handle; the tumor is removed with a pituitary rongeur or cup forceps.
5. Small stainless-steel, copper, or Ray curettes, as well as suction, may be used during tumor removal.
6. A wide clip may be applied to the stalk of the pituitary, which may then be cut distally. A long angulated scissors is especially helpful for this.
7. If the tumor capsule is to be removed, bayonet forceps, cup forceps, nerve hooks, and suction aid in the dissection.
8. Closure and dressing are as described for craniotomy.

Extreme caution must be used in removing fluid from the capsule of a craniopharyngioma because the fluid is extremely irritating and may cause chemical leptomeningitis. Calcified pieces of tumor are dissected and removed in the same manner as the capsule of a pituitary adenoma. This is an extremely difficult procedure because of deposits on the carotid arteries, optic nerves, and optic chiasma. The tumor capsule is often left behind on the hypothalamus to avoid stripping off blood vessels supplying this structure. Many moist cottonoid strips are used to protect the surrounding areas from the cystic contents.

Suprasellar meningiomas usually arise from the tuberculum sellae just anterior to the optic nerves and chiasma. Tumor removal is similar to that of a pituitary adenoma except that the electrosurgical cutting loop may be used to excavate the interior of the tumor. After the tumor has been removed, the site of its attachment to the dura is thoroughly electrocoagulated to prevent recurrence. Other meningiomas arising at the base of the skull are treated by similar techniques.

Suboccipital Craniectomy for Posterior Fossa Exploration

The posterior occipital bone is perforated and removed using a drill and rongeurs, and the foramen magnum and arch of the atlas are exposed to remove a lesion in the posterior fossa (Figure 20-53). Posterior fossa lesions include lesions in the cerebellum, the fourth ventricle, and the brainstem; posterior fossa meningiomas; and nerve sheath tumors.

Procedural Considerations. Depending on the type and size of the lesion, the exposure may be unilateral or bilateral. The operation may include the removal of the arch of the atlas. This approach gives the surgeon access to the fourth ventricle, the cerebellum, the brainstem, and the cranial nerves.

The prone position with the head of the OR bed elevated is the preferred position, but other positions may also be used. An extra-high instrument table or two Mayo stands and standing stool are necessary for the surgical technologist.

Operative Procedure

1. Before the initial surgical incision, the surgeon may make an occipital burr hole for placement of a ventricular catheter. This can be done as a separate procedure or concurrently with the procedure.
2. The incision may be made from mastoid tip to mastoid tip, in an arch curving upward 2 cm above the external occipital protuberance. Alternatively, a posterior midline incision can be used.
3. Scalp bleeding is controlled, and the skin flap is retracted with Weitlaner retractors.
4. The surgeon uses a periosteal elevator to free the muscles, and then divides them with an electrosurgical blade. The incision is deepened. A self-retaining retractor is used. The laminae of the first two or three cervical vertebrae may be exposed.
5. One or more holes are drilled in the occipital bone. The Midas Rex or Anspach drill is used to perform the craniectomy.
6. The dura mater is stripped from the bone. A double-action rongeur, Raney punch, Kerrison punch, or Leksell rongeur is used to enlarge the hole and smooth the edges.
7. Osseous and cerebellar venous bleeding is controlled at each step with bone wax, Gelfoam, and electrocoagulation to prevent air embolism.
8. The dura mater is opened. A small brain spoon or cottonoid strip is used to protect the brain as the initial nick is extended with scalpel or scissors. The dural incision is continued until the cerebellar hemispheres, the vermis, and the cerebellar tonsils can be visualized. Hemostatic clips are used on the dura mater as necessary. Dural traction sutures are placed.
9. The cisterna magna is opened, emptied of spinal fluid, and protected with a cottonoid strip.
10. The cerebellar hemispheres are inspected. Bleeding is controlled with the bipolar coagulator. A needle may be introduced through a small, coagulated incision into the cerebellar hemisphere in an attempt to palpate or tap a deep lesion.
11. Brain retractors over cottonoid strips are placed for exposure. The handle of the retractor must be kept dry to avoid slippage in the surgeon's hand. However, the inserted edge should be wet to prevent damage or tears in the brain surface. These retractors may be positioned in areas that control respiration or other vital functions, so every effort must be made to avoid jarring these instruments in the operative field. When the pathologic entity is identified, a self-retaining retractor may be placed.
12. Long bayonet forceps, bayonet cup forceps, pituitary forceps, suction, and the electrosurgical loop tips may be used to remove the lesion. Clips may be used to aid in hemostasis. A nerve stimulator may be used to identify cranial nerves; EPs for brainstem monitoring are becoming routine practice.
13. After the lesion has been removed and bleeding controlled, further checking for adequate hemostasis is required. Venous pressure in the patient's head is increased by the anesthesia provider by generating Valsalva's maneuver.
14. The dura mater may be partially or completely closed. The cranial defect may be repaired with titanium mesh. The muscle, fascia, and skin are closed. A dressing is applied.

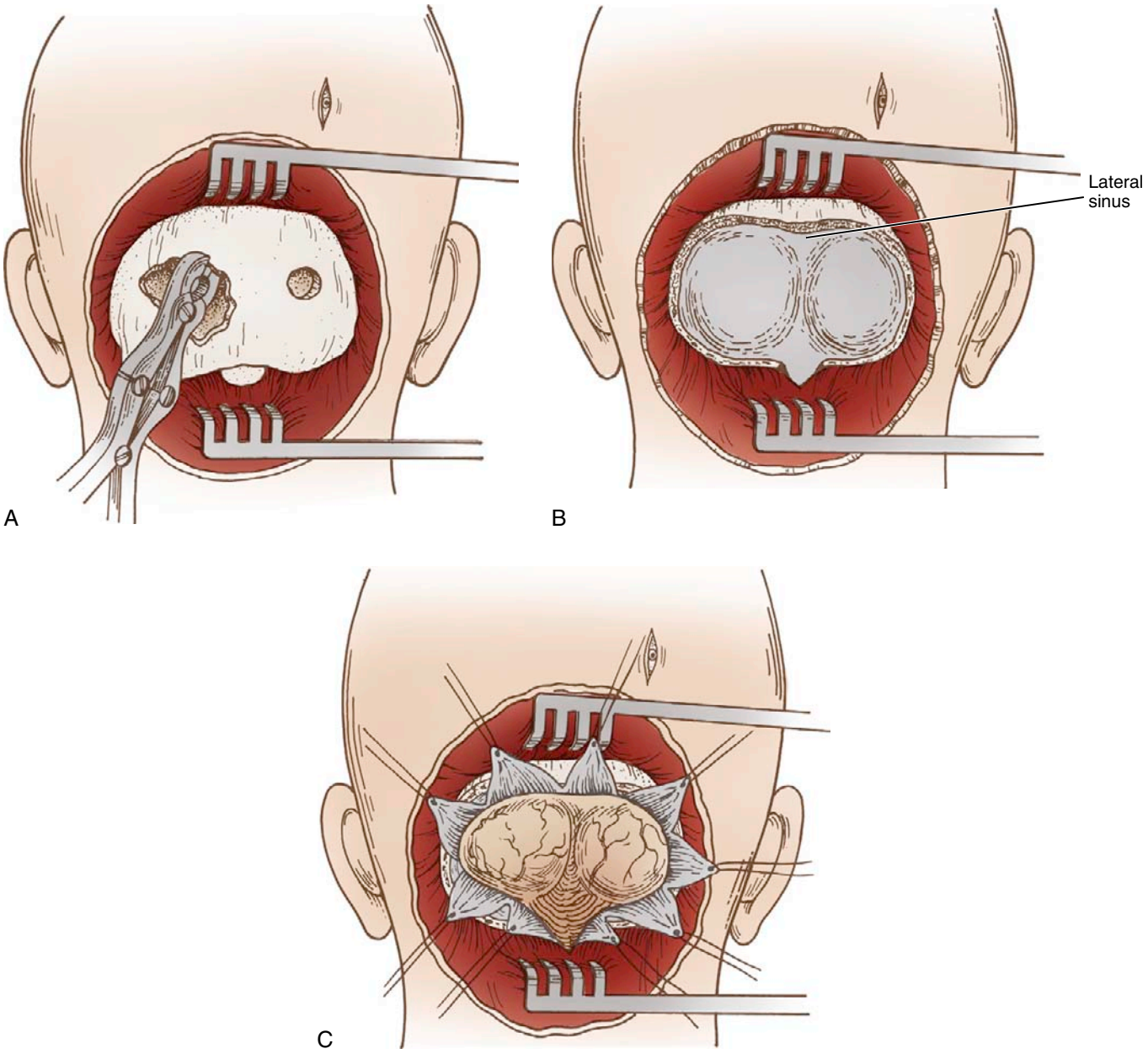


FIGURE 20-53 Suboccipital craniectomy. **A**, Craniectomy being performed. **B**, Dura exposed. **C**, Dura incised and cerebellum exposed.

15. The patient must remain anesthetized until the supine position is achieved and the prongs of the headrest are removed. Particular attention must be given to the patient's head when these prongs are removed to prevent tearing the scalp or damaging the eyes.

Retromastoid Craniectomy for Microvascular Decompression of the Trigeminal Nerve

Trigeminal neuralgia (tic douloureux, fifth cranial nerve pain) is a condition characterized by brief, repeated attacks of excruciating, lancinating pain in the face. The etiology of this facial pain is believed to be the compression of the trigeminal nerve at its exit from the pons by an adjacent artery that has elongated over time to become wedged against the nerve, resulting in demyelination. Pain distribution follows one or all of the trigeminal nerve branches. It is characteristically severe, with sudden onset, short duration, and paroxysmal nature. Triggers often precipitate the pain, such as touching the face, chewing, and talking. When pharmacologic measures fail, surgery to decompress the nerve is undertaken. Frequently more than one treatment is necessary during the course of the disease. Newer options include Gamma Knife radiosurgery.

Procedural Considerations. The patient is in the supine, lateral, or sitting position, depending on the surgeon's preference. An endoscope can be used along with the microscope to improve visualization.

Operative Procedure

1. The surgeon makes a vertical retromastoid incision.
2. The soft tissue is freed from the bone with a periosteal elevator. The bone exposure is maintained with a self-retaining retractor.
3. A burr hole is made, and the dura mater is freed.
4. The surgeon uses a drill and rongeurs to enlarge the burr hole to a diameter of about 2½ inches.
5. With a moist brain retractor, the dura mater overlying the pons and cerebellum is retracted.
6. A self-retaining brain retractor is placed deeper into the wound to retract the cerebellum. The microscope is used to provide light as well as magnification.
7. The surgeon identifies the pons, the superior cerebellar artery, and the trigeminal nerve.
8. Additional blunt dissection frees the vessel from the nerve. A synthetic microsponge is inserted between the vessel and nerve to maintain the separation.
9. The dura and cranial defect are repaired, the incision is closed, and dressings are applied.

Transsphenoidal Hypophysectomy

Endocrine pituitary disorders (such as Cushing's syndrome, acromegaly, malignant exophthalmos, and hypopituitarism resulting from intrasellar tumors) as well as nonpituitary disorders (such as advanced metastatic carcinoma of the breast and prostate, diabetic retinopathy, and uncontrollable severe diabetes) have been successfully treated by transsphenoidal hypophysectomy (TSH). A transnasal or a sublabial incision can be used for rapid access to the sella turcica.

More recently, an endoscope has been used to assist with access through the sphenoid sinus into the pituitary fossa. Otorhinolaryngologic surgeons can be consulted to assist the neurosurgeon with this approach. The endoscope and instrumentation access the sphenoid sinus by the transnasal route. Endoscopic transsphenoidal surgery eliminates the need for an incision and the need for a microscope. When the sphenoid sinus is reached, instruments and technique are similar to the microsurgical technique. Stereotactic image-guided navigation can also be used with the transsphenoidal technique.

All these approaches produce similar results. Complete extracapsular enucleation of the pituitary in cases of hypophysectomy and possible complete removal of small pituitary tumors, with the remaining normal portion of the gland left intact, can be achieved. Patients are relatively free from pain after surgery. No visible scar remains.

Procedural Considerations—Microsurgical Approach for Transsphenoidal Hypophysectomy. General endotracheal anesthetic, combined with a local anesthetic is used. The surgical team places the patient in a semisitting position, with the head against the headrest. The surgeon may use a subnasal midline rhinoseptal approach or a transnasal route, both exposing the sphenoid bone, the sphenoid sinus behind the bone, and the sella containing the tumor. Frequently, an otorhinolaryngologist assists the neurosurgeon in gaining access to the surgical site.

The face, mouth, and nasal cavity are prepped with an antiseptic solution. The surgeon infiltrates the patient's nasal mucosa and gingiva with a local anesthetic agent containing 1:2000 epinephrine to initiate submucosal elevation and diminish oozing from the mucosa. A sterile adhesive plastic drape is applied to the entire face, with additional sterile drapes to ensure a relatively sterile operative field. Sterile sponges (or cotton) are placed in the patient's mouth so that only the upper gum margin is exposed.

Although sterile technique is used, this approach through the nose or mouth is technically not a sterile procedure. Therefore a separate sterile field and instruments must be maintained for adjunct procedures. The thigh or abdomen is prepped if a muscle or fat graft is to be taken. A lumbar drain may be placed preoperatively or postoperatively.

Specialized transsphenoidal instruments are required. The operating microscope is used for the cranial portion of the procedure. A fluoroscopy unit with C-arm may be used to verify the anatomic location of the sella.

Operative Procedure—Microsurgical Approach for a Transsphenoidal Hypophysectomy

1. Using the biopsy setup on a separate small Mayo table, the surgeon may take a small piece of muscle from the previously prepared thigh or a fat graft from the abdomen to be used later in the procedure. This is kept in a moist sponge or soaked in antibiotic solution.
2. An incision is made in the middle of the upper gum margin. The soft tissues of the upper lip and nose are elevated from the bone with an elevator, and the nasal septum is exposed. The nasal mucosa is elevated from either side of the nasal septum, which is flanked by the blades of a Cushing bivalved speculum. The transnasal approach avoids the sublabial incision, instead operating through a bivalve speculum inserted directly through the nares. The inferior third of the anterior cartilaginous septum and osseous vomer are resected, as is the floor of the sphenoidal sinus, exposing the sinus cavity. The floor of the sella turcica can then be identified.
3. The surgeon opens the floor with a sphenoidal punch, and incises the dura mater. The hypophyseal cavity should be opened only in patients undergoing surgery for pituitary adenoma. In these patients, the gland is explored and the tumor is identified and removed.
4. The extracapsular cleavage plane is identified, and the superior surface of the pituitary is dissected until the stalk and the diaphragmatic orifice are found. Cotton pledgets are applied for exposure, hemostasis, and protection of structures.
5. Using a sickle knife, the surgeon sections the pituitary stalk and uses an enucleator to dissect the lateral posterior and inferior surfaces of the gland.
6. The gland is removed, and the sellar cavity may be packed to prevent CSF leakage. The packing is accomplished with muscle obtained previously from the thigh or with the fat graft previously obtained from the abdomen or thigh. The floor is reconstructed with cartilage from the nasal septum.
7. Antibiotic powder may be used and nasal packing introduced for 2 days. If a gingival incision is used, it is closed with suture of the surgeon's preference.
8. Some surgeons prefer to perform this operation by means of a lateral rhinotomy with a transantral-transsphenoidal approach.

SURGERY OF THE SPINE

Surgery of the spinal column is also discussed in Chapter 19, Orthopedic Surgery.

Anterior Cervical Decompression and Fusion

Anterior cervical decompression and fusion (ACDF) is performed to treat cervical disk herniation or cervical spondylosis (degeneration in the spine) with myelopathy (disorder of the spinal cord) or radiculopathy (disorder of the nerve roots). Symptoms include pain in the neck, shoulders, arms, and hands; and weakness of the upper extremity. An ACDF entails a corpectomy (removal of a vertebral body), diskectomy, and fusion of the vertebral bodies. Bone grafts for the fusion are obtained from the patient's iliac crest (autograft) or from a bone bank (allograft).

Procedural Considerations. Awake endoscopic intubation may be required if the patient's neck is unstable or unable to extend. Neurologic monitoring is commonly employed to prevent further injury during surgery. The patient is placed in the supine position, with a small shoulder roll placed horizontally for mild neck extension. The perioperative nurse ensures the patient's arms are tucked, and the hip is elevated for exposure if bone graft is to be taken from the iliac crest (Figure 20-54). Intraoperative x-ray may be employed to confirm the correct surgical site and verify placement of the graft and related hardware.

Operative Procedure

1. The surgeon may harvest the iliac crest bone graft before the neck procedure begins, or it may be completed after exposure of the anterior cervical spine. An incision is made over the iliac crest, at least 3 cm posterior to the anterior superior iliac spine. The skin and subcutaneous tissues are retracted with a Weitlaner retractor.
2. Soft tissue is dissected until the crest is reached and exposed.
3. The surgeon uses an osteotome or oscillating saw to remove the bone graft. The graft is soaked in antibiotic solution and set aside. The perioperative nurse initiates a sponge and sharp count for this portion of the procedure. Following verification of a correct count, the surgeon irrigates and closes the wound and covers it with a sterile towel.
4. A transverse or horizontal skin incision is made on one side of the neck, directly over the involved cervical level.
5. A Weitlaner retractor is placed, and the surgeon uses sharp dissection to divide the platysma.
6. The medial edge of the sternocleidomastoid muscle is defined with the scissors by blunt and sharp dissection.
7. Using blunt finger dissection, the surgeon creates a vertical plane of dissection between the carotid artery laterally and the trachea and esophagus medially. This plane is held open with retractors.
8. The anterior surface of the spine is identified, and the long muscles of the neck are peeled off the anterior surface of the spine with periosteal elevators or peanut dissectors. The bipolar ESU is used for hemostasis.
9. A 20-gauge spinal needle is inserted a short distance into the disk space, and the location is confirmed radiographically.
10. Self-retaining retractors are inserted into the neck incision. Care is used to protect the carotid artery and the esophagus. A combination of sharp and dull blades is used to acquire the best retraction. If a toothed blade is used, the teeth are carefully hooked beneath the long muscle of the neck.

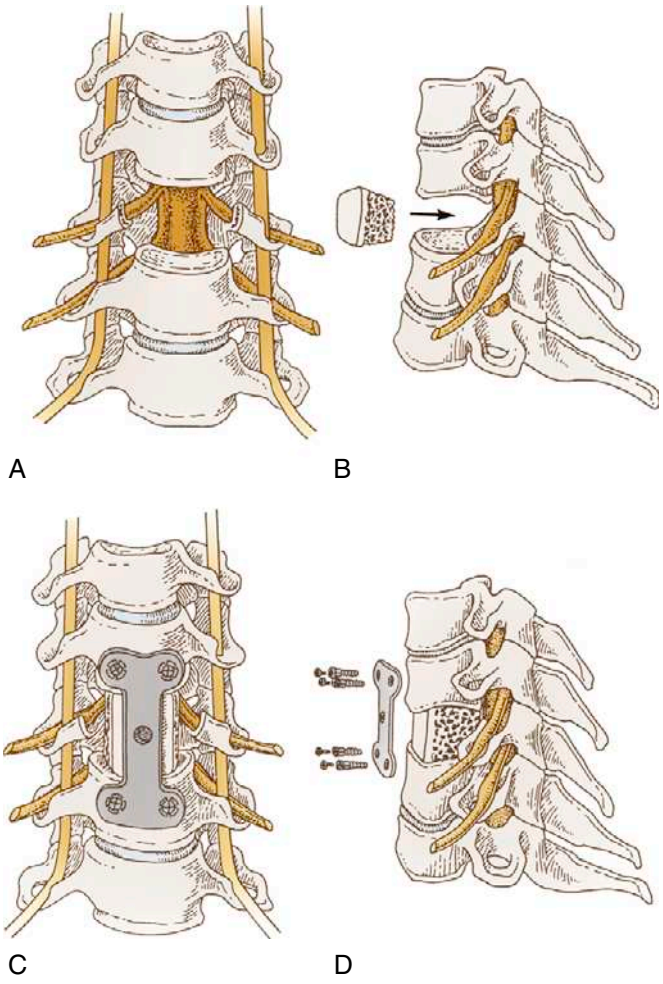


FIGURE 20-54 Anterior cervical decompression and fusion. **A** and **B**, A bone graft from the iliac crest or fashioned from bank bone is tailored to fit the site of corpectomy, resting on the vertebral endplates. **C** and **D**, An anterior spinal plate and screws are secured to the vertebral bodies above and below the spanned segment to stabilize and promote a stable fusion.

11. The surgeon uses a #15 or #11 blade on a #7 knife handle to incise the disk space; a pituitary rongeur is used to remove the disk material, which may be saved as a specimen. A vertebral spreader may be inserted into the vertebral space to widen the area. Residual disk material is removed with the rongeur or small curettes (angled or straight, #0 to #4-0) until the entire surface of both vertebrae is clean. A small burr may also be used until complete anterior decompression of the nerve root or dural sac is obtained. Nerve hooks may be used for demonstration of adequate decompression.
12. A depth gauge and caliper measure the size of the interbody defect. The bone graft is cut to the appropriate size and placed into the defect with a tamp and a mallet.
13. The anterior cervical plate and screws are secured to the vertebral bodies above and below the bone graft.
14. Lateral x-ray or fluoroscopy is done to confirm location, degree of distraction, and alignment.

15. Hemostasis is obtained, and the wound is irrigated. A drain may be placed. The platysma is closed with absorbable suture. A subcuticular closure of the skin is done, and wound closure strips are applied.
16. A cervical collar is placed before the patient awakens.

Posterior Cervical Approach

The posterior cervical approach is used for laminectomy for decompression, intradural tumor removal, cordotomy, diskectomy, and fusion (Connolly et al, 2009).

Procedural Considerations. A patient with severe spondylosis may require fiberoptic intubation. Intraoperative neurologic monitoring should be used to detect a change in neurologic status. The patient is positioned prone with a three-pin skull clamp (Mayfield). The OR bed is positioned in mild reverse Trendelenburg's position to encourage venous drainage. The patient's arms are tucked. If allograft bone graft is desired for fusion, the posterior iliac spine will be prepped. A cervical collar may be required postoperatively.

Operative Procedure

1. The cervical spinous processes are palpated to plan the incision, and a midline incision is made.
2. Soft tissue dissection is done, and a clamp is placed on the spinous process to verify the correct level with x-ray.
3. Self-retaining retractors help to gain exposure. A subperiosteal dissection is made to the lateral margins of the involved facets using the Bovie, suction, and a cervical Cobb elevator.
4. Hemostasis is maintained with the bipolar ESU, Gelfoam, and patties.
5. A laminectomy is performed using a drill, Leksell rongeurs, curettes, a nerve hook, and Kerrison punch rongeurs.
6. Disk is removed with pituitary rongeurs and curettes.
7. If a fusion is required, instrumentation and allograft or autograft may be needed.
8. The wound is irrigated. A drain may be placed.
9. Bupivacaine may be injected into the paraspinal muscles and subcutaneous tissue for postoperative pain.
10. Absorbable sutures are used to close the fascia and subcutaneous layers. Suture or staples are used for the skin.

Anterior Thoracic Approach

A transthoracic thalamotomy is done to access the spine for a thoracic diskectomy, burst fracture, osteomyelitis, and metastatic disease (Connolly et al, 2009). Usually a thoracic surgeon assists the neurosurgeon in obtaining adequate exposure.

Procedural Considerations. The anesthesia provider may need to place a double-lumen endotracheal tube to allow for deflation of the lung for exposure of the higher thoracic levels. Lateral position with a bean bag is preferred. If intraoperative fluoroscopy is necessary, a Jackson table is needed. A bean bag interferes with fluoroscopy. For T1 to T4, a right-sided approach is preferred to avoid the aortic arch and heart. For T5 to T12, a left-sided approach is preferred because the aorta is safer to manipulate than the vena cava (Connolly et al, 2009). If allograft is desired for fusion, prep the iliac spine.

At times, an anterior thoracic surgery is performed in combination with a posterior thoracic surgery. In this case, the patient is repositioned prone after the completion of the anterior portion of the surgery. The posterior surgical site is prepped and draped, and the posterior portion of the surgery is completed.

Operative Procedure

1. A thoracotomy incision is made, and the latissimus dorsi and other muscles are transected. A rib may be resected with a rib cutter to gain exposure.
2. The parietal pleura is opened, and a thoracotomy retractor is placed. If necessary, the lung is deflated manually.
3. A localization x-ray is done to verify the correct level. The parietal pleura is incised further onto the vertebral body and cleared with blunt dissection. Segmental vessels are ligated as necessary with hemoclips and transected to mobilize the aorta.
4. For diskectomy or decompression, a drill, rongeurs, and curettes may be needed. For spinal fusion, instrumentation and autograft or allograft may be used.
5. The wound is irrigated, and a chest tube is placed. The ribs are reapproximated with a rib approximator and sutured with heavy absorbable suture.
6. The fascia and subcuticular layers are closed.

Laminectomy

Laminectomy is removal of one or more of the vertebral laminae to expose the spinal canal. Laminectomy, hemilaminectomy, and the interlaminar approach are performed to reach the spinal canal and its adjacent structures to treat compression fracture, dislocation, herniated nucleus pulposus, and cord tumor, as well as for spinal cord stimulation. Section of the spinal nerves, including cordotomy and rhizotomy, requires similar surgical exposure.

Procedural Considerations. Laminectomy is done with the patient in the prone or lateral position. It is performed on the cervical, thoracic, or lumbar spine. Laminectomy instruments include the basic neurosurgical set, the retractor of the surgeon's choice, and an assortment of specialty rongeurs.

Operative Procedure—Laminectomy for Spinal Stenosis

1. The surgeon makes a midline vertical incision at the operative site.
2. Two self-retaining retractors (Cone, Weitlaner, or Beckman-Adson) are inserted for exposure.
3. The fascia is incised in the midline with Mayo scissors, electrosurgical cutting tip, or a scalpel.
4. The surgeon uses sharp dissection to expose both sides of the spinous processes.
5. Correct surgical level is verified by lateral spine x-ray film.
6. The paraspinous muscles and periosteum are stripped off the laminae with sharp periosteal elevators. Dissection with the ESU may be used.
7. As each area is stripped, the surgeon packs a radiopaque sponge around the bony structures with a periosteal elevator to aid in further blunt dissection of muscles from the laminae and to tamponade bleeding.
8. A laminectomy retractor is then placed. A Scoville (with a blade on the tissue side and a slightly shorter hook on the bone side), Tower, Crank, or Adson-Beckman retractor can be used.
9. Cottonoid strips or patties may be placed in the extremes of the field for hemostasis.

10. The surgeon removes the spinous processes over the involved area with a rongeur. The bone edges are waxed.
11. The ligamentum flavum is cut with a scalpel, Metzenbaum scissors, or a rongeur. Cottonoid strips or patties are passed through this incision to protect the underlying dura, and a window is cut into the flaval ligament with a #15 blade on a #7 knife handle.
12. Additional ligaments in the lateral gutter of the spinal canal may be removed with a large curette or a Cloward rongeur after first protecting the dural sac.
13. Bleeding from the epidural veins is controlled by packing with narrow cottonoid strips and if necessary by careful coagulation with a bipolar bayonet forceps.
14. Various rongeurs are used to remove the laminae after edges are defined with a curette. Bone drills are commonly used to reduce bone down to epidural fat, saving time and wear on the surgeon's hands.
15. Rongeurs—straight and angled, narrow and wide—are used to remove further bony areas until the cord with its dural covering is exposed and decompressed.
16. The surgeon uses a blunt nerve hook to explore the nerve roots and extradural space.
17. If no further stenosis is felt, hemostasis is secured.
18. The cottonoid strips are removed from the epidural space, and the area is further irrigated. All cottonoid strips and patties and retractors are removed, and the wound is closed.

Operative Procedure—Laminectomy for Intradural Spinal Cord Tumor

1. The fascial incision is made in the midline, both sides of the spinous processes are dissected out, and the paraspinous muscles are reflected bilaterally, one side at a time. The level is confirmed with x-ray.
2. One or more Gelpi or Adson-Beckman self-retaining retractors are placed to maintain the bony exposure.
3. The surgeon performs a midline laminectomy and excises the spinous processes. Various rongeurs (e.g., Leksell, double-action, Cloward) are used to remove the laminae after the edges are defined with a curette. The Midas Rex drill may also be used. The bone edges are waxed for bleeding.
4. The remaining flaval ligament is removed with scissors, scalpel, and Kerrison or Cloward rongeurs. Epidural fat is removed so that the dura mater is fully exposed.
5. A wide, moist cottonoid strip is placed over the superficial soft tissues and muscle down to the bone bordering the exposed dura mater. This provides additional hemostasis.
6. Intraoperative ultrasound may be employed to verify the exact location of the tumor beneath the dura.
7. The surgeon elevates the dura mater with a small hook and nicks it with a #15 blade. A grooved director is inserted beneath the dura mater, and the dural incision is extended over it using long forceps and fine scissors. Alternatively, the surgeon may lengthen the incision with Metzenbaum scissors. Traction sutures of 4-0 silk or braided nylon on dura needles are placed in the dural edges, and the cord is exposed (Figure 20-55). The operating microscope may be used.
8. The cord is explored for the pathologic area. Aspiration through a #22 needle on a plain-tipped syringe may be carried out. Whenever possible, the tumor mass is dissected free and removed using suction, the dissecting scissors, the bipolar forceps, small (pituitary) scoops, curettes, pituitary rongeurs, or an ultrasonic aspirator. Bleeding is controlled with moist cottonoids, hemostatic clips, gelatin gauze, and topical hemostatics. Bipolar electrocoagulation is used around the nerves and spinal cord.
9. The wound is irrigated and hemostasis is obtained, being careful to protect the spinal cord.
10. The dura mater is closed with a braided nylon or polytetrafluoroethylene (PTFE) suture.
11. The incision is checked for further bleeding, and the paraspinous muscles are approximated with absorbable suture. The remainder of the wound is closed.

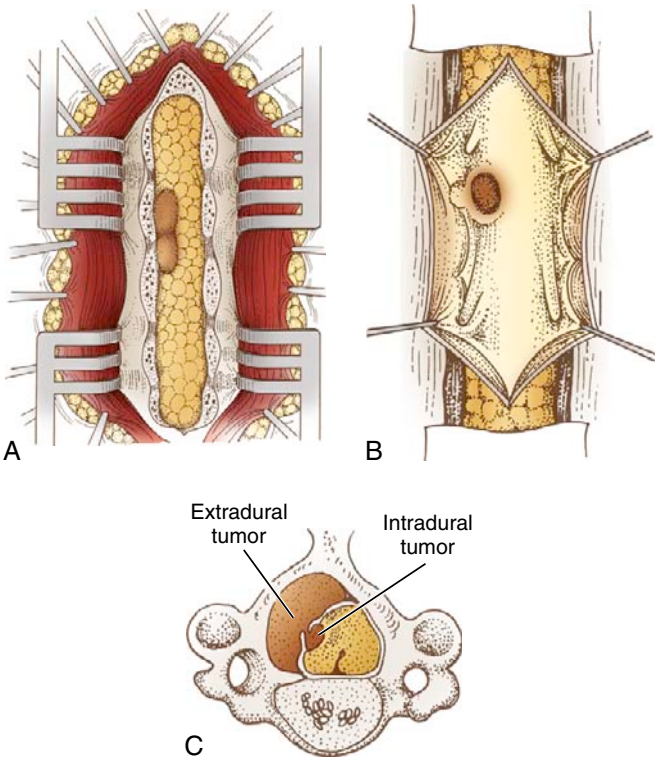


FIGURE 20-55 A, Laminectomy completed: dura mater and tumor exposed. B, Dura mater incised and retracted, revealing pia arachnoid over spinal cord and part of tumor. C, Diagram of cross section of tumor site and location of extradural and intradural pathologic areas.

In the case of extradural tumors, invasion of the dura is avoided. Once the dura is opened from a tear or an incision, the neurosurgeon may require that the patient remain flat for 24 hours or longer to allow healing of the dura.

Laminotomy

Laminotomy is the traditional approach to posterior microdiskectomy at the cervical, thoracic, and lumbar levels. Laminotomy is performed on the symptomatic side with resection of a small portion of the medial facet. The goal of this surgery is the resolution of leg pain with little to no residual back pain and a return to preinjury activity and lifestyle. In the twenty-first century, patients with herniated lumbar disks will continue to have a range of minimally invasive surgical options, many of which will be performed on an outpatient basis. Some of these newer procedures include nucleoplasty (decompression of a contained herniated disk by ablating and coagulating part

of the nucleus), intradiskal electrothermal therapy (IDET), and selective endoscopic diskectomy (Singh et al, 2005). Disk replacement is discussed in Chapter 19.

Procedural Considerations. The operating microscope has improved this surgical approach by offering magnification and illumination, which allows for smaller incisions and less tissue dissection. This surgical procedure is associated with less postoperative discomfort and shorter hospital stays. The majority of patients who undergo this procedure can be discharged home on the same day (Figure 20-56) (Ambulatory Surgery Considerations).

Operative Procedure—Lumbar Laminotomy and Microdiskectomy

1. With the patient in prone position or modified knee-chest position, a midline skin incision is made, extending from the spinous process above the involved level to the spinous process below. The correct surgical level is confirmed radiographically.
2. Dissection is carried down through the subcutaneous tissue to fascia, which is incised through a paramedian incision on the symptomatic side.
3. Paravertebral muscles are then dissected off the spinous processes and laminae.
4. A self-retaining retractor is placed to provide a visual field.
5. The hemilaminotomy, with a small portion of the medial facet removed, is performed.
6. The ligamentum flavum is incised longitudinally and removed with curettes or rongeurs, exposing the thecal sac.
7. A foraminotomy is then performed to expose and decompress the nerve root.
8. The epidural space is explored with a blunt dissector, nerve hook, dental tool, or Penfield #4 dissector.
9. The root is then gently retracted medially, exposing the disk bulge or herniation.
10. A window is made in the disk annulus with a #15 blade, and the disk space is entered.
11. Curettes and disk rongeurs are used to remove loose fragments of disk.
12. After diskectomy, the epidural space and the intervertebral foramen are explored with a blunt nerve hook to confirm patency and resolve nerve root pressure.
13. Hemostasis is achieved, and the wound is irrigated generously with saline/antibiotic solution.
14. The wound is then closed in layers.

For cervical or thoracic disks, only the protruding fragment is removed. Limited, if any, exploration of the interspace is performed because attempts at adequate interspace exploration require retraction of the dural sac, which contains the spinal cord at these levels. Such retraction would result in cord injury and paralysis. For a thoracic disk, a costotransversectomy or transthoracic approach is used.

Endoscopic diskectomy for far lateral disk herniations and annular tears has become an applied surgical approach in this subgroup of patients. Endoscopic spine systems have been developed, and further development and evolution of endoscopic equipment will continue to make minimally invasive procedures attractive to both the patient and the neurosurgeon.

AMBULATORY SURGERY CONSIDERATIONS

Microdiskectomies

Microdiskectomies are one of several spinal surgeries performed to relieve pain caused by disk herniations. Patients selected for this specific procedure typically complain of leg pain longer than 6 weeks in duration, and receive minimal relief from prescribed pain medications. An MRI confirming the level of nerve root compression as well as a detailed history and physical will determine if the patient is a candidate for surgery.

Ambulatory surgeries are designed for patients who have a nominal health history and pose minimal risk for operative complications. Microdiskectomies have the flexibility of being performed either in a same-day surgery center or in a hospital OR suite. The procedure is typically performed using a general or spinal anesthetic, depending on the needs of the patient. Once the anesthesia provider has control of the airway, the patient is positioned prone for maximum operative accessibility. Positioning may take time, and it is essential that every precaution is taken to prevent patient injury. If the patient is awake, talking should be kept to a minimum, and OR traffic should be closely monitored by the perioperative nurse. Before making the incision the surgeon may inject a local anesthetic containing epinephrine into the lumbar spine to minimize bleeding intraoperatively.

The procedure is approximately 2 hours in duration, and many patients are able to return home the same day. Postoperative pain relief is maximized by the use of intraoperative topical steroids on the nerve root, local anesthetics, and prescribed oral pain medications.

Possible complications include bleeding, infection, and, on rare occasions, nerve damage. Upon discharge the patient is instructed to keep the surgical site clean, restrict activity, and notify the surgeon immediately if he or she experiences excessive pain, swelling, or discharge from the incision site. Follow-up appointments are generally scheduled 2 weeks following the procedure, and most patients can return to work after 4 to 6 weeks.

Spinal Cord Stimulators

A spinal cord stimulator (SCS) is an implantable, non-destructive, medical device used to treat chronic intractable pain of the trunk and limbs. The device generates an electrical impulse to the epidural space which produces a tingling sensation that masks the perception of pain.

The goal of the stimulation is to lower the perception of pain, reduce medication use, increase function, and improve quality of life. Patients who are considered good candidates for a spinal cord stimulator placement undergo a trial to check for efficacy prior to permanent implantation. During the trial, a temporary percutaneous lead is placed and connected to an external pulse generator for approximately 3 to 7 days. The patient must experience at least 50% improvement in pain to be considered a candidate for permanent lead placement. The trial is generally performed in the OR using monitored anesthesia care (MAC) or general anesthesia.

The permanent spinal cord stimulator lead is implanted into the epidural space, and the impulse generator (IPG), which is the device battery, is implanted in the abdomen or buttocks. The lead is positioned at a specific level of the spinal cord. The targeted level is determined by the individual patient's symptoms, and by information obtained from the trial. A thoracic spinal cord stimulator is placed for lower back and leg pain.

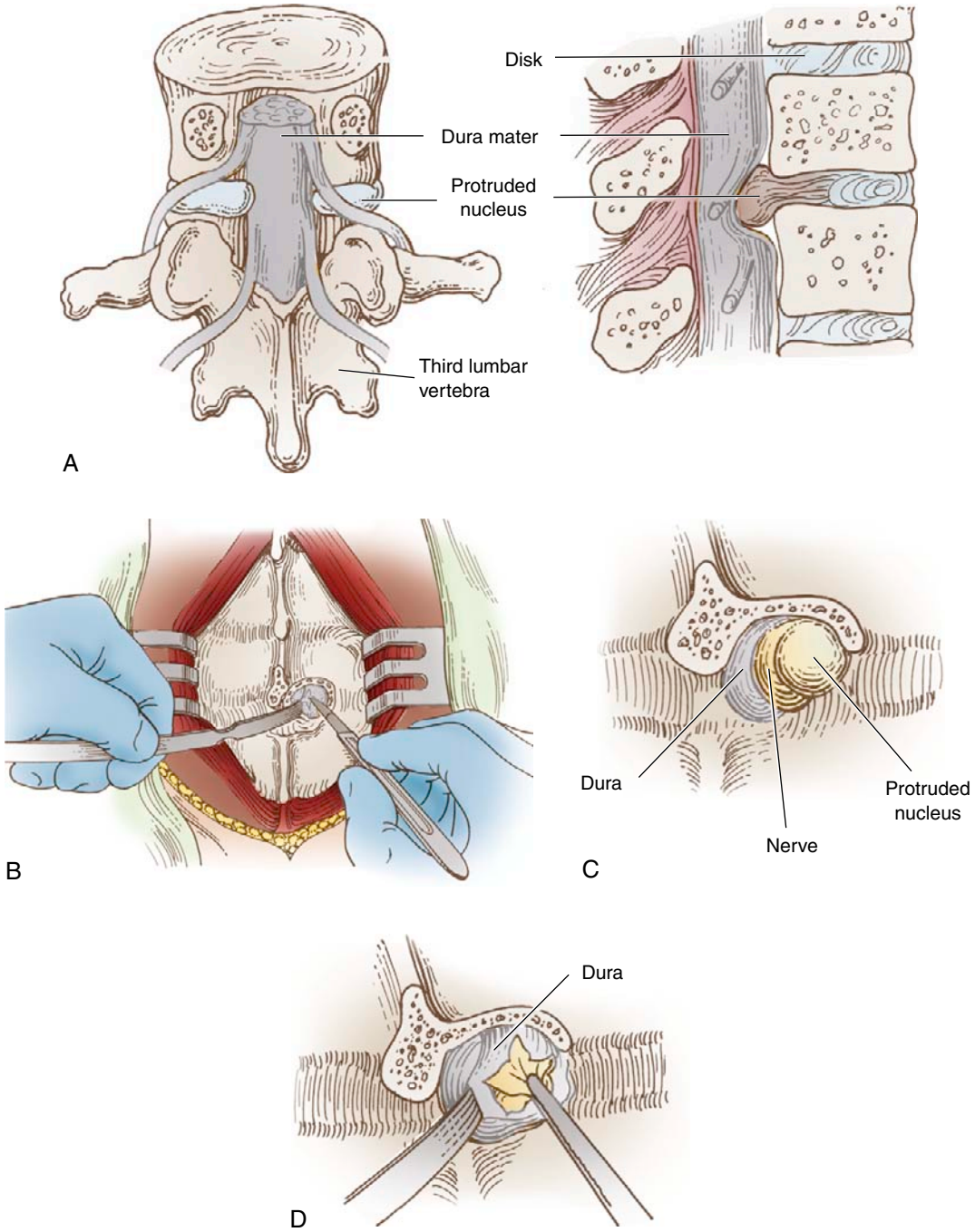


FIGURE 20-56 **A**, Normal and herniated nucleus pulposus (disk). **B**, Window has been made in lamina, and ligament has been incised to expose underlying dura mater and nerve root. **C**, Relationship of dura mater, nerve root, and protruded nucleus pulposus (disk). **D**, Retraction of nerve root over dura mater and removal of disk.

A cervical spinal cord stimulator is placed for upper extremity pain. Peripheral nerve stimulators are an alternative or conjunctive neuromodulation technique that targets peripheral nerves.

Procedural Considerations. Lead placement must be assessed during the surgery. This can be done by waking the patient during the surgery and asking them where they feel the stimulation. To secure the airway, lateral position is used with this method. Alternatively, electromyogram (EMG) monitoring may be used while the patient is under general anesthesia to verify motor responses in the targeted muscle groups. Fluoroscopy is also employed to verify lead placement.

The surgeon determines the battery site and directs the patient's position accordingly. The prone position is used if the battery will be inserted into the subcutaneous tissue of the buttocks. The lateral position is used if the battery is placed in the subcutaneous tissue of the abdomen, or if the patient will be awakened during surgery. The perioperative nurse ensures that the spinal cord stimulator system, the product representative, and the fluoroscopy unit are available, and that the OR bed is compatible with fluoroscopy. The surgeon marks the operative site before the patient is prepped. The surgical prep includes the entire area from the lead placement site to the IPG site.

Operative Procedure

1. The surgeon makes a midline incision at the proper level over the spine and uses sharp and dull dissection through the subcutaneous tissues to reach the fascia.
2. Paravertebral muscles are then dissected off the spinous process and lamina. A self-retaining retractor is placed to provide a visual field.
3. Instruments such as Kerrisons, pituitaries, and rongeurs are then used to perform a surgical laminectomy. The stimulator lead is placed in the epidural space. Proper placement is confirmed by testing with the stimulator programmer while waking and assessing the patient's perception of the stimulation, or while using EMG monitoring. Lead placement is also verified with fluoroscopy or x-ray. Once testing is complete, the surgeon anchors the lead with a 4-0 non-absorbable suture.
4. The surgeon creates a pocket in the subcutaneous tissue of the buttocks or the abdomen for IPG placement.
5. Using a tunneling device the lead is tunneled from the lead site to the battery location. The IPG is attached. Excess wire is protected by placing it beneath the IPG.
6. The IPG is anchored with 2-0 non-absorbable suture to prevent migration.
7. Both incisions are irrigated and closed
8. An abdominal binder is applied to compress the battery site.
9. A postoperative x-ray is obtained to confirm lead placement.

Intrathecal Pump Therapy

An intrathecal pump (ITP) is a specialized device that offers precise, targeted, and adjustable medication treatment for patients with spasticity and/or chronic pain. It delivers medication directly into the CSF via a small catheter attached to a pump.

The pump is controlled via a radio-telemetry link from an external programmer. This controls the rate and mode of infusion. The pump reservoirs are refilled with medication in the physician's office. Baclofen for spasticity or morphine sulfate for pain are most commonly used.

All patients are carefully screened for specific criteria, such as ineffective results or intolerable side effects with oral medication, limited functional abilities, no significant addiction history, and a diagnosed pathology. Contraindications for ITP therapy include active or frequent infections, medication allergy, failed screenings, and lack of patient reliability, resources, or support. ITP complications can include:

- Infection
- Mechanical failure
- CSF leak
- Overdose or adverse drug reactions

Each patient undergoes a trial injection that lasts 6 to 8 hours. Positive results must be noted before final implantation. Trials are performed in the physician's office, while final implantation is performed in the OR using MAC or general anesthesia.

Procedural Considerations. The nurse ensures the availability of the intrathecal pump system and the prescribed intrathecal medication before the procedure. A representative from the manufacturer should be present to assist with pump programming. Intraoperative fluoroscopy is used to verify proper placement of the catheter, so a compatible OR table is necessary. The surgeon will determine the patient's preference for pump placement (right or left abdomen) and mark the abdomen and back incisions. The back incision is typically marked at the area of L3-4. The abdominal incision is marked strategically to avoid the belt line, umbilicus, and the iliac crest. The perioperative nurse assists with placing the patient in the lateral position, using pillows and side braces as positioning aids. The surgical prep extends from the posterior incision site to the abdominal pump site.

Operative Procedure

1. The surgeon makes an incision in the patient's back and extends it through the subcutaneous tissue to the fascia. Hemostasis is obtained with the ESU.
2. A Tuohy needle is inserted paraspinally and at a 30-degree angle through the fascia into the intrathecal space, usually at L3-4. The surgeon confirms proper needle placement by removing the inner stylet of the Tuohy needle and visualizing a flow of CSF through the outer cannula.
3. The surgeon threads the catheter through the needle and feeds it to the proper level of the spine. This is determined by the patient's symptoms and the type of medication that will be administered. The catheter placement is verified under fluoroscopic visualization and is secured with anchors and a 4-0 non-absorbable suture.
4. The abdominal incision is made to create a pocket approximately 2.5 cm deep subcutaneously for pump placement.
5. Using a tunneling device the surgeon tunnels the catheter from the back to the abdominal pocket. The flow of CSF is once again verified through the catheter before it is connected to the pump. The pump is placed in the abdominal pocket and secured with 2-0 non-absorbable suture to prevent migration.
6. Both the back and abdominal incisions are irrigated and closed.

7. Dressings are applied to both incisions, and an abdominal binder is secured. In the recovery room, the pump is set with the external programmer.

Additional spine techniques are covered in Chapter 19.

PERIPHERAL NERVE SURGERY

Sympathectomy

Sympathectomy is excision of a portion of the sympathetic division of the autonomic nervous system. Most sympathectomies are performed on the paravertebral chain and are named for the region resected, such as cervical, thoracolumbar, and lumbar. The periarterial sympathectomy, vagotomy, and presacral neurectomy are other procedures that are occasionally performed on the autonomic system. The principal diseases treated by sympathectomy are vascular disorders of the extremities, intractable pain from certain nerve injuries, chronic abdominal conditions, and hyperhydrosis (overactivity of sweat glands).

The position of the patient depends on the region to be resected. Basic dissecting instruments and the microscope are used. For retropleural and transthoracic approaches, rib-resecting instruments are added. For the thoracic approach, Beckman or Scoville laminectomy retractors and an assortment of handheld retractors, including malleables, Deavers, and Richardsons, are added. For the abdominal approach, Balfour self-retaining retractors are added.

Cervicothoracic Sympathectomy—Dorsal. Dorsal sympathectomy entails removal of the cervicothoracic chain, often from the fourth cervical to the third thoracic ganglion. Sympathetic denervation of the upper extremities and heart may be accomplished by cervicothoracic sympathectomy. The vasospastic phenomenon of Raynaud's disease is relieved by this procedure. It also may be beneficial in relieving intractable angina pectoris.

PROCEDURAL CONSIDERATIONS. For the anterior approach, both the laminectomy set and rib instruments are used, plus deep retractors and a nerve stimulator. The setup for the posterior approach is the same as that for the anterior approach, plus rib-resecting instruments, periosteal elevators, small rib retractors, a firm rubber pad, and OR bed attachments for the posterolateral position.

OPERATIVE PROCEDURE—ANTERIOR APPROACH

1. The patient is placed in a supine position with the head rotated to the opposite side. General endotracheal anesthesia is necessary because puncturing the pleura is a possibility.
2. A transverse incision is made one fingerbreadth above the clavicle, the clavicular head of the sternocleidomastoid muscle is severed, and the deep cervical fascia is divided.
3. The phrenic nerve and the jugular vein are protected, and the anterior scalene muscle is divided to expose and isolate the underlying subclavian artery. One of its branches, the thyroid axis, is ligated and divided.
4. The stellate ganglion, deep against the vertebral body, is brought into view and lifted on a nerve hook. The sympathetic chain is traced upward to the middle cervical ganglion and divided. Deep dissection behind the pleura exposes the upper thoracic ganglia, which are removed to below the third thoracic ganglion. Clips may be placed on the sympathetic nerves before their division.
5. The wound is closed, and dressings are applied.

OPERATIVE PROCEDURE—POSTERIOR APPROACH

1. The patient is placed in the lateral position, and a paravertebral incision is centered over the third rib. The trapezius muscle is divided, and the rhomboid is split in line with its fibers. The third and fourth ribs are isolated extrapleurally, and the posterior 4 to 5 cm is resected. The transverse processes may be removed to provide better exposure.
2. The sympathetic trunk, which lies on the anterolateral aspect of the vertebral body, is reached by carefully reflecting the pleura. The trunk is picked up on a nerve hook, traced up and down, and removed, usually from the stellate ganglion to the fourth thoracic ganglion. Clips may be applied to the nerve before the fibers are severed.
3. A firm rubber tube may be left in the wound during closure. Suctioning apparatus is applied to this tube as the last deep fascial suture is drawn tight; all air is aspirated, and the tube is quickly withdrawn.
4. The subcutaneous tissue and skin edges are closed.

Nerve Repairs

Peripheral nerve injuries are the most common indication for nerve repair. Nerve tumors are rare in comparison. When the continuity of a nerve is destroyed, function distal to the site of injury is lost. Recovery will occur only if regeneration of nerve axons takes place from the healthy proximal segments. These axons must grow down the axis cylinders of the nerve beyond the injury if they are to reinnervate their end-organs and allow function to return.

When a nerve is divided, the cut ends retract, become scarred, and form neuromas. Regenerating axons from the proximal segment cannot bridge such a gap or penetrate the scar tissue. An unobstructed path down the axis cylinder must be made available if nerves are ever again to move muscles or transmit sensation. All procedures are directed toward obtaining the best possible conditions for regeneration.

Procedural Considerations. A basic dissecting instrument set, microinstruments, a microscope, and a nerve stimulator are used. For lesser procedures such as spinal accessory–facial anastomosis in the neck, division of the volar carpal ligament for median nerve compression at the wrist, or repair of a small digital nerve, suitable modification may be made. The positioning, skin prep, and draping of the patient depend on the site of the injury. A large area is prepped.

General anesthesia is usually preferred, with the patient positioned for maximum accessibility to the injured nerve. Exposure must be adequate because considerable mobilization of the nerve is often necessary. A dry field may be achieved using a tourniquet on the involved extremity.

Operative Procedure

1. The site of injury is explored, with careful attention to hemostasis. Nerve ends are dissected from surrounding scar tissue, and neuromas are excised. Moist umbilical tapes, vessel loops, or Penrose tubing may be passed around the nerve to handle it more easily and with less trauma.
2. The nerve repair anastomosis is made with multiple fine sutures placed only through the nerve sheath or epineurium (Figure 20-57). Tension at the suture line is eliminated by maneuvers such as freeing a long length of nerve on either

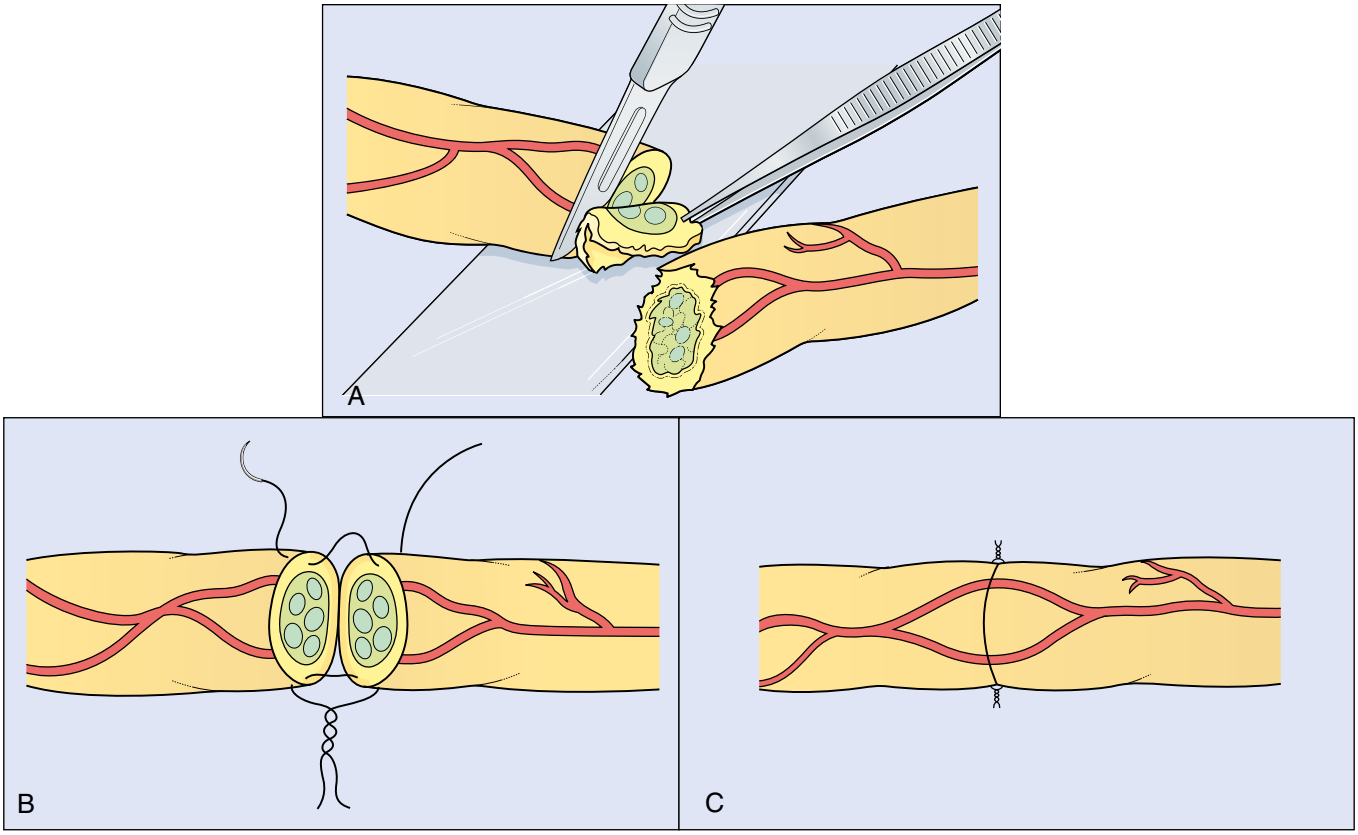


FIGURE 20-57 Nerve repair. **A**, Serial resection of neuroma to healthy nerve fibers. **B**, Placement of sutures in epineurium. **C**, Approximation and tying of sutures.

side of the point of injury, transposing the nerve to shorten its course, appropriately positioning the extremity with plaster splinting during the postoperative period, and, rarely, using a nerve graft. Some surgeons apply a cuff of inert material, such as silicone, around the anastomosis.

REFERENCES

Al-Mefty O, Heth J: Meningiomas. In Rengachary SS, Ellenbogen RG, editors: *Principles of neurosurgery*, ed 2, St Louis, 2005, Mosby.

American Association of Neurological Surgeons (AANS): Endovascular surgery, available at www.neurosurgerytoday.org/what/fact/endo_vascular.pdf. Accessed May 1, 2009.

American Cancer Society (ACS): *Cancer facts and figures 2009*, Atlanta, 2009, American Cancer Society.

Batjer HH et al: Intracranial aneurysm. In Rengachary SS, Ellenbogen RG, editors: *Principles of neurosurgery*, ed 2, St Louis, 2005, Mosby.

Central Brain Tumor Registry of the United States (CBTRUS): Statistical report: primary brain tumors in the United States, 2007-2008, available at www.cbtrus.org/reports//2007-2008/2007report.pdf. Accessed June 20, 2009.

Connolly ES et al: *Fundamentals of operative techniques in neurosurgery*, ed 2, New York, 2009, Thieme.

Denholm B: Tucking patient's arms and general positioning, *AORN J* 89(4):755–757, 2009.

Doherty GM, Way LW: *Current surgical diagnosis and treatment*, ed 12, Columbus, 2006, McGraw-Hill.

Donthineni R: Diagnosis and staging of spine tumors, *Orthop Clin North Am* 40:1–7, 2009.

Greenberg MS: *Handbook of neurosurgery*, ed 6, New York, 2005, Thieme.

Harrop JS: Intradural spinal neoplasms. In Vaccaro AR, editor: *Spine core knowledge in orthopaedics*, St Louis, 2005, Mosby.

Khatri R et al: Interventional neuroimaging, *Neurol Clin* 27:109–137, 2008.

McCutcheon IE: Metastatic brain tumors. In Rengachary SS, Ellenbogen RG, editors: *Principles of neurosurgery*, ed 2, St Louis, 2005, Mosby.

Mendel E et al: Injuries to the cervical spine. In Vaccaro AR, editor: *Spine core knowledge in orthopaedics*, St Louis, 2005, Mosby.

Meyers PM et al: Indications for the performance of intracranial endovascular neurointerventional procedures, a scientific statement, *Circulation* 119:2235–2239, 2009, available at http://circ.ahajournals.org/cgi/reprint/CIRCULATIONAHA.109.192217. Accessed May 1, 2009.

National Cancer Institute (NCI): Adult brain tumors treatment, available at www.cancer.gov/cancertopics/pdq/treatment/adultbrain/HealthProfessional/page3. Accessed June 20, 2009

National Institute of Neurological Disorders and Stroke (NINDS): NINDS arteriovenous malformation information page, 2009, available at www.ninds.nih.gov/disorders/avms/avms.htm. Accessed April 14, 2009.

Oyesiku NM: Nonfunctioning pituitary adenomas. In Rengachary SS, Ellenbogen RG, editors: *Principles of neurosurgery*, ed 2, St Louis, 2005, Mosby.

Pagana KD, Pagana TJ: *Mosby's diagnostic and laboratory test reference*, ed 9, St Louis, 2009, Mosby.

Perrin RG, McBroom RJ: Metastatic tumors of the spine. In Rengachary SS, Ellenbogen RG, editors: *Principles of neurosurgery*, ed 2, St Louis, 2005, Mosby.

Pollock BE, Brown PD: Stereotactic radiosurgery. In Rengachary SS, Ellenbogen RG, editors: *Principles of neurosurgery*, ed 2, St Louis, 2005, Mosby.

Schumacher HC, Marshall RS: Arteriovenous malformations: treatment & medication, emedicine, 2006, available at http://emedicine.medscape.com/article/1160167-treatment. Accessed April 14, 2009.

Singh K et al: Intradiscal therapy: a review of current treatment modalities, *Spine* 30(17s):s20–s26, 2005.

Sloan AE et al: Gliomas. In Rengachary SS, Ellenbogen RG, editors: *Principles of neurosurgery*, ed 2, St Louis, 2005, Mosby.

Teo C, Mobbs R: Neuroendoscopy. In Rengachary SS, Ellenbogen RG, editors: *Principles of neurosurgery*, ed 2, St Louis, 2005, Mosby.

Wang P, Avellino AM: Hydrocephalus in children. In Rengachary SS, Ellenbogen RG, editors: *Principles of neurosurgery*, ed 2, St Louis, 2005, Mosby.

Whiten C, Gunning P: Carotid endarterectomy: intraoperative monitoring of cerebral perfusion, *Curr Anaesth Crit Care* 20:42–45, 2009.

Zonenshayn M, Rezai A: Stereotactic surgery. In Rengachary SS, Ellenbogen RG, editors: *Principles of neurosurgery*, ed 2, St Louis, 2005, Mosby.

CHAPTER 21

Plastic and Reconstructive Surgery

VICTORIA DREGER

Derived from the Greek word *plastikos,* which means to mold or give form, plastic surgery is a medical specialty that restores or gives shape to the body. There are two different subspecialties of plastic surgery. *Cosmetic surgery* restores or reshapes normal structures of the body, to improve appearance and self-esteem. *Reconstructive surgery* treats abnormal structures of the body caused by birth defects, developmental problems, disease, tumors, infection, or injury to restore function and correct disfigurement or scarring (American Society of Plastic Surgeons [ASPS], 2009a.) As a surgical specialty, plastic surgery owes much of its heritage to knowledge gained from the wars of the twentieth century (History box).

Despite the economic downturn, 12.1 million cosmetic surgical procedures were performed [by surgeons certified by the American Society of Plastic Surgeons (ASPS)] in 2008, an increase of 3%; the majority were minimally invasive procedures. Females constituted 91% of all patients undergoing cosmetic procedures. Hispanic, Asian, and African American patients showed an increase in cosmetic procedures; the number of Caucasians undergoing cosmetic procedures decreased by 2%. Office-based cosmetic procedures increased by 13%, with a total of $10.3 billion dollars spent on the cosmetic procedures in the United States (Ambulatory Surgery Considerations). The 4.9 million reconstructive procedures also showed a 3% increase, although breast reductions decreased by 16% (ASPS Stats, 2009).

Surgical Anatomy

Plastic and reconstructive surgery is not limited to a single anatomic or biologic system. It is based on thorough understanding of the anatomy and biology of tissue. Operative techniques are complex and staged to achieve the expected results. The surgery also involves removing, reducing, enlarging, and recontouring, as well as camouflaging scars into existing skin lines (Figure 21-1). The tissues of the body can be transferred to use as various types of flaps. Free flaps are the transfer of

HISTORY

Origins and Growth of Plastic Surgery

Historically, battlefield combat has been an impetus for the development of new medical and surgical techniques based on the injuries sustained. As battlefield technology and the weapons of war became more sophisticated throughout history, the degree of injury and tissue devastation became more horrific. The trench warfare of World Wars I and II gave rise to a whole new category of facial injuries. Helmets protected combatant's skulls and the trenches offered some protection to the chest, but the face was exposed, and as a result, devastating burns and fractures of the face occurred. Special hospitals were created to address these problems, and even before the United States joined the first World War, the Harvard unit sent 35 physicians and surgeons, 3 dentists, and 75 nurses from various medical centers to assist in caring for the wounded. These visionaries were soon developing new techniques and procedures to correct the disfiguring injuries. They were credited as being the first generation of modern plastic surgeons, and helped give much needed respect to the specialty.

While World War I helped reinvent plastic surgery, the specialty has been identified as long ago as 600 BC, when a Hindu surgeon described using a cheek flap to reconstruct a nose. Another flap technique, this time using the forehead to reconstruct a severed nose, was performed around 1000 AD in India. The Italian surgeon Gaspare Tagliacozzi, also known as the "father of plastic surgery," developed still another flap surgery using the upper arm to reconstruct a nose. History tells us that the condition of the nose, whether from war, punishment, or social disease (syphilis), presented a story that often was undesirable. This resulted in impetus in the different societies to camouflage the injuries, thus propelling advances in plastic surgery.

Following the end of the first World War, plastic surgery turned its attention to the rest of society, and concentrated on deformities caused by birth or trauma. Soon, some surgeons began using their talents to improve less than desirable facial features. For example, Fanny Brice underwent a rhinoplasty in her apartment in 1923 to change the appearance of her nose from "prominent to decorative." In 1924 a New York newspaper had a contest to transform the city's homeliest woman into a beauty. Dr. John Howard Crum performed the first facelift on record in the Grand Ballroom of the Pennsylvania Hotel in New York City in 1931, during which "a pianist accompanied him with appropriate popular tunes, flashbulbs popped, and men and women fainted."

Modified from Feldman E: Before & after: cosmetic surgery was born 2,500 years ago and came of age in the inferno of the western front, *Am Herit* 55(1):60-70, 2004; *The history of plastic surgery: the early years,* available at www.plasticsurgery.org/About_ASPS/History_of_Plastic_Surgery.html. Accessed July 6, 2009.

AMBULATORY SURGERY CONSIDERATIONS

Patient Choices in Facility

There has been a dramatic shift toward encouraging patients to be more involved and informed in all of their healthcare decisions. Many organizations are focusing on active participation of patients in their own care. One aspect of this is choosing the outpatient facility for their plastic surgery. In keeping with this trend, the American Society of Plastic Surgeons (ASPS) has developed a brochure, with an excerpt available on-line, to help patients choose a facility. The brochure includes the following information:

- *Types of facilities*: For ambulatory (discharge same day as surgery) procedures, the facility may be part of the surgeon's office, a surgical suite adjacent to the office, a free-standing facility, or part of a hospital.
- *Choice and benefits:* Some patients prefer no overnight stay at a hospital. Cost savings and convenience along with added privacy and personalized care may all be factors.
- *Accreditation:* As a result of the strict guidelines for equipment, staff, anesthesia services, and hospital access, patients are encouraged to determine if a facility is accredited, as it could indicate the quality of the facility. (All ASPS member surgeons are required to operate in an accredited medical facility.)
- *Insurance:* The accreditation mentioned above also impacts financial aspects. Although facility fees are typically not covered by insurance providers for elective procedures, facility fees for reconstructive procedures may be covered. Reimbursement may be expedited for facilities that carry accreditation because the accreditation ensures that certain quality standards are met at that facility. Also, similar services at a hospital generally cost more than in an ambulatory facility.
- *Individual considerations:* Each patient must discuss the options with his/her surgeon. Depending on medical history and condition requiring surgery, ambulatory surgery may not be appropriate for everyone.

Modified from American Society of Plastic Surgeons: *Ambulatory facilities: same day facilities: choosing same day surgery facilities,* Arlington Heights, Ill, 2008, available at www.plasticsurgery.org/Patients_and_Consumers/Planning_Your_Surgery/Same_Day_Surgery_Facilities.html. Accessed June 17, 2009.

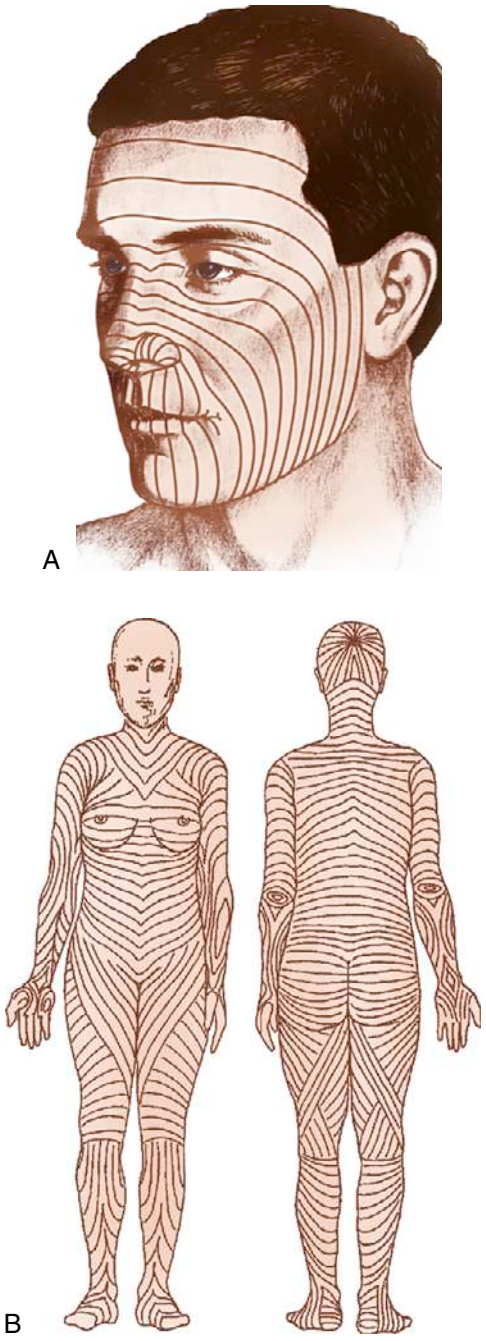


FIGURE 21-1 The surgeon adheres to several principles when planning skin incisions, one of which is to reduce the amount of tension across the wound, thus minimizing scarring. Elective incisions should preferably parallel relaxed skin tension lines (RSTLs) in the face (**A**) and the body (**B**).

tissue along with its vascular pedicle. When nerve is anastomosed with these flaps, they are called neurovascular free flaps. Flaps are used to cover defects or create new structures such as breasts, digits, or facial structures. Body parts can also be transplanted. By improving the patient's deformity, the patient's self-esteem will improve and the patient will feel more comfortable in public and social activities. The body changes as we age. The patient's concern with aesthetics, the variety of acquired defects, the diversity of operative techniques, and the psychologic responses of patients offer unique learning experiences and challenges for perioperative nursing care.

Perioperative Nursing Considerations

The prospect of surgery, even elective, can produce anxiety and fear. Because it is so often associated with body image and self-esteem, plastic and reconstructive surgery can trigger these emotions, especially when the proposed surgery is associated with potential disfigurement because of disease or trauma. Even a planned (desired) change in body image can be stressful. Many cosmetic patients lack the traditional support system one comes to expect during illness and recuperation because of a desire for confidentiality, making the sensitivity of the perioperative nurse all the more critical.

In general, the nurse creates a therapeutic environment in the following ways: introducing self and other members of the

surgical team; explaining all perioperative events and any sensations likely to be experienced; determining the patient's normal coping patterns; communicating with the patient in a calm, unhurried, and reassuring manner; encouraging the patient to verbalize feelings and concerns, and listening attentively; reducing distracting stimuli in the perioperative environment; providing reassurance and information about the progress of surgery (for awake patients); communicating progress reports to family; providing comfort measures (e.g., warm blankets, soft music of patient preference); and encouraging and assisting the patient to use personally effective coping strategies (e.g., meditation, guided imagery, relaxation).

Appropriate candidates for plastic surgery include those who have positive self-image but are bothered by a physical aspect that they would like to improve; after surgery, these patients maintain their positive self-image. Another category of appropriate surgical candidates includes patients who have a physical defect or cosmetic flaw that has lowered their self-esteem over time; these patients require time to adjust (rebuild confidence) postoperatively and generally their self-esteem is strengthened, even dramatically. Other patients are not as suitable for plastic surgery, including the following: patients in crisis or with unrealistic expectations; patients who are impossible to please (seeking multiple consultants for only answers they want to hear); patients obsessed with minor defects (again unrealistic about perfect life once defect is fixed); and patients who are mentally ill/psychotic, delusional, or paranoid (unless their seeking care is unrelated to psychosis). Some of the aforementioned patients could benefit from screening and referral with a psychiatrist as appropriate (ASPS, 2009b) (Research Highlight).

The nursing process is dynamic, fluid, and complex. The nature of plastic and reconstructive surgery is rarely simple, routine, or predictable, and the nursing care must mirror that fact. It must include thorough and ongoing assessment, establishment of nursing diagnoses and outcomes, fastidious planning, superior implementation, and thoughtful evaluation. The perioperative nurse's goal is to produce positive, high-quality outcomes in an environment that is safe and nurturing and will facilitate physical and emotional healing.

Throughout the nursing process, effective communication is necessary with the patient and the patient's family or significant others as well as with all members of the perioperative team. Communication is a two-way process that includes verbal and nonverbal messages. Respect for the individual, a nonjudgmental attitude, and effective communication skills are essential ingredients for the perioperative nurse caring for plastic surgery patients. Within this patient population, nurses must individualize the care based on assessment.

Assessment

As part of a holistic assessment, perioperative nurses consider physical and emotional factors of the planned procedure. A comprehensive review of the chart is the first step. The presence of a signed and witnessed informed consent, a systems review and health history, pertinent laboratory and diagnostic data, interdisciplinary planning, anesthesia evaluation, and the surgical plan will disclose vital information necessary to begin the assessment process. Visual inspection should include the patient's overall physical condition, the condition and integrity of the skin, nutritional status, and physical limitations. The next step is the patient interview, which includes checking patient identification, explaining the perioperative nursing role, and verifying the patient's understanding of the planned procedure. The perioperative nurse must be skilled in establishing communication quickly to create an instant relationship. Greeting the patient by name in a calm, comforting manner, perhaps with a gentle, caring touch (if welcomed by the patient), and maintaining good eye contact will help establish the rapport needed to assess emotional status, body image disturbances, and anxiety level. Asking the patient questions will help reveal any barriers to communication or learning; religious, cultural, or other preferences; mental status; and insight into compliance. Other vital pieces of knowledge the nurse must obtain include the presence of realistic expectations and motivation for surgery, as well as support systems available to the patient.

RESEARCH HIGHLIGHT

Nursing Survey of Psychologic Complications After Plastic Surgery

The author of this study notes that the two components of plastic surgery, aesthetic and reconstructive, both integrate the patient's sense of body image into the surgical process. Nurses must be aware of the scope and nature of negative psychologic complications resulting from plastic surgery to better understand and support the plastic surgery patient through the many intereactions that comprise the surgical experience.

An anonymous, confidential survey was mailed to 502 randomly selected certified plastic surgery nurses from a list of members of their professional organization (American Society of Plastic Surgical Nurses [ASPSN]). The response rate for the survey was 62%, with 312 nurses returning the survey.

The perceptions of the plastic surgery nurse indicated that psychologic complications occur at higher rates than do physical complications for this patient population. "Patients with pre-existing psychological conditions are more at risk for perioperative psychological complications. Nurses should be adequately prepared to screen, support, and coordinate psychological treatment for plastic surgery patients with the plastic surgeon."

The study concludes that patients experiencing physical complications are much more likely to experience psychologic complications at the same time. Lack of appropriate screening for mild or severe depression before plastic surgery leads to multiple, major problems in the postoperative period, specifically anger and hostility, sleep disorders, and disappointment. The most frequently seen psychologic complications include disappointment, anxiety, and depression. Patients exhibiting ongoing high anxiety, depression, or sleep disorders beyond a 2- or 3-week postoperative period need to be referred for appropriate psychiatric counseling or evaluation. The researcher discussed implications of these findings noting, "plastic surgeons and their staff need to…proactively manage their patients' emotional health in the perioperative period…Ongoing education regarding psychological and complementary treatment options must be a mandatory sequence of the plastic surgical team."

Modified from Rankin M: Psychological complications: national plastic surgical nursing survey, *Plast Surg Nurs* 29(1):25-30, 2009.

An important component of the assessment phase of nursing care involves communication with the surgeon and anesthesia provider to determine the need for special equipment, supplies, sutures, or implants. The perioperative nurse should verify the procedure and position and, in the case of multiple procedures on the same patient, identify the planned order of surgeries. The office staff of the plastic surgeon can be a useful source of information about the patient and the surgery and are often able to offer insight into the psychosocial dimensions of the patient.

Clear and effective hand-off communication is critical to patient safety. According to The Joint Commission, communication lapses among patient care providers cause more than two thirds of the serious medical errors reported. At least half those incidents occurred as responsibility for the patient was transferred from one team of care providers to another. In the perioperative suites, hand-offs occur as patients move to and from the ORs, involving many different care providers for one patient (Lenth, 2007).

The Department of Defense and the Agency for Healthcare Research and Quality of the U.S. Department of Health and Human Services initially developed the TeamSTEPPS™ approach, which emphasizes higher quality and safer patient care. "The goal of TeamSTEPPS is to produce highly effective medical teams that optimize the use of information, people, and resources to achieve the best clinical outcomes for their patients. TeamSTEPPS is scientifically-rooted in over 20 years of research and lessons learned from the application of teamwork principles in High-Reliability Organizations (HROs)" (DOD, 2009).

The Association of periOperative Registered Nurses (AORN) Presidential Commission on Patient Safety and the Department of Defense entered into an agreement that allowed AORN to expand and apply the more general information developed for TeamSTEPPS specifically to hand-off communications within perioperative units. Whatever form the hand-off communication takes at each facility, it must be standardized and provide thorough discussion of patient history, issues, special needs, and precautions for safety, with opportunity for the receiving provider to ask questions.

Nursing Diagnosis

Nursing diagnoses related to the care of the patient undergoing plastic and reconstructive surgery might include the following:

- Anxiety related to surgical interventions or outcomes
- Risk for Infection related to operative/invasive plastic/reconstructive procedure
- Deficient Knowledge related to perioperative process
- Disturbed Body Image related to congenital or acquired defect or developmental abnormality
- Risk for Ineffective Tissue Perfusion related to surgical intervention
- Impaired Comfort related to surgical/invasive procedure

Outcome Identification

Nursing diagnoses lead to the formulation of desired or expected patient outcomes. These are desirable and measurable patient states, including biologic or physiologic states; psychologic, cultural, and spiritual aspects; and the knowledge, behavior, or skills related to these states. As such, the patient outcome indicates progress toward or resolution of the nursing diagnosis. Outcomes should be mutually formulated with the patient, family, and other healthcare providers. Such formulations should be realistic, involve consideration of the patient's present and potential capabilities and resources, and provide direction for continuity of care, as well as determine satisfaction with that care. Outcomes identified for the selected nursing diagnoses could be stated as follows:

- The patient will verbalize management of anxiety.
- The patient is free from signs and symptoms of infection.
- The patient participates in decision-making affecting the perioperative plan of care.
- The patient will acknowledge feelings about altered structure or function.
- The patient has wound/tissue perfusion consistent with or improved from baseline levels established preoperatively.
- The patient demonstrates knowledge of pain management.

Planning

The perioperative nurse designs a plan of care using critical thinking to integrate knowledge gained from prior steps with the plastic surgical patient. The nurse should seek to create and maintain a culture and environment of safety for the patient, the OR, and all members of the surgical team during the planning process. A Sample Plan of Care for a patient undergoing plastic and reconstructive surgery is on pp. 889–890.

Implementation

The implementation phase typically begins with preparation of the OR and requires a thorough understanding of the procedure and the special needs of the patient, surgeon, and anesthesia provider. The perioperative nurse must continuously monitor and reassess the patient as well as the needs of the perioperative team, implementing and documenting the delivery of care. Constant consideration is given to the safety of the patient and the perioperative environment during this phase.

Preparation of the OR Suite. Before transporting the patient to the OR, the perioperative nurse will assemble all necessary medical and surgical supplies, equipment, suture material, positioning aids, implantable devices, and medications. The nurse is responsible for ensuring that lights and video equipment are in working order, that emergency supplies are present, and that compressed gases are adequate. Depending on the procedure to be performed, the OR bed may need to be configured differently from the standard room setup. To minimize inefficiencies during the procedure the nurse should confirm with the surgeon and anesthesia provider the position of the bed and any proposed intraoperative changes to the bed or room configuration. Plastic and reconstructive surgeons frequently use preoperative photographs of the patient when attempting to restore or modify appearance. These photographs help the surgeon maintain perspective since features may change because of surgical positioning. The nurse should collaborate with the surgeon to determine the best placement of these photographs for intraoperative viewing. Preoperative and postoperative photos, in order to be accurate, should be taken with the same lighting, angle, and distance (Hagan, 2008).

Equipment and Special Mechanical Devices. Essential equipment for any OR includes a fully functional bed that may be positioned for any number of special needs and also has

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Anxiety related to surgical intervention or outcome

OUTCOME
The patient will verbalize management of anxiety.

INTERVENTIONS
- Broadly classify the patient's anxiety (mild, moderate, severe).
- Try to understand the patient's perception of the stressors or stressful situation or event.
- Identify contributing factors.
- Introduce self and other members of the surgical team.
- Explain all perioperative events and any sensations likely to be experienced.
- Determine the patient's normal coping patterns.
- Communicate with the patient in a calm, unhurried, reassuring manner.
- Encourage the patient to express feelings and concerns; listen attentively.
- Reduce distracting stimuli in the perioperative environment.
- Provide reassurance and information about the progress of the surgery (if the patient is awake); implement mechanism for family progress reports also.
- Provide comfort measures (e.g., warm blankets, soft music that the patient prefers).
- Use touch as appropriate (e.g., softly stroking the hand).
- Encourage and assist the patient to use personally effective coping strategies (e.g., meditation, guided imagery, relaxation).

NURSING DIAGNOSIS
Risk for Infection related to surgical/invasive plastic/reconstructive procedure

OUTCOME
The patient is free of signs and symptoms of infection.

INTERVENTIONS
- Assess susceptibility for infection and risk for inadvertent hypothermia.
- Assess nutritional habits and patterns.
- Implement thermoregulation measures and aseptic technique (create and maintain a sterile field, prevent contamination of open wounds, and isolate the operative site from the surrounding physical environment).
- Minimize the length of invasive procedure by planning care (coordinate team members' efforts to set priorities and efficiently accomplish the tasks necessary to achieve a common goal).
- Perform skin preparations.
- Administer prescribed antibiotic therapy and prophylactic treatments, verifying physician orders.
- Protect from cross-contamination; maintain continuous surveillance.
- Record devices implanted during the operative or invasive procedure (according to federal regulations for tracking).
- Administer care to wound sites and invasive device sites.
- Monitor for signs and symptoms of infection.
- Encourage deep-breathing and coughing exercises.
- Evaluate response to thermoregulation measures and progress of wound healing.

NURSING DIAGNOSIS
Deficient Knowledge related to the perioperative process

OUTCOME
The patient demonstrates knowledge of the expected responses to the operative or other invasive procedure.

INTERVENTIONS
- Determine knowledge level (assess knowledge and comprehension of new information and ability to apply in self-care activities); assess readiness to learn (evaluate factors that may affect abilities to learn or demonstrate knowledge).
- Provide instruction based on age and identified needs; identify barriers to communication and adapt instructions to these.
- Evaluate environment for home care; identify expectations of home care.
- Explain expected sequence of events related to perioperative care; include family members in preoperative teaching; identify family members' knowledge and provide education and support.
- Assess knowledge; provide and evaluate response to instructions (e.g., about wound care and phases of wound healing) (evaluate patient's/family members' understanding of instruction regarding perioperative experience and ongoing care, listening to explanations and observing return demonstrations, techniques of wound care, and signs and symptoms to report).
- Provide information and explain Patient Self-Determination Act.
- Include patient and family members in discharge planning, including resources available to facilitate the rehabilitation process.
- Initiate institution's checklist policy for correct site surgery.
- Verify surgical consent with OR schedule and patient's statement of planned surgery.
- Solicit the patient's questions; answer or refer questions as appropriate.
- Explain the sequence of perioperative events and their purpose, as appropriate (e.g., holding area, OR attire, insertion of lines and attachment of monitoring devices, type of anesthesia, postoperative recovery unit, protocols).
- Provide sensory (what the patient will hear and feel, using lay terms) as well as factual procedure-related information.
- Provide printed material to reinforce patient education (e.g., preoperative routines, explanations of surgical intervention, postoperative management of pain, discharge instructions).

NURSING DIAGNOSIS
Disturbed Body Image related to disease, congenital or acquired deformity, developmental abnormality

OUTCOME
The patient will acknowledge feelings about altered structure or function and identify effective, optimistic coping options.

INTERVENTIONS
- Identify psychosocial status; elicit perceptions of surgery.
- Identify individual values and wishes concerning care.
- Assess coping mechanisms.
- Implement measures to provide psychologic support.
- Maintain patient's dignity and privacy (e.g., keep OR doors closed, only expose body as needed for care).
- Assist patient to identify and discuss feelings, stressors, and perception of physical deformity.
- Provide environment (e.g., privacy, supportive listening) conducive to expression of feelings.
- Help patient identify significance of culture, religion, gender, and age on perceived changes in body structure or function or image.
- Determine patient's body image expectations and whether expectations are realistic; clarify unrealistic expectations or misconceptions.
- Convey sense of respect for abilities and strengths in coping with problems or concerns.

Continued

SAMPLE PLAN OF CARE—cont'd

- Assist patient to separate physical appearance from feelings of personal worth, self-concept, and self-esteem (as appropriate).
- Refer the patient to other health professionals (e.g., clergy, social worker, psychiatric liaison) or support groups as appropriate.

NURSING DIAGNOSIS

Risk for Ineffective Tissue Perfusion related to surgical intervention

OUTCOME

The patient has wound/tissue perfusion consistent with or improved from baseline levels established preoperatively.

INTERVENTIONS

- Assess factors related to risks for ineffective tissue perfusion (e.g., presence of diabetes, immunosuppression); assess history of previous radiation exposure.
- Evaluate postoperative tissue perfusion.
- Identify factors associated with an increased risk for hemorrhage or fluid and electrolyte loss (e.g., patients with recent traumatic injury, abnormal bleeding or clotting time, extensive surgical procedure, complicated renal/liver disease, and major organ transplant).
- Implement hemostasis techniques (provide supplies, instrumentation, and appropriate surgical techniques as needed to control hemorrhage).
- Evaluate for signs and symptoms of physical injury to skin and tissue.
- Note any sensory or perceptual alterations in the affected body part, and document them.
- Maintain body temperature with the use of warming device or reflective blankets, for example.
- Warm intravenous fluids, blood and blood products, and irrigating fluids.
- Increase the temperature in the OR as indicated.
- Collaborate with anesthesia provider in monitoring the patient's core temperature.
- Provide intraoperative medications as prescribed for local irrigation (e.g., heparinized saline); label all medications on and off the sterile field, and document their administration.
- Apply compression stockings and antiembolic devices as indicated.
- Monitor tissue perfusion (e.g., by assessing blanching and capillary refill; using Doppler ultrasound), as prescribed, and flap ischemic time; record results.
- Note any swelling, change in color or temperature, or drainage from graft sites before discharge from the OR.
- Provide warm blankets for the patient at the conclusion of the surgical procedure.
- Teach the patient or the family how to care for the incision, including signs and symptoms of infection and graft failure (as applicable).

NURSING DIAGNOSIS

Impaired Comfort related to surgical procedure

OUTCOME

The patient demonstrates knowledge of pain management.

INTERVENTIONS

- Assess pain control using validated pain scale.
- Identify cultural and value components related to pain (e.g., stoicism, alternative therapy, verbalization, meditation).
- Implement pain guidelines; provide pain management instruction (purpose, administration, and desired, side, and adverse effects of prescribed medications and nonpharmacologic techniques for managing pain).
- Evaluate response to pain management instruction and instruction about prescribed medications.
- Collaborate in initiating patient-controlled analgesia.
- Evaluate response to pain management interventions (physiologic parameters and subjective and objective findings) and response to medications.
- Implement alternative methods of pain control (diversified activities, therapeutic touch, meditation, breathing, and positioning to augment pain control methods).

accessory attachments, such as headrests and aids for extremity positioning. The room must also have well-positioned and numerous electrical outlets, good overhead lighting, suction equipment, mounted x-ray view boxes, and computer terminals for those facilities using electronic medical records. Step stools, tables, chairs, hand tables, tourniquets, microscopes, and intravenous (IV) poles should be in appropriate supply and accessible. Surgeons often provide their own digital cameras although facilities may have them available for use.

INSTRUMENTATION. Basic instrument trays are available for the plastic surgery OR. A "local" tray may include Bishop Harmon and Adson tissue forceps (with and without teeth); straight and curved iris, Stevens, and Metzenbaum scissors; fine mosquito forceps; and skin hooks. Minor and major trays for plastic surgery may contain a range of tissue forceps, scissors, hemostats, and retractors. With the addition of instruments for specific surgeries, these trays usually suffice for all plastic surgery operations. Adequate instrumentation should be available to avoid flash sterilization (Risk Reduction Strategies).

DERMATOMES. Dermatomes are used for removing split-thickness skin grafts (STSGs) from donor sites; they are of three basic types: knife, drum, and motor-driven (Figure 21-2). Sterile mineral oil and a tongue blade should be available when STSGs are being obtained.

SKIN MESHERS. Several types of skin meshers are available. Each is designed to produce multiple uniform slits in a skin graft, approximately 0.05 inch apart. These multiple apertures in the graft can then expand, permitting the skin graft to stretch and cover a larger area. Meshing also facilitates drainage through the graft, preventing fluid accumulation under a graft. The graft is placed on the carrier and passed through the mesher (Figure 21-3). The manufacturer supplies sterile carriers for meshers. They are usually available in several sizes, which determine the expansion ratio of the skin graft.

PNEUMATIC-POWERED INSTRUMENTS. Pneumatic-powered instruments use an inert, nonflammable, and explosion-free compressed gas as their power source. The motor may be activated by a foot pedal or hand control. The various attachments should be sterilized as recommended by the manufacturer to prolong instrument life and ensure effective sterilization. The following attachments may be used in plastic surgery:

- Wire driver and bone drill
- Oscillating saw
- Derma-Tattoo (used with reciprocating-saw handpiece)

RISK REDUCTION STRATEGIES

Flash Sterilization

With high volumes of plastic surgery cases, it may be tempting/convenient to flash autoclave instruments or even implants when insufficient instruments are available or sales representatives do not bring sets until the day of surgery. Centers for Disease Control and Prevention (CDC) guidelines have clear information about this practice: "Do not use flash sterilization for convenience, as an alternative to purchasing additional instrument sets, or to save time; do not flash sterilize implanted surgical devices unless doing so is unavoidable." Although challenging, two facilities showcased their effective efforts in reducing flash sterilization. To meet AORN's benchmark of ≤5% of sterilization cycles using flash autoclave, the team decided on various approaches, including the following:

- Provide administration with an estimated cost for purchasing needed instrumentation.
- Review safety issues with staff; staff should consult manager whenever flash sterilization is necessary.
- Ask vendors to bring trays the evening before the procedure.
- Coordinate/meet with sterile processing staff to discuss next day's instrument needs and priorities.
- Communicate with surgeons the day before surgery to discuss order of procedures to avoid flash sterilization.

These approaches allowed one facility to decrease their flash cycles from 42% in 2005 and 62.8% in 2006 to an average of <5% per month; with proactive planning and thoughtful, coordinated effort, benchmarks can be met. Similarly, safety can become an issue when using loaner instruments; the condition upon arrival may be questionable. Literature is also available on proper decontamination, sterilization, tracking, and overall processing of such loaner items.

Modified from Hunter-Kunish GG: Processing loaner instruments in an ambulatory surgery center, *AORN J* 89(5):861-866, 2009; Kaufman-Gonzales H, Swaffield J: Decrease flash cycles in the OR (Poster Presentation AORN Congress, 2009), *AORN J* 89(6):1061-1062, 2009; Marsch C, Allend-Smith J: A collaborative approach to reducing flash sterilization, *AORN J* 89(6):1061, 2009; Rutala WA, Weber DJ: Healthcare Infection Control Practices Advisory Committee (HICPAC): *Guideline for disinfection and sterilization in healthcare facilities, 2008,* Washington, DC, November 2008, Department of Health and Human Services, Centers for Disease Control and Prevention, available at www.cdc.gov/ncidod/dhqp/pdf/guidelines/Disinfection_Nov_2008.pdf. Accessed June 27, 2009.

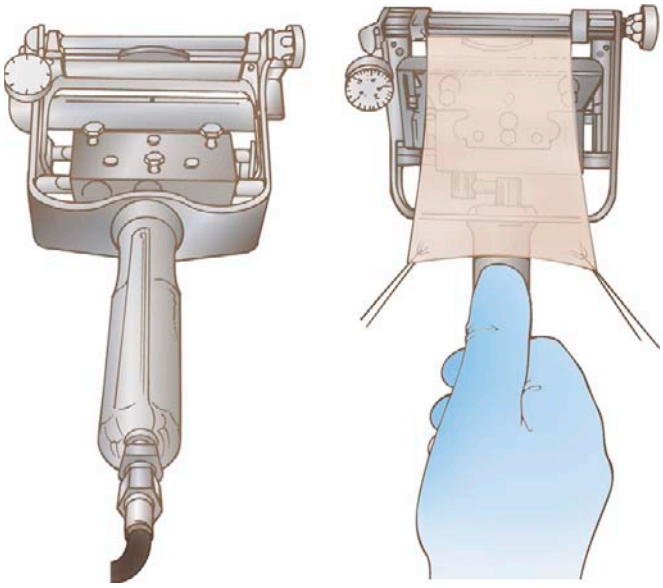


FIGURE 21-2 Powered Brown dermatome.

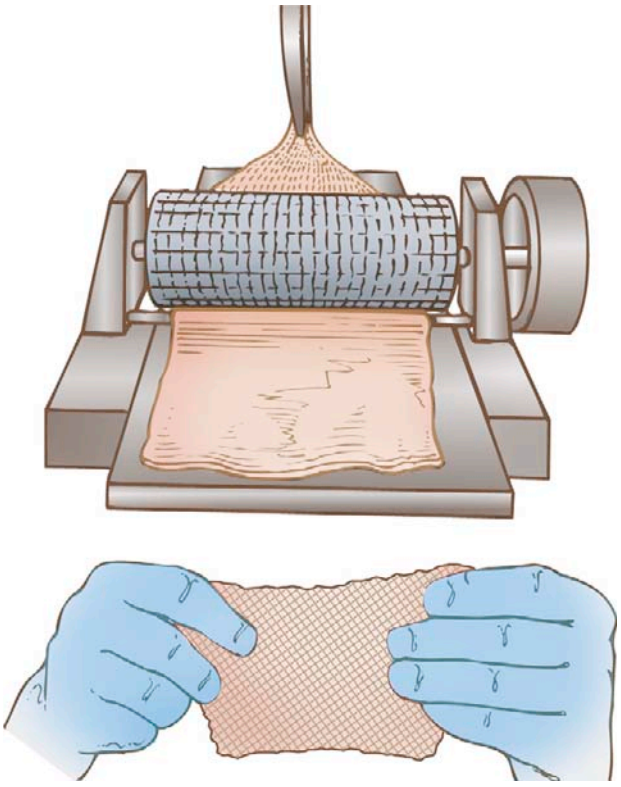


FIGURE 21-3 Manual skin graft meshing device.

- Reciprocating saw
- Dermabrader
- Sagittal saw

A pneumatic tourniquet with an inflatable cuff is used in most hand surgery procedures as well as in other upper and lower extremity surgical interventions. The tourniquet is described in Chapter 18.

ELECTROSURGICAL UNIT. The electrosurgical unit (ESU) and safety precautions taken by the perioperative nurse are described in Chapter 7.

BIPOLAR COAGULATION UNIT. Bipolar electrosurgery (also described in Chapter 7) is the use of electrical current in which the circuit is completed by means of two parallel poles located close to one another. One pole is positive; the other is negative. The flow of current is restricted between these two poles, which are usually the tines of the bipolar forceps. Because the poles are so close, low voltages are used to achieve the tissue effect. Because electrical current does not flow through the patient, a return electrode (dispersive pad) is

not necessary. This makes bipolar electrosurgery very safe and permits precise electrocoagulation.

LASERS. A variety of lasers are employed for plastic surgical procedures. The perioperative nurse must ensure that the laser safety accessories specific to the type of laser being used are available. Laser safety is discussed in Chapter 7.

FIBEROPTIC INSTRUMENTS. Examples of fiberoptic instrument attachments used in plastic surgery are a headlight for rhinoplasties, augmentation mammoplasties, and other procedures; a mammary retractor for augmentation mammoplasties; a rhytidectomy retractor; abdominoplasty retractors; and endoscopic face and forehead fiberoptic instrumentation.

LOUPES. Loupes (Figure 21-4) are magnifying lenses used by many plastic surgeons for microvascular surgery and nerve repairs and for numerous other instances in which cosmetic results are improved by the magnification effect. The nurse should inquire about the use of loupes before the surgeon dons a headlight because adjustments will need to be made to the headlight alignment if the loupes are required in midprocedure. Adjusting or removing the headlight in midprocedure has the potential to contaminate the sterile field.

MICROSCOPE. The microscope is frequently used in nerve repairs and microsurgical anastomoses; the nerves or vessels to be repaired, such as in hand surgery, and the suture used to do so (sometimes 9-0, 10-0, or even 11-0 size) can be finer than human hair and thus requires magnification. While each microscope has different features, an important matter to avoid confusion is whether the surgeon control overrides the assistant view, or if each can separately adjust the field of view.

WOOD'S LAMP. The Wood's lamp is an ultraviolet lamp used in a darkened room to determine the viability of skin flaps. After IV injection of fluorescein, the blood vessels appear bright purple (the skin appears yellow). Sodium fluorescein is excreted in the urine, and patients should be informed of this.

SPECIAL SUPPLIES. Surgeon-specific and procedure-specific special supplies are frequently added to instrument setups for plastic and reconstructive procedures. These commonly include the following: sterile marking pen or methylene blue; ruler; local anesthetic of choice for injection, with syringes and needles; and ESU, with active electrode (pencil) and tip of choice, with tip cleaner.

Sutures. Sutures range from permanent to absorbable and include monofilament and multifilament materials. The perioperative nurse should be a good steward of costly resources and should verify the type and number of sutures needed before opening suture packages, as well as needle preference, to prevent waste. Many plastic surgical procedures have multiple techniques, each of which necessitates very specific suture choices. See Chapter 6 for further discussion and explanations.

Dressings. Dressings are an essential part of the operative procedure in plastic surgery and may contribute to the ultimate outcome of the surgical intervention. Dressings are usually applied while the patient is still anesthetized. In general, the dressing should accomplish the following five goals:

1. Immobilize the surgical part.
2. Apply even pressure over the wound.
3. Collect drainage.
4. Provide comfort for the patient.
5. Protect the wound.

FIGURE 21-4 Loupes from Carl Zeiss, used for magnification.

Pressure dressings may be used to eliminate dead space, to prevent seroma and hematoma formation, and to prevent third spacing associated with liposuction and reconstructive procedures involving transfer of large muscle or tissue flaps. In some cases pressure can be achieved by the use of catheters or drains placed within the operative site and connected to closed-wound suction devices, such as a Hemovac or Jackson-Pratt. In smaller wounds a butterfly cannula may be inserted into the operative site, with the needle end placed into a red-top tube, such as a blood collection tube, that has a vacuum (evacuated tube).

The perioperative nurse should be familiar with the following common general dressings and supplies available in sterile form and various sizes:

- Nonadherent gauze (e.g., Betadine gauze, Adaptic, Nu Gauze, Xeroform, Biobrane, Scarlet Red)
- Petrolatum gauze, ½ inch (or other packing material, such as Merocel sponge for nasal packing)
- Telfa
- Fine mesh gauze
- Interface
- Gauze dressing sponges, 4 × 4 inches, 2 × 2 inches
- Kling, Kerlix fluff, and Kerlix gauze rolls (2, 4, and 6 inches wide)
- Abdominal pads (most commonly used are 5 × 8 inches)
- Cotton sheets and balls
- Webril
- Tape (paper; silk; and foam; skin tapes, flesh-colored and regular [⅛, ¼, ½, and 1 inch wide])
- Benzoin spray or swab or Mastoplast
- Ace bandages
- Coban
- Casting supplies and splints (as required for postoperative immobilization)
- Abdominal binders and other postoperative garments
- Slings

In some instances, such as a free flap, transparent dressings are used so that the flap can be monitored and observed for vascular flow. Compression garments and support devices are also frequently used by plastic surgeons. Proper fit is essential to minimize vascular compromise. Compression garments are typically applied over a light dressing. A proper garment is selected based on its characteristics (e.g., fabric, stretch, softness, antimicrobial properties) and proper sizing according to measurement instructions. Educating patients of the needs and benefits of compression garment use as well as providing hints for their proper application (avoid ripping with long nails,

instructions on how to don the garment) promotes comfort and compliance (Gladfelter, 2007).

Implant Materials. The range of materials available for implantation and augmentation in the specialty of plastic and reconstructive surgery has benefited from ongoing research. Perioperative nurses are responsible for complying with tracking regulations for implantable materials and devices (Patient Safety).

Biologic materials (autogenous grafts) are preferred when available. Autologous human tissue successfully utilized includes fat, solid dermis, and collagen. Human cadavers are used as a source for acellular collagen (AlloDerm) (Figure 21-5). This product is available in various sizes of sheeting and must be rehydrated in several steps. AlloDerm integrates with the body's tissue and helps to prevent rejection over the long term.

Implant failure may be directly linked to bacterial contamination; therefore meticulous aseptic technique with minimal handling is essential when using implants of any sort. Most alloplastic implants are presterilized from the manufacturer.

Anesthesia. A variety of anesthesia techniques are employed with plastic surgery procedures. Local, regional, tumescent, conscious sedation, deep sedation, and general anesthesia may be used, depending on the type of procedure, the patient's anesthetic history, the American Society of Anesthesiologists (ASA) physical status classification, and the surgeon's preference. Regardless of the type of anesthesia, patients should have baseline vital signs recorded and fully monitored, including blood pressure, heart rate, respirations, cardiac rate and rhythm, oxygen saturation, and $ETCO_2$ pressure if indicated. If a local or regional anesthetic is employed without an anesthesia provider, appropriate staffing should be determined based on patient assessment and nurse competency. The presence of a

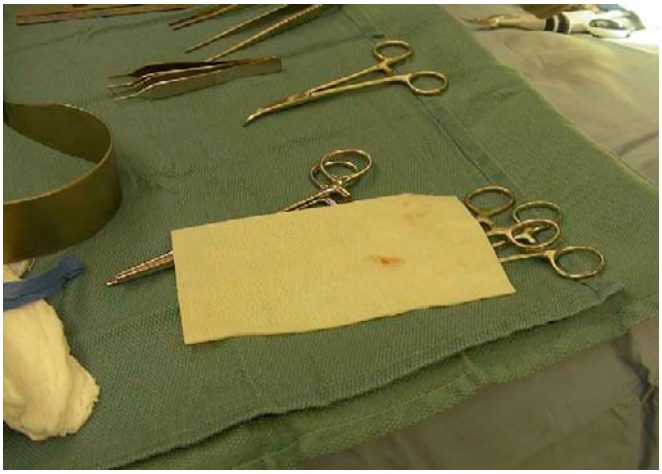


FIGURE 21-5 AlloDerm.

PATIENT SAFETY

Tracking Medical Devices

A variety of implantable devices are used in aesthetic and reconstructive plastic surgery procedures. Tracking of these devices is critical to patient safety. The manufacturer of the device must have a mechanism to locate implantables after they have been distributed. Devices may be recalled for sterility issues, malfunction, or any event that is found to pose a serious health risk.

The U.S. Food and Drug Administration (FDA) regulates the process of tracking medical devices and directs the tracking of devices whose failure would result in serious, adverse health consequences; devices that are intended to be implanted in the human body for more than 1 year; and devices that are life-sustaining and life-supporting and are used outside of a facility such as a hospital, nursing home, or ambulatory surgery center.

The perioperative nurse plays an important role in the accurate documentation of implantable devices for tracking purposes. Information that the nurse typically will gather for tracking purposes includes:

- Device identification (i.e., lot, batch, model number, serial number)
- Date of device manufacture and shipping
- Name, address, telephone number, and social security number of the patient who received the device
- Location the device was implanted
- Name, address, and telephone number of the physician who is caring for the patient, if different from the prescribing physician

If an implantable device is sterilized within the sterile processing department of the facility, monitoring requirements include the use of a process challenge device containing a biologic indicator. The load should be quarantined until the result of the biologic indicator is determined. Documentation should include a record of the sterilizer load identification number on the patient's medical record, or the patient's name on the load record. Lot identification provides a method for tracing problems in the event of a recall. Flash sterilization of implantable devices is not recommended.

Patients have the right to refuse tracking of their devices and may refuse to have their social security number used for tracking. The patient's consent for tracking should be obtained before the procedure. If the patient refuses to have the device tracked, the nurse will document the refusal along with the required product information and report these data to the manufacturer.

Under the Safe Medical Device Act, institutions must also report any incident of death or serious injury relating to the use of a medical device. The FDA has classified and identified more than 1700 different devices that must be reported if the device is suspected of causing serious injury or death to an individual. Nurses should work within their institutional policies to report these incidents.

Modified from Association for the Advancement of Medical Instrumentation: *Comprehensive guide to steam sterilization and sterility assurance in health care facilities,* Arlington, Va, 2006, AAMI; Chard R: Clinical issues, *AORN J* 90(1):117, 2009; Denholm B, Downing D: Clinical issues, *AORN J* 87(2):432-434, 2008; U.S. Food and Drug Administration: *Medical device tracking, guidance for industry and FDA staff,* available at www.fda.gov/cdrh/comp/guidance/169.html. Accessed July 6, 2009; U.S. Food and Drug Administration: *Medical device reporting,* available at www.fda.gov/cdrh/devadvice/351.html. Accessed July 6, 2009.

perioperative registered nurse whose sole responsibility is to monitor the patient may be warranted, depending on clinical assessment and patient behavior. This nurse must be sufficiently skilled in assessment and knowledgeable about the agents being used so that changes in the patient's status can be promptly reported and appropriate interventions to prevent complications can be initiated (AORN, 2009).

Injectable anesthetics are frequently used, not only for strictly local cases but also in conjunction with regional, sedation, and even general anesthesia. Local anesthetics (e.g., Xylocaine, Marcaine, Citanest) act by reversibly blocking nerve impulses—they stop nerve conduction by blocking sodium channels in the axon membrane. When combined with a vasoconstrictor such as epinephrine, local blood flow is decreased and systemic absorption of the anesthetic delayed. This prolongs anesthesia time and reduces the risk of toxicity. In addition, infiltration of a local anesthetic can help define tissue planes through hydrodissection. Use of epinephrine is contraindicated in areas with limited vascularity, such as digits, the penis, nasal tip, and ears. Systemic toxicity from the vasoconstrictor itself (palpitations, tachycardia, nervousness, and hypotension) may occur. For excessive symptoms, α- and β-adrenergic antagonists may control the symptoms (Lehne, 2007).

Although true allergic reactions to local anesthetics are rare, they are still possible; they are more likely with ester-type anesthetics (e.g., procaine). Amides (e.g., lidocaine) may be used when allergies contraindicate use of ester-type anesthetics. Thus amide-type anesthetics often replace ester-type agents for injection (Lehne, 2007).

Central nervous system toxicity from local anesthetics is a more frequent occurrence and is dose related. Maximum doses for several local anesthetics (volume for 70-kg adult) are 70 ml of 0.25% bupivacaine, 28 ml of 1% lidocaine solution, or 50 ml of a 1% solution of lidocaine with epinephrine (1:200,000) (Barberio, 2007). The nurse must be familiar with the signs and symptoms of toxicity, which are frequently heralded by restlessness. Early symptoms may include lightheadedness, dizziness, nystagmus, and numbness of the tongue and lips; these may progress to slurred speech, disorientation, psychosis, muscle twitching, tremors and convulsions, and cardiac arrest (Rapid Response Team box). Lehne (2007) notes, "toxicity is greater risk since absorption occurs more readily through mucous membranes than through skin. Extent of absorption is also proportional to the surface area covered so risk is greater with large areas covered. Applying topical anesthetics to the smallest surface area needed, and avoiding application to injured skin minimizes absorption and risk of toxicity."

Topical anesthetics used by the plastic surgeon include tetracaine (Pontocaine) 2% ophthalmic drops (for blepharoplasty or before application of eye shields), EMLA (eutectic mixture of local anesthetics) for penetration on intact skin (associated with laser surgery), and cocaine 4% for mucous membranes (for rhinoplasty).

Preoperative Skin Preparation. Most surgical interventions require that the operative site and adjacent areas be cleansed before surgery. The physician may prescribe that the patient carry out this treatment before surgery. Special attention is given to the fingernails for patients undergoing hand surgery; to hair for surgery of the head, face, or neck; and to oral hygiene for surgery in or near the mouth. The perioperative nurse should verify with the patient that the prescribed regimens have been performed. All body jewelry that pierces the skin should be removed before the skin prep. The operative site should be inspected for any rashes, bruises, open sores, cuts, or other skin conditions. Hair should only be removed if it interferes with the procedure. Shaving is avoided and clippers, not a razor, are used if needed, because shaving creates an access for the entry of bacteria into the operative site (Health Stream, 2007). The eyebrows and eyelashes, in particular, are left intact to preserve facial appearance and expression. The surgical site is marked before surgery by the surgeon to designate the correct site and to define landmark areas. Either a povidone-iodine solution, an iodine-alcohol mixture, chlorhexidine gluconate (CHG), or another broad-spectrum agent may be selected for the antimicrobial skin prep. The use of CHG should be avoided around the ears and eyes. It is important to place shields on the eyes if prepping the periorbital site or performing an extensive head and neck prep, place plugs in the ear canals, and prevent pooling of the prep agent. The perioperative nurse should query the patient regarding any allergies to antimicrobial agents. If indicated, the plan of care should be changed to avoid the use of these products. When prepping for a skin graft procedure, separate skin prep setups are needed for the graft and donor sites.

Positioning and Draping. The OR bed must be positioned so that the remaining space in the room can comfortably accommodate anesthetic equipment, members of the surgical team, instrument tables, and any adjunct equipment (hand table, drills, microscope, laser) to be used. The patient is carefully positioned on the OR bed so that all operative sites may be appropriately exposed and the airway easily observed and accessed.

Before implementing any positioning changes, the perioperative nurse should verify the appropriate placement of the OR bed and the desired patient position. Adequate numbers of personnel and supportive positioning devices must be present. No changes should begin until the anesthesia provider gives permission. Whereas a majority of plastic surgical procedures are performed in the supine position, many also take place with the patient prone or lateral. Liposuction and postbariatric body contouring procedures may also require repositioning one or more times during surgery. Abdominal procedures may start supine and usually require repositioning to facilitate closure. With each new position, reassessment and documentation of the position and devices used to stabilize the patient should occur. Chapter 5 reviews patient positioning and appropriate safety measures for the supine, lateral, and prone positions, all of which may be used during plastic surgical patient care. The perioperative nurse pays particular attention to the patient's arms during positioning to ensure that they are placed on padded armboards with the palms up and fingers extended (for the supine position). Armboards are maintained at less than a 90-degree angle to prevent brachial plexus stretch. If there are surgical reasons to tuck the arms at the side, the elbows are padded to protect the ulnar nerve, the palms face inward, and the wrist is maintained in a neutral position (Denholm, 2009). A drape secures the arms. It should be tucked snuggly under the patient, not under the mattress. This prevents the arm from shifting downward intraoperatively and resting against the OR bed rail.

RAPID RESPONSE TEAM

Local anesthetics are often utilized and administered via various routes for plastic surgery procedures (e.g., regional blocks, local/subcutaneous infiltration, indwelling catheters, and topical preparations). While widely used, they are not free from hazards. A recent FDA warning notes that the potential life-threatening complications, "such as irregular heartbeat, seizures, breathing difficulties, coma and even death," can occur when applied to a large area of skin or when the area of application is covered. The FDA encourages collaboration and clear instructions between healthcare professionals and patients who may use the products.

Teamwork within the plastic surgery department requires all to be vigilant in monitoring the patient during use of local anesthesia. This corresponds to the following *2009 National Patient Safety Goals and Requirements for Hospitals:* "Goal 2—improve the effectiveness of communication among caregivers; Goal 3—improve the safety of using medications; Goal 13—encourage the patient's active involvement in their care as a patient safety strategy; and Goal 16—improve recognition and response to a patient's condition" (Blanchard, 2008).

The principle of rapid response is to intervene early, to prevent life-threatening complications. Again, teamwork and sharing of information are pivotal to patient safety and optimal outcomes. Early signs and symptoms may be easier to detect with an awake, "strictly local" patient; they should serve as an alert for the anesthesia provider or surgeon to immediately stop administration of the local anesthetic, assess the situation, and intervene to prevent progression. Although rare, adverse events and toxic effects are dose related; symptoms may include metallic taste, tinnitus, light-headedness, syncope, visual disturbances, numbness of the tongue or lips, confusion, tremors, shivering, generalized seizures, initial tachycardia and hypertension, progressing with increased toxicity to ventricular dysrhythmias, cardiac arrest, and respiratory arrest (Ogg, 2008). Treatment may include administration of additional benzodiazepine, or small bolus doses of propofol in the event of tonic-clonic seizures. Airway support with oral or nasal airway insertion and oxygen via facemask is essential (Clark, 2008).

To effectively and rapidly intervene in a situation involving local anesthetic toxicity, the perioperative nurse must have a comprehensive knowledge of the mechanism of action driving toxicity and resuscitative protocols. The perioperative nurse needs to keep abreast of developments within fields of other disciplines to be able to respond to urgent situations and avoid potentially fatal patient outcomes. An example of a newer treatment for local anesthetic toxicity is lipid emulsion (LE) rescue therapy, which has been used in isolated situations for bupivacaine toxicity. Lipid rescue therapy is thought to be effective because the high lipid solubility of bupivacaine and rapid binding of excess local anesthetic with lipid infusion reduce the plasma drug level and allow for restoration of hemodynamic stability. An American Society of Anesthesiologists' newsletter discusses the evolution and science of using lipid emulsion therapy for patients not responding to conventional cardiopulmonary resuscitation after local anesthetic toxicity. An editorial in an anesthesia journal describes a difficulty, "There is little question that the absolute, scientific 'proof' of lipid emulsion's efficacy in reversing local anesthetic-induced cardiac arrest is yet lacking. Such a proof would require prospective, double-blind, placebo-controlled studies in humans, and such studies will thankfully never be performed, for obvious ethical reasons. However, when deciding on the patient safety implications of a novel, potentially life-saving, therapy, one must consider the tenuous and often unknown balance between the purported benefits and potential risks" (Brull, 2008). A summary of medical judgment shows a balance: "CNS symptoms such as loss of responsiveness, disorientation, tremors, or seizures must be treated conventionally by ensuring oxygenation and ventilation, securing the airway to protect aspiration of gastric contents in patients at risk, administering anticonvulsants, and instituting advanced cardiac life support protocols in the case of cardiac arrest. Once these conventional treatment modalities have begun, however, immediate IV administration of LE would seem very reasonable and desirable."

Modified from U.S. Food and Drug Administration, U.S. Department of Health and Human Services, MedWatch: *The FDA Safety Information and Adverse Event Reporting Program: safety alerts for human medical products: topical anesthetics,* January 16, 2009, available at www.fda.gov/Safety/MedWatch/SafetyInformation/SafetyAlertsforHumanMedicalProducts/ucm092082.htm. Accessed June 16, 2009; Blanchard J: Clinical issues: national patient safety goals update, *AORN J* 88:822-823, 2008; Ogg M: Clinical issues: recommended practices for local anesthesia, *AORN J* 88:277-278, 2008; Rowlingson JC: Resuscitation of local anesthetic toxicity with intralipid, *ASA Newslett* 71(10):October 2007, Park Ridge, Ill, available at www.asahq.org/Newsletters/2007/10-07/rowlingson1007.html. Accessed June 16, 2009; Brull SJ: Lipid emulsion for the treatment of local anesthetic toxicity: patient safety implications, *Anesth Analg* 106(5):1337-1339, 2008; Clark MK: Lipid emulsion as rescue for local anesthetic-related cardiotoxicity, *J Perianesth Nurs* 23(2):111-121, 2008.

Correct draping procedures depend on the location of the operative site or sites. Disposable drapes (see Chapter 3) are often used because of their barrier qualities, ease of handling and storage, and versatility in adapting to a variety of plastic surgery procedures. Two of the most frequently used draping techniques in plastic surgery are the head drape and the hand drape. Both of these draping techniques have the goal of providing maximum mobility of the operative part. The head drape includes a fluid-resistant drape that encircles the head and the addition of a drape to cover the remainder of the body. The following techniques represent methods of obtaining maximum accessibility and sterile coverage for facial surgery:

1. A barrier sheet, folded in half, and two towels are placed beneath the patient's head with the towels uppermost. The folded barrier sheet covers the headrest or head portion of the OR bed. One towel is brought around the patient's head on each side to cover all hair, leaving the entire face (and ears, as necessary) exposed; the towel is then secured with nonpenetrating towel clamps. For craniofacial procedures a towel folded lengthwise in quarters may be placed under the head to assist with moving the head from side to side. Two additional towels are then placed diagonally across the neck, just under the chin; they are secured to each other (with nonpenetrating towel clamps) in the middle over the neck and are secured on each side to the towel around the head. A full sheet is then added to cover the patient from neck to feet.
2. After the head portion of the drape is placed, a split, or U, drape is added to cover the patient from neck to feet.

Additional Considerations. Preparation is a key ingredient in success. Having backup supplies or equipment, sometimes as elementary as an extra bulb for the light source, can mean the difference in a positive outcome for the patient. Occasionally, during the course of a procedure, a flap may become

congested and fail, the anatomy may dictate a change in the surgical plan, or perhaps a preselected implant just may not be right. Flexibility, meticulous preparation, and a willingness to improvise and innovate will always serve the perioperative nurse well when working with plastic surgeons.

Evaluation

During the surgical intervention, the perioperative nurse is constantly evaluating the patient's response to nursing interventions, anesthesia, and the surgery itself. Progress or lack of progress toward the identified patient outcomes is continuously assessed. The results of this ongoing evaluation enable the perioperative nurse to reassess the patient, reorder priorities of patient care, establish new patient outcomes, and revise the perioperative plan of care.

At the conclusion of the surgical intervention the perioperative nurse reviews whether identified patient outcomes have been achieved. The patient's skin integrity is assessed; dressings are applied and their integrity is established before discharge from the OR. Any drains or tubes incorporated in the dressing should be noted. Infusion sites are inspected, and the type of infusing solution, flow rate, and amount infused are noted in the patient record. Local anesthetics, sedatives, or other medications received by the patient are similarly documented. The patient's response during the perioperative period is noted; any unusual or untoward responses are reported to the nurse in the recovery unit. The transport vehicle is obtained; any special equipment needed for patient transport is also obtained and checked for proper functioning. Warm blankets may be provided, and the patient is gently moved to the transport vehicle. The patient who is recovering from general anesthesia is placed in a safe position on the vehicle; the awake patient should be assisted to a position of comfort.

The perioperative nurse, in collaboration with the anesthesia provider, should give the hand-off report to the nurse in the postanesthesia care unit (PACU). Areas requiring ongoing patient observation should be noted in this report; the patient's preoperative, intraoperative, and immediate postoperative statuses are also reported. Using the Sample Plan of Care introduced earlier in this chapter, the perioperative nurse may give part of the report based on patient outcomes. If they were achieved, they may be stated as listed under the Outcomes section.

Patient and Family Education and Discharge Planning

Education of the plastic surgery patient begins at the time of consultation. Anxiety inhibits the retention of information; therefore it is always helpful to have written information or other tools for the patient to use as a reference source, beginning with the preoperative instructions as well as postoperative information. The approach to teaching should lend itself to the patient's preferred learning style (e.g., auditory, visual). Specifics that should be addressed include pain management (Surgical Pharmacology), self-care, diet, exercise, care of incisions and drains, return to the clinic for follow-up appointments, signs and symptoms of infections or complications, and how to reach the physician in case of an emergency.

Benefits of an effective education intervention are numerous; it serves to decrease anxiety, improves compliance, reduces the incidence of complications, empowers the patient to become an active participant in his or her own care, and maximizes independence, allowing the patient to more quickly return

SURGICAL PHARMACOLOGY

Postoperative Pain Medications/Administration Options

A discussion about postoperative pain management is an important component of the patient education process. Patients undergoing plastic surgery procedures have several options available for pain control. The perioperative nurse must be familiar with analgesic medications used in the immediate and discharge phases of postanesthesia recovery to provide safe care and appropriate education to the patient.

PATIENT-CONTROLLED ANALGESIA

Depending on the extent and scope of the procedure, patient-controlled analgesia (PCA) may be an effective option in the inpatient setting. PCA is controlled by a special infusion pump that is programmed to administer a calculated intravenous dose of medication when the patient presses a button on the hand control. Opioid analgesics are typically used for PCA.

LOCAL ANESTHETIC INFUSION SYSTEMS

An alternative technique for managing postoperative pain is the continuous instillation of local anesthetic to the surgical site by way of multilumen catheters placed intramuscularly or in the subcutaneous tissue.

As the procedure is ending, the surgeon places the catheters in the surgical wound, exiting through the skin. The catheters are attached to a pump that can contain up to 300 ml of local anesthetic. The surgeon or registered nurse first assistant (RNFA) fills the pump reservoir during the intraoperative phase of care, calculating the volume needed based on the anticipated length of time the pump will be in use and the volume to be administered per dose. Alternatively, the pump may come prefilled from the pharmacy. A tissue adhesive agent may be used at the exit site to prevent leakage of the local anesthetic. The catheters are secured with wound closure strips at the exit site and covered with a transparent, occlusive dressing.

The pump enables a continuous infusion of the local anesthetic agent for the desired number of days (usually 2 to 4). A new option for this technique is a device that offers on-demand delivery of local anesthetic by the patient, which features a protective lockout that prevents overdosage. Plastic surgeons routinely use this technique after submuscular augmentation, abdominoplasty, and breast reconstruction.

NURSING IMPLICATIONS

Refer to Chapter 4 for information relating to local anesthetics. Commonly used agents include bupivacaine (Marcaine, Sensorcaine), levobupivacaine (Chirocaine), ropivacaine (Naropin), and lidocaine (Xylocaine).

SURGICAL PHARMACOLOGY

Postoperative Pain Medications/Administration Options—cont'd

Contraindications for use of the pump include known allergy to local anesthetic, significant kidney or liver disease, insulin-dependent diabetes, a current bacterial infection, or long-term use of local anesthetic. The patient may be sent home with the catheters in place; however, since there is no maintenance once the reservoirs are filled and secured, it is not necessary to use home health nurses. The perioperative nurse should make sure the patient or caregiver has the necessary information to monitor for signs of local anesthetic toxicity: tinnitus, blurred vision, confusion, a metallic taste or numbness of the tongue, or tingling of the fingers or toes. Signs of infection (temperature >38.5° C, warmth or drainage from the catheter insertion site) should also be reviewed. Patients will need the following information: possible need for opioid analgesia for breakthrough pain; driving restrictions; protecting the surgical limb and taking sponge baths instead of showers; and how and when to stop the infusion and how to remove the catheter.

Medication	Dosage	Side Effects	Nursing Implications
Morphine sulfate	Loading dose: 5-10 mg Intermittent bolus: 0.5-3 mg Lockout interval: 5-12 min	◆ Sedation ◆ Hypotension ◆ Nausea	◆ Monitor for respiratory depression. ◆ Initiate deep-breathing and coughing exercises. ◆ Provide instruction to patient on how to operate system.
Demerol (meperidine hydrochloride)	Loading dose: 50-100 mg Intermittent bolus: 5-30 mg Lockout interval: 10-20 min	◆ Vomiting ◆ Dizziness ◆ Diaphoresis ◆ Somnolence	◆ Breakthrough pain may be possible as administration ceases when the patient is asleep. ◆ Monitor patient's response to PCA and treat oversedation per institutional protocol.

Modified from Hodgson BB, Kizior RJ: *Saunders nursing drug handbook 2010,* St Louis, 2010, Saunders; Paul M: Breast augmentation and abdominoplasty: postoperative management with pain pumps, *Aesthet Surg J* 25:69-71, 2005; Banks A: Innovations in postoperative pain management: continuous infusion of local anesthetics, *AORN J* 85(5):904-914, 2007.

to an optimal state of health. The patient's readiness to learn, needs, and styles of learning must be assessed. A teaching plan should be individualized based on the desired outcomes of all parties. The teaching should be implemented with respect to the most effective methods of learning for the individual, taking into account cultural, psychologic, physical, and cognitive limitations.

Older adults need to learn the same material as other patients, such as usual expectations for before, during, and after surgery and during the recovery period. Depending on sensory deficits, the nurse may need to speak slower, more clearly and concisely, allowing time for the patient to respond, absorb the information, and ask questions. It is important to verify the patient's understanding by asking the patient to repeat back the information. The nurse should take cues from the patient and family about how much information they want to know, as some prefer less detail (Clayton, 2008).

Surgical Interventions

Reconstructive Plastic Surgery

Reconstructive plastic surgery seeks to restore or improve function after trauma, disease, infection, congenital anomalies, or acquired defects while trying to approximate an aesthetic appearance.

REMOVAL OF SKIN CANCERS

The estimated number of new skin cancer cases diagnosed in 2009 is 1 million (National Cancer Institute [NCI], 2009). The three most common skin cancers are basal cell, squamous cell, and melanoma (Gutierrez and Peterson, 2007). Basal cells account for approximately 70% of all skin cancers (Figure 21-6, *A*). If basal cell cancer is left untreated, it will grow locally, but rarely metastasizes (Box 21-1). Treated early, it may be cured by simple excision and closure (with pathologic diagnosis to ensure disease-free margins). Squamous cell skin cancers are considered more aggressive (Figure 21-6, *B*). Surgical treatment is the same as that for basal cell carcinomas. Melanoma accounts for the smallest percentage of skin cancers (5%), but it is treated much more aggressively because of its high mortality rate, comprising 75% of skin cancer deaths (Sladden et al, 2009) (Figure 21-6, *C*). Excision of melanoma may involve sentinel node mapping and excision. Early diagnosis of melanoma is imperative to successful treatment (Evidence for Practice). A Cochrane Database Systematic Review is underway (Sladden et al, 2009) since various international organizations varied in their recommendations regarding optimal excision margins. Excision margins that are too narrow may result in higher local recurrence rates and/or mortality; wider excisions may increase hospital length of stay and require costlier procedures such as skin grafting and anesthesia.

Procedural Considerations

Consideration must be given to the type of skin cancer to be excised and the anticipated closure technique. Simple excision and closure with adjacent tissue will be the simplest technique, requiring a local plastic tray accompanied by skin markers and the electrosurgical unit (ESU), and usually involving use of a local anesthetic with epinephrine. A simple excision may be performed with the patient administered a local or general anesthetic or after induction of sedation. If additional procedures will be performed (e.g., reconstruction with skin graft, flap, or sentinel node mapping), refer to those sections for additional procedural considerations.

Operative Procedure—Simple Excision

1. The site is prepped and draped.
2. The surgeon infiltrates the site with a local anesthetic.
3. The lesion is curetted or excised and may be sent for frozen section or pathologic diagnosis.

4. Hemostasis is obtained.
5. The surgeon closes the wound if necessary.

Mohs' Surgery

Mohs' surgery is a specialized excision used to treat basal and squamous cell skin cancers. The procedure involves excising the lesion layer by layer and examining each layer under the microscope until all the abnormal tissue is removed.

Procedural Considerations. Mohs' surgery is usually completed on an ambulatory basis with the patient administered a local anesthetic. The procedure can be very time-consuming to accomplish, but it typically results in the preservation of the surrounding healthy tissue. Because the procedure is lengthy, patient preparation and comfort are essential to facilitate cooperation during the procedure. A minor plastic surgery set is required, along with fine (5-0 or 6-0) suture material.

BOX 21-1

Important Trends for Skin Cancer

INCIDENCE
Approximately 1 million cases per year with the majority being the highly curable basal or squamous cell cancers, accounting for more than 50% of all cancers; not as common is the most serious malignant melanoma, with an estimated 68,720 cases per year.

MORTALITY
Total estimated deaths for 2009 were 8650 from malignant melanoma and 11,590 from other skin cancers.

RISK FACTORS
- Excessive exposure to ultraviolet radiation from the sun
- Fair complexion
- Occupational exposure to coal tar, pitch, creosote, arsenic compounds, and radium
- Exposure to human papillomavirus and human immunodeficiency virus
- Skin cancer negligible in African Americans because of heavy skin pigmentation

WARNING SIGNALS
Any unusual skin conditions, especially a change in the size or color of a mole or other darkly pigmented growth or spot.

PREVENTION AND EARLY DETECTION
Avoid sun when ultraviolet light is strongest (e.g., 10:00 AM to 3:00 PM); use sunscreen preparations, especially those containing ingredients such as *para*-aminobenzoic acid (PABA). Basal and squamous cell cancers often form a pale, waxlike, pearly nodule or a red, scaly, sharply outlined patch; melanomas are usually dark brown or black pigmentation; they start as small molelike growths that increase in size, change color, become ulcerated, and bleed easily from a slight injury.

TREATMENT
The four methods of treatment are surgery, electrodesiccation (tissue destruction by heat), radiation therapy, and cryosurgery (tissue destruction by freezing). For malignant melanomas, wide and often deep excisions and removal of nearby lymph nodes are required.

SURVIVAL
For basal cell and squamous cell cancers, cure is virtually ensured with early detection and treatment. Malignant melanoma, however, metastasizes quickly; this accounts for a lower 5-year survival rate for Caucasian patients with this disease.

Modified from American Cancer Society (ACS): *Cancer facts and figures 2009,* Atlanta, 2009, The Society; Huether SE: Structure, function, and disorders of the integument. In Huether SE, McCance KL: *Understanding pathology,* ed 4, St Louis, 2008, Mosby.

EVIDENCE FOR PRACTICE

Melanoma Awareness, Prevention, and Detection

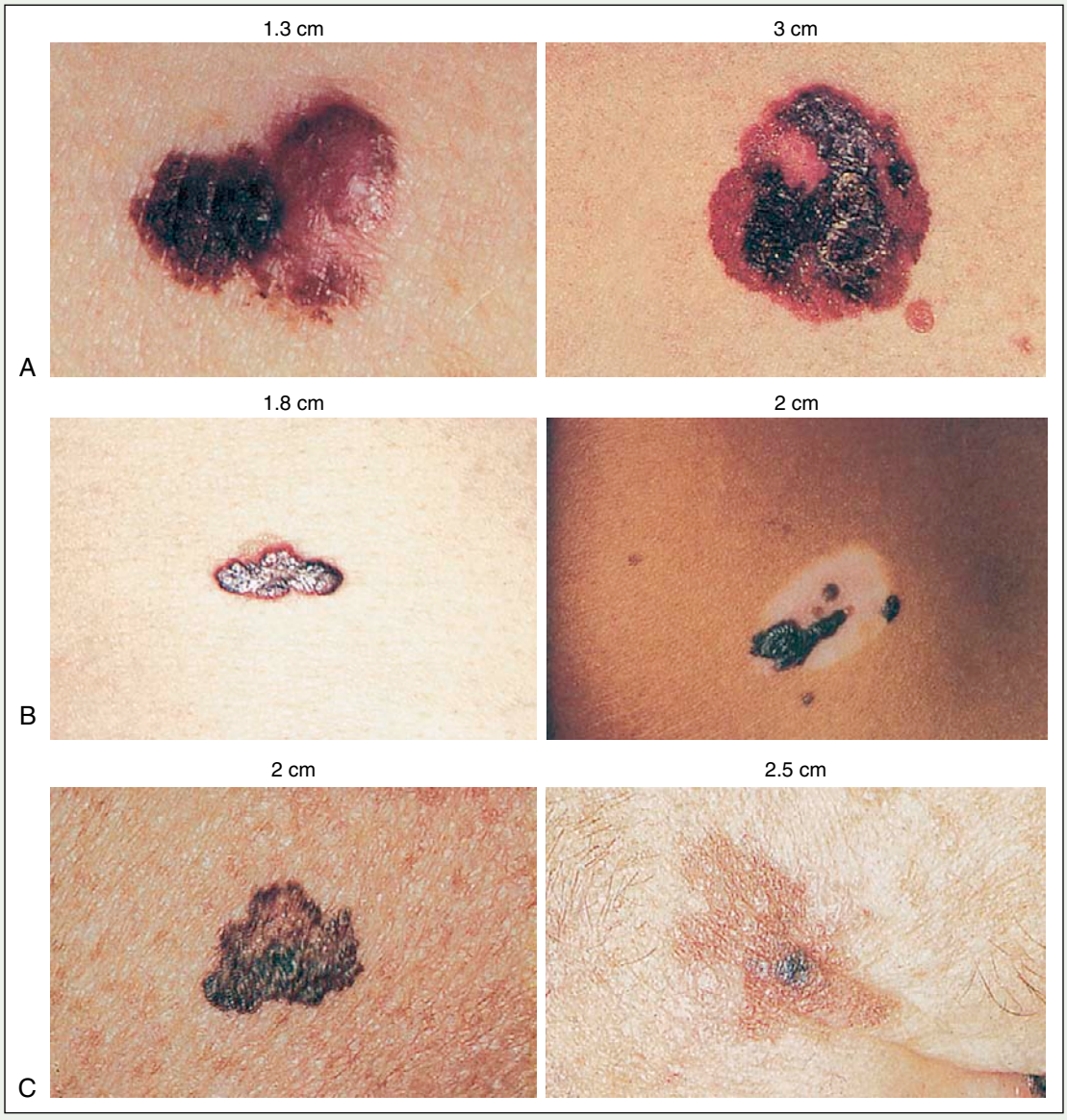
It is estimated that more than 68,720 men and women will be diagnosed with melanoma in 2009, according to the American Cancer Society. In the most recent time period, rapid increases have occurred among young white women (3.8% annual increase since 1995 in those aged 15 to 34 years) and older white men (8.8% annual increase since 2003 in those 65 and older). Although the exact cause of developing a melanoma is not known, certain risk factors have been identified:
- **Ultraviolet (UV) radiation:** sunlight, tanning beds
- **Moles:** more than 50 = greater risk
- **Fair skin:** fair skin, freckling, red or blond hair
- **Family history:** 10% have a relative with melanoma
- **Immune system compromise:** taking antirejection medications after organ transplantation surgery
- **Age:** increased risk in older adults
- **Gender:** men more than women
- **Previous melanoma:** increased risk for having another melanoma

PREVENTION
Limit UV radiation exposure:
1. Wear protective clothing (tight weave) and a hat with a broad brim.
2. Shade is good—avoid too much sunlight; remember that it reflects off water, sand, concrete, and snow.
3. Use sunscreen—SPF 15 or higher; apply 20 to 30 minutes before sun exposure; reapply every 2 hours; protect your lips.
4. Do not forget your eyes—look for sunglasses with 99% UV absorption.
5. Stay away from tanning beds and lamps—more UV exposure; try using self-tanning lotions.
6. Children need sunscreen—their skin is fragile; most damage to skin is acquired before the age of 18 years.
7. Take an inventory—know your moles and what they normally look like so you can detect changes if and when they occur.

KNOW YOUR A-B-C-Ds
A: Asymmetry—one half of the lesion looks different from the other side.
B: Border irregularity—instead of a smooth edge, the border is ragged or irregular.
C: Color—the color is usually irregular as well; may have a number of different hues and colors.
D: Diameter—lesions larger than 6 mm have a greater chance of being a melanoma.

EVIDENCE FOR PRACTICE

Melanoma Awareness, Prevention, and Detection—cont'd



Malignant melanomas. Note presence of "ABCDE" characteristics (*a*symmetry, irregular *b*order, variation in *c*olor, *d*iameter >6 mm, *e*nlargement and *e*levation). **A**, Superficial spreading melanoma. **B**, Nodular melanoma. **C**, Lentigo malignant melanoma.

Modified from American Cancer Society (ACS): *Cancer facts and figures 2009,* Atlanta, 2009, The Society.

Operative Procedure. Current procedures involve removal of all visible portions of the skin cancer lesion. A horizontal layer of tissue is removed and divided into sections that are color-coded with dyes. A map of the surgical site is then drawn. Frozen sections are immediately prepared and examined microscopically for any remaining tumor. If tumor is found, the location or locations are noted on the map and another layer of tissue is resected. The procedure is repeated as many times as necessary to completely remove the tumor.

BURN SURGERY

A majority of burns result from exposure to high temperatures, which injures the skin. Flame, scalding, or direct contact with a hot object may cause thermal skin injury. Similar destruction of skin can result from contact with chemicals such as acid or alkali or contact with an electrical current. The latter, however, often involves extensive destruction of the underlying tissue and physiologic systems in addition to the skin. A 2007 fact sheet on burn statistics includes the following information:

FIGURE 21-6 **A**, Basal cell carcinoma. **B**, Squamous cell carcinoma. **C**, Melanoma.

approximately 500,000 burn injuries receive medical treatment yearly; 40,000 patients are hospitalized in the United States for burn injuries, with 25,000 of those admitted to the 125 hospitals with specialized burn centers (American Burn Association [ABA], 2007).

Intact skin provides protection against the environment for all underlying tissues and organs. It aids in heat regulation, prevents water loss, and is the major barrier against bacterial invasion. The tissue injury resulting from a burn disrupts this normal protective function, resulting in local and systemic effects (Box 21-2). Burn patients are therefore some of the most acutely ill patients brought to the OR. The greater the degree of injury to the skin, expressed in percentage of total body surface area (BSA) and depth of burn, the more severe the injury. One method of measuring BSA in adults is by use of the rule of nines (Song et al, 2007) (Figure 21-7).

Partial-thickness (first- and second-degree) burns heal by regeneration of skin from dermal elements that remain intact. First-degree burns involve the epidermis, which appears pink or red; sunburn is usually a first-degree burn. Second-degree burns, also called partial-thickness burns, involve the epidermis and some of the dermis. Full-thickness (third-degree) burns (Figure 21-8) involve the epidermis, the entire dermis, and the subcutaneous tissues; they require skin grafting to heal because no dermal elements remain intact. Both partial- and full-thickness burns may require debridement of necrotic tissue (eschar) before healing can occur by skin regeneration or grafting. An allograft may be used to cover the burned area during the initial healing process. However, the allograft must be carefully tested for immunodeficiency diseases. A xenograft (e.g., pig skin) may also be used for covering the burned area.

SURGICAL PHARMACOLOGY

Topical Medications Used in Burn Therapy

Agent	Indication	Implications
Petroleum-based antimicrobials (bacitracin, Neosporin, polymyxin B)	Partial-thickness burns	Provides barrier protection to wound. Has mild antimicrobial activity. Cleaning wound before applying prevents caking. Maintain layer adequate to keep wound from drying.
Silver sulfadiazine (Silvadene)	Deep partial to full-thickness burns Wound infection	Has broad-spectrum antimicrobial action against gram-negative bacteria, gram-positive bacteria, and *Candida* organisms. Penetrates eschar to inhibit bacterial growth at dermis-eschar interface. Soothes pain with ¼-inch layer applied directly to wound or on impregnated gauze applied 2-3 times daily. May cause slimy, grayish appearance with repeated applications. Inhibits epithelial tissue development. Discontinued when eschar no longer present. Side or toxic effects include skin rash on unburned tissues, transient decrease in WBCs for 24-48 hr after application. Contraindicated in patients with sulfa hypersensitivities.
Mafenide acetate (Sulfamylon)	Deep partial to full-thickness burns Wound infection	Is bacteriostatic against gram-negative and gram-positive bacteria. Is applied in ¼-inch layer directly to wound or on impregnated gauze 2-3 times daily. 11.1% cream: penetrates thick eschar and cartilage; inhibits epithelial tissue development. 5% solution: antimicrobial solution used to prevent and treat wound infections. Discontinued when eschar no longer present. Side or toxic effects include pain on application (may necessitate pain management), metabolic acidosis (when applied to more than 40% total body surface area), hypersensitivity rash, pruritus, fungal growth.
Silver nitrate (5% solution)	Deep partial to full-thickness burns Wound infection	Is bacteriostatic against gram-negative and gram-positive bacteria. Has poor penetration of eschar. Side or toxic effects include staining of the wound black (making assessment difficult), pain on application (may necessitate pain management), staining of clothing and linens, decreases in electrolytes (sodium, potassium, calcium, chloride).

Modified from Green-Nigro CJ: Burns. In Monahan F et al, editors: *Phipps medical-surgical nursing,* ed 8, St Louis, 2007, Mosby.

Procedural Considerations

The essentials of skin grafting are discussed under Skin and Tissue Grafting. This section therefore deals only with the procedure for debridement of burn wounds.

A basic plastic instrument set is required, plus a knife dermatome, an ESU, topical thrombin solution, a pneumatic tourniquet for isolated extremity burns, and a topical antimicrobial agent of choice.

Because patients who have sustained burns are vulnerable to hypothermia from the loss of body surface area (BSA), the perioperative nurse should ensure the temperature and humidity in the OR are increased and exposure is limited only to the areas related to the planned surgical event. Anesthesia is often induced while the patient is on the burn unit bed; transfer to the OR bed is done carefully and gently, with attention to maintaining the airway. Most burn patients arrive in the OR with dressings covering their wounds. The dressings are removed after the patient has been anesthetized to minimize pain and loss of body heat through the open burn wounds. Throughout the procedure, the temperature in the OR is constantly monitored to prevent hypothermia. The OR team caring for burn patients coordinates activities to prevent any delays in obtaining required equipment or supplies. The perioperative nurse will need to collaborate with the anesthesia provider in determining fluid replacement requirements. A variety of topical agents are used to dress wounds. Perioperative nurses must be familiar with these agents and their uses (Surgical Pharmacology).

Operative Procedure

1. The surgeon excises all nonviable tissue down to underlying muscle fascia.
2. An alternative method is tangential excision of the burn wound, which is performed with a knife dermatome. This type of excision is usually carried down only to the bleeding subcutaneous fat, rather than to fascia.
3. Hemostasis is obtained with the ESU or use of topical thrombin solution.
4. Dressings saturated with the topical antimicrobial agent of choice are applied.

Although skin grafting may be done at the time of wound debridement, it is usually performed several days later, particularly in burns that are extensive.

BOX 21-2

Pathophysiology of Burn Injuries

Thermal and chemical injuries disrupt the normal protective function of the skin, causing local and systemic effects. The extent of these effects depends on the type, duration, and intensity of exposure to the causative agent. With electrical burns, heat is generated as the electrical current passes through body tissues, causing thermal burns along the path taken by the current. Local damage is marked by histamine release and severe vasoconstriction, followed in a few hours by vasodilation and increased capillary permeability, which allows plasma to escape into the wound. Damaged cells swell and platelets and leukocytes aggregate, causing thrombotic ischemia and escalating tissue damage. Systemic effects, which are caused by vascular changes and tissue loss, include hypovolemia, hyperventilation, increased blood viscosity, and suppression of the immune system. The severity of the burn determines the extent of local and systemic effects. Severity is judged by the depth of the burn and the quantity of tissue involved. The depth of the burn is classified by degree. First-degree (superficial) burns affect the epidermis only; second-degree burns (split thickness) affect the epidermis and dermis; third-degree burns (full thickness) affect all skin layers and extend to subcutaneous tissue, muscle, and nerves; fourth-degree burns involve all skin layers, plus bone. The percentage of body surface area (BSA) system of the American Burn Association classifies quantity as follows:

- Minor burn: full-thickness burns over less than 2% of BSA; partial-thickness burns over less than 15% of BSA
- Moderate burns: full-thickness burns over 2% to 10% of BSA; partial-thickness burns over less than 15% to 25% of BSA
- Major burns: full-thickness burns over 10% or more of BSA; partial-thickness burns over 25% or more of BSA; any burn to face, head, hands, feet, or perineum; inhalation and electrical burns; burns complicated by trauma or other disease processes

From Langford RW, Thompson JD: *Mosby's handbook of diseases,* ed 3, St Louis, 2005, Mosby.

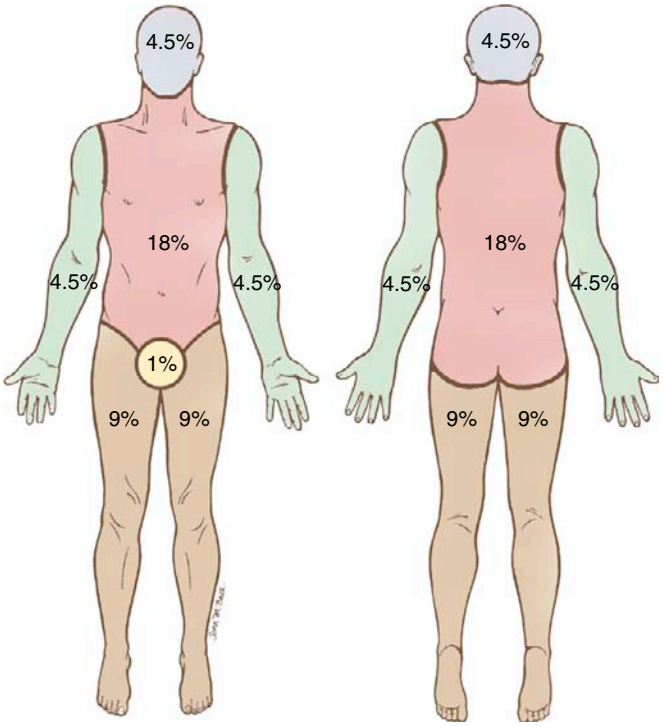


FIGURE 21-7 The "rule of nines." The amount of skin surface burned in an adult can be estimated by dividing the body into 11 areas of 9% each.

FIGURE 21-8 Full-thickness thermal injury.

EXCISIONAL DEBRIDEMENT

Excisional debridement is the act of removing dead or devitalized tissue to promote healing. Plastic surgeons use debridement in conjunction with treatment of injuries, trauma, and infection. Additional information on wound debridement may be found in Chapter 8.

TREATMENT OF PRESSURE ULCERS

Pressure ulcers result from prolonged compression of soft tissues overlying bony prominences (Figure 21-9). However, whether excessive pressure is sufficient to create an ulcer depends on the intensity and duration of the pressure as well as on tissue tolerance. Factors that contribute to pressure ulcer development are immobility, sensory and motor deficits, reduced circulation, anemia, edema, infection, moisture, shearing force, friction, and nutritional debilitation (Cuzzell and Workman, 2010). The most common sites of pressure ulcers are the sacrum, the ischium, the trochanter, the malleolus, and the heel; these are called decubitus ulcers. These ulcers are different from chronic ulcers such as vascular, diabetic, and neurogenic ulcers. Surgical interventions for pressure ulcers are usually based on ulcer staging (also referred to as *grading*). In stage I the ulcer involves the epidermis and has soft tissue swelling that is irregular and ill-defined; heat and erythema at the ulcer site are characteristic. A stage II ulcer involves the epidermis and dermis but not the subcutaneous fat. Stage III ulcers show full-thickness skin loss with injury to underlying tissue layers and may contain necrotic material. Thorough excisional debridement is performed, and IV antibiotic therapy is instituted. Although debrided stage III ulcers often heal on their own, surgical excision and closure may be done to prevent a lengthy spontaneous closure, which may result in a weak, unstable scar with resultant recurrence. Stage IV ulcers are the deepest, requiring more radical excisional debridement. Adequate soft tissue cover may be obtained by either split-thickness or full-thickness skin grafting or tissue flaps (Figure 21-10). Tissue expansion may be used when

there is not enough tissue adjacent to the ulcer site to provide flap coverage.

The use of a CO_2 laser minimizes blood loss and possibly reduces infection rates in the presence of gross contamination. Although many techniques and flaps are surgical options, basic principles apply to all pressure ulcer closure procedures. The following procedure is for an adjacent flap.

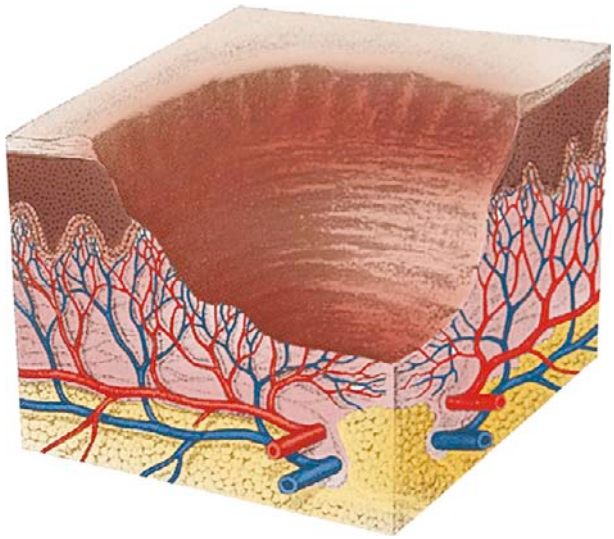


FIGURE 21-9 Pressure ulcers often appear after blood flow to an area slows or is obstructed because of pressure on bony prominences. Infections often follow, since lack of blood flow causes tissue damage or death.

Procedural Considerations

A basic plastic instrument set is required, as well as assorted sizes of osteotomes (straight and curved), a mallet, the Gigli saw and handle, assorted curettes, a Key periosteal elevator, a duckbill rongeur, bone wax, the dermatome of choice, the ESU, a sterile marking pen, and a closed-wound drainage system. The patient is positioned and draped so that the pressure ulcer, adjacent flap donor site, and skin graft donor site are well exposed.

Operative Procedure

1. The area to be excised and the local flap are outlined.
2. The surgeon excises the ulcer along with the underlying bony prominence.
3. Large suction catheters are placed into the defect left by excision of the ulcer and beneath the flap.
4. The flap is sutured in place.
5. A split-thickness skin graft generally is used to resurface the flap donor site.
6. A stent dressing is placed over the skin graft, and gauze dressings or a plastic spray dressing is applied over the suture lines of the flap.

DIABETIC FOOT CONDITIONS

In the past decade, the incidence of diabetes and concomitant severe foot infections has risen significantly. The severity of these infections is conveyed by diagnoses and sequelae (e.g., necrotizing fasciitis, gas gangrene, ascending cellulitis,

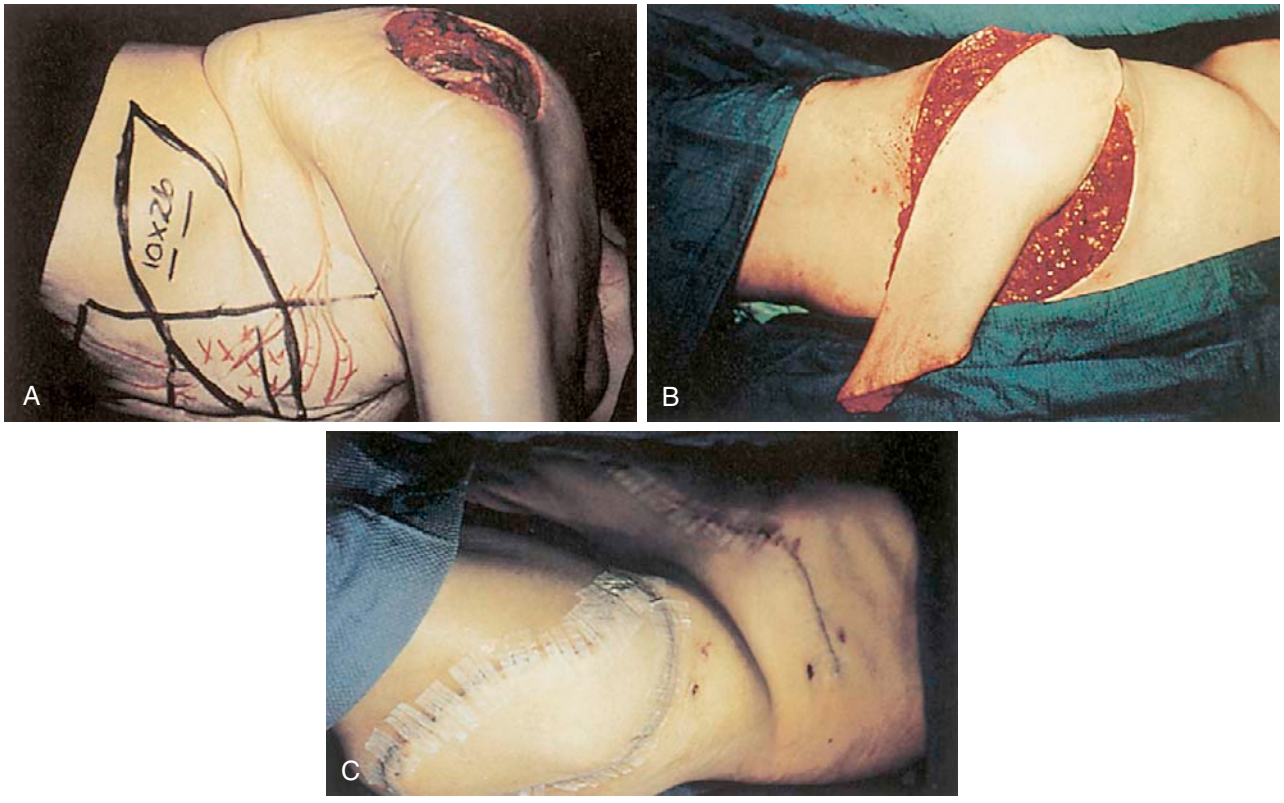


FIGURE 21-10 **A**, Rotational flap from abdomen for pressure sore coverage. **B**, Placement of flap. **C**, Completed coverage with flap placement.

and infection with systemic toxicity or metabolic instability). Because patients with diabetes mellitus may have peripheral neuropathies, they may not feel and therefore not notice any tenderness or early signs of infection. These foot infections can lead to hospitalization and eventual lower extremity amputation for patients with preexisting ulcerations; surgical management is often required for the severe infections. The experienced surgeon determines when and how to intervene. Main principles for management include stabilization of the patient; adequate debridement along with antibiotic therapy; vascular evaluation and revascularization as necessary; delayed soft tissue reconstruction; and postoperative information and intervention for medical and surgical issues. In addressing all these aspects, the surgeon optimizes the possibility for limb salvage. This overview serves as a reminder to emphasize the importance of overall adherence in managing diabetes mellitus to prevent further complications (Zgonis et al, 2008a).

These complex patients are best handled with multidisciplinary consultations to coordinate care and determine optimal timing for soft tissue reconstruction. Primary closure may not be an option and secondary healing is not necessarily reliable. The proactive surgical approach aims to salvage the diabetic limb by improving overall health and to provide a stable, mechanically sound limb that will resist further breakdown once the patient is able to walk again. To prevent complications, patients need ongoing support and validation. Hospital care focuses on dressing changes, wound care, physical therapy, limb position, shower privileges, and laboratory testing. Postoperative nursing care should provide instruction for follow-up and frequency of monitoring of the surgical results, ambulatory status, work and social restrictions, and bathing. Especially important for the perioperative nurse to review with the patient are identification of infection and ways of contacting the surgical team if problems arise (Zgonis et al, 2008b).

SKIN AND TISSUE GRAFTING

Skin grafting provides an effective way to cover a wound if vascularity is adequate, infection is absent, and hemostasis is achieved. Skin from the donor site is detached from its blood supply and placed in the recipient site, where it develops a new blood supply from the base of the wound. Color match, contour, and durability of the graft are all considerations in selection of an appropriate donor area. Other types of grafts that are available for surgical reconstruction include bone, cartilage, nerve, tendon, and autologous fat grafts.

Split-Thickness and Full-Thickness Skin Grafts

Skin grafts can be either split-thickness (STSGs) or full-thickness grafts (FTSGs) (Figure 21-11). A split-thickness (or partial-thickness) skin graft contains epidermis and only a portion of the dermis of the donor site; it varies from a thin graft to a thick graft. Although this type of graft becomes vascularized more rapidly and the donor site heals more rapidly than a full-thickness graft, it may exhibit postgraft contraction, be minimally resistant to surface trauma, and be least like normal skin in texture, suppleness, pore pattern, hair growth, and other characteristics. A split-thickness skin graft may be meshed (Figure 21-12); meshed grafts can expand to many times their original size. Meshing allows the graft to be placed on an irregular recipient area; however, its appearance may be aesthetically undesirable. A full-thickness skin graft contains both epidermis and dermis; any remaining subcutaneous tissue is trimmed before the FTSG is applied to the graft site. The advantages of this type of graft are that it causes minimal contracture, can be used in areas of flexion, has a greater ability to

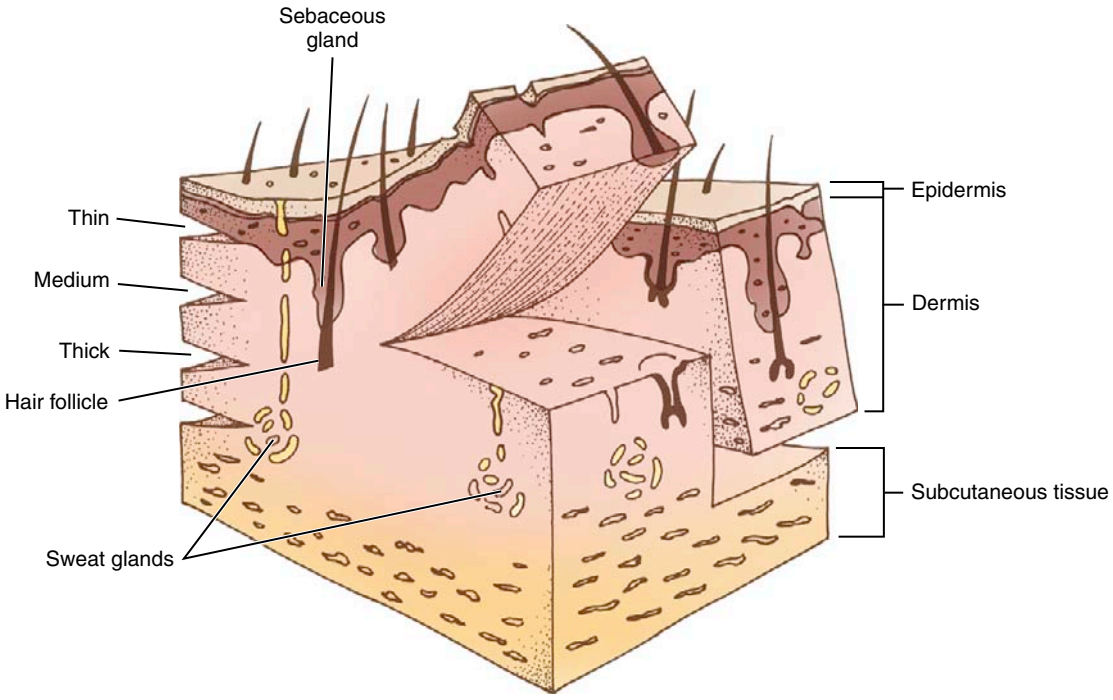


FIGURE 21-11 Split-thickness and full-thickness skin grafts.

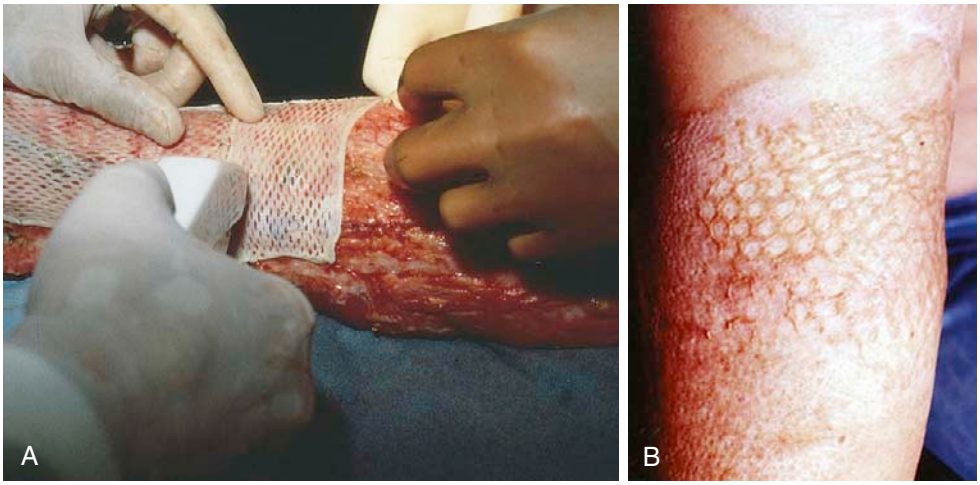


FIGURE 21-12 **A**, Split-thickness skin is meshed and used to cover a marginal wound. Minimal expansion is used, and the holes provide drainage. **B**, Appearance of the graft after healing.

withstand trauma, can add tissue where a loss has occurred or where padding is required, and is aesthetically more acceptable than an STSG. The donor site can be closed primarily, leaving a minimal defect.

The donor site for an STSG heals by regeneration of epithelium from dermal elements that remain intact. Thus only a dressing is placed over this donor site. Because no dermal elements remain when an FTSG is taken, this donor site does not heal spontaneously. It heals either when the wound edges of the donor site are sutured together (primary closure) or when an STSG is applied over it. A scar remains at the donor site of a skin graft; therefore donor sites that are covered by clothing are generally chosen.

For a graft to survive, the vascularity of the recipient area must be adequate, contact between the graft and recipient bed must be maintained, and the graft-bed unit must be adequately immobilized.

Color, temperature, signs of infection, blanching of the skin, excessive pain and discomfort, edema, vasoconstriction, and venous congestion should be noted and any change reported to the surgeon.

Any changes should be documented. If the patient is discharged to home after surgery, patient and family education should include reportable signs and symptoms of potential complications.

A stent or tie-over dressing is often placed over a skin graft (Figure 21-13). This exerts even pressure, ensuring good contact between graft and recipient site. It also eliminates potential shearing forces at the graft and recipient site interface that might disrupt new blood vessels growing into the graft.

Procedural Considerations. A plastic local instrument set is required, with the addition of a dermatome of choice, a skin mesher, and sterile marking pen. The patient is positioned so that both donor and recipient sites are well exposed. Both areas are prepped and draped to maintain adequate exposure and mobility, as required.

Operative Procedure

1. The recipient site is prepared as necessary. This step may involve excision of a benign or malignant skin tumor, debridement of an open wound, or release of a scar contracture.

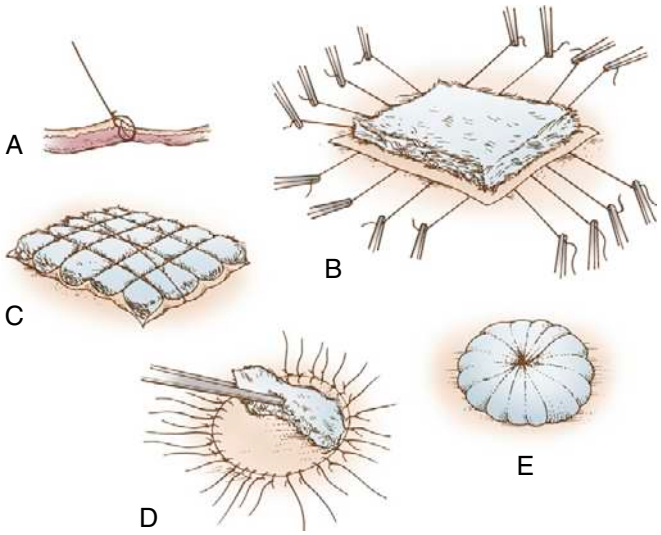


FIGURE 21-13 **A**, Method of fixation of skin graft to edges of wound. **B**, Nonadherent dressing is applied over skin graft, on top of which is placed a generous pad of acrylic fiber. **C**, Long ends of suture are tied over fiber to produce area of pressure between graft and base. **D**, Similar dressing is applied to circular graft. **E**, Long suture ends are tied over circular graft (often called *stent dressing*).

2. Careful planning and marking before harvesting the graft from the recipient site are essential. Patterns matching intended recipient site and the donor site are outlined with a sterile marking pen.
3. STSGs are harvested with a knife dermatome or powered dermatome of the surgeon's choice (Figure 21-14).
4. Moist sponges soaked in normal saline, an antibiotic solution, or a solution of 20 mg of phenylephrine HCl (Neo-Synephrine) per 1000 ml of normal saline may be applied to the donor sites to aid hemostasis. Medication labels indicating strength are placed on all solutions, including Neo-Synephrine, to further identify all solutions on the sterile field. These sponges are removed, and the donor site is covered with Biobrane or OpSite.
5. If the graft is to be meshed, it is now applied to specifically supplied carriers for use with certain skin meshers.

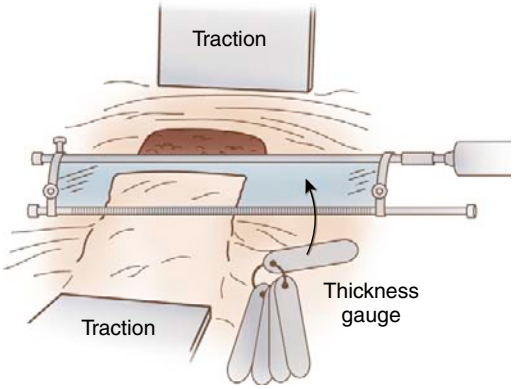


FIGURE 21-14 Harvesting a split-thickness skin graft (STSG) with the Humby knife.

6. A graft that is not immediately applied to the recipient site dries quickly, particularly a meshed graft. The surgical technologist should ensure that the graft is kept on the carrier and covered with moist gauze sponges to prevent inadvertent loss of the graft. Meshed skin should not be removed from its carrier until it is applied directly to the recipient site. Whether applied as a sheet or meshed, the STSG may be sutured or stapled with a skin stapler. Nonadherent gauze is usually applied as the first layer of dressing over a graft. Moist dressings should be applied to all meshed grafts to prevent desiccation and loss of the graft.
7. Fat adherent to the graft is trimmed. The graft is applied to the recipient site and usually sutured at the edges, and these sutures are left long to tie over a stent dressing. Blood clots beneath the graft are removed by saline irrigation before the dressing is applied.

Composite Graft

Composite grafts are composed of skin and underlying tissues that are completely separated from the blood supply of the donor site and transplanted to another area of the body. The survival of a composite graft depends on ingrowth of new blood vessels from the recipient site around the periphery of the graft. Therefore composite grafts are usually small so that no portion of the graft is more than 1 cm from its periphery. An example of compound tissues used as composite grafts is hair transplants, composed of skin, fat, and hair follicles, which are used to treat male pattern baldness. The term *composite* thus indicates a defect that requires a graft be transferred to the area to meet more than one type of tissue deficiency.

Procedural Considerations.

A plastic local instrument set is required, plus a sterile marking pen. The patient is positioned, prepped, and draped such that adequate exposure of both donor and recipient sites is achieved.

Operative Procedure

1. The recipient site is prepared by excising tissue, such as a scar or a benign or malignant skin lesion.
2. When feasible, the surgeon makes a pattern of the recipient site and transfers it to the donor site.
3. The surgeon excises the composite graft. The donor site is either closed by approximating its skin edges or left unsutured (as in hair transplant donor sites).
4. Meanwhile, the composite graft is kept in a moist sponge until it is sutured to the edges of the recipient site.
5. Dressings of choice are applied to the composite graft and donor site.

Replacement of Lost or Absent Tissue

When coverage for a defect cannot be achieved through skin grafting, plastic surgeons rely on other techniques to replace tissue. Just as the flap has evolved, other techniques for tissue restoration through biologic engineering have also evolved. Four principal avenues have been explored to make new tissues for biologic replacement: the injection of isolated cell populations, the placement of polymer scaffolds to guide tissue regeneration, the development of encapsulated systems, and the transplantation of cells in polymer matrices (Marler and Upton, 2006). A discussion of flap techniques follows.

Flaps

The term *flap* refers to tissue that is detached from one area of the body and transferred to the recipient area with either part or all of its original blood supply intact. In a free flap the flap is detached from one part of the body with its vascular pedicle and then reestablished by reanastomosis with the recipient vascular system; thus it has a self-contained vascular system. The base or pedicle of the flap is that portion through which the blood supply enters or exits. Because flaps carry their own blood supply, they generally are used to cover recipient sites that have poor vascularity and full-thickness tissue loss. Flaps are used for reconstruction or wound closure. They are useful for covering exposed bone, tendon, or nerve. They may be used if surgery through the wound may be necessary at a later date to repair underlying structures. Flaps containing skin and subcutaneous tissue retain more properties of normal skin and shrink less than skin grafts. Flaps, however, have some disadvantages, such as bulky appearance, failure to match tissue of the recipient site in texture or color, and the possibility of requiring multiple operations and prolonged hospitalization.

Flaps may be classified according to blood supply. *Random pattern flaps* consist of skin and subcutaneous tissue vascularized by random perforators with limited length/width ratio. *Axial pattern flaps* have a well-defined arteriovenous supply along the long axis; they can be comparatively long in relation to width. Flaps may also be classified according to position or how they are rotated after elevation. *Advancement flaps* are cut and advanced to reconstruct a nearby defect. *Transposition flaps* are advanced along an axis that forms an angle to the flap's original position. *Rotation flaps* are similar to transposition flaps but are semicircular and rotate along a greater axis. *Island flaps* of isolated sections of skin and subcutaneous tissue are tunneled beneath the skin to new sites. *Pedicle flaps* were the forerunners of muscle and musculocutaneous flaps. These consist of skin and underlying muscle; they are very mobile and can be rotated into distant defects. *Free flaps* are actually a form of tissue transplantation. Using microvascular techniques, a defined amount of skin, muscle, or bone can be isolated, totally detached, and reattached at the recipient site by microvascular anastomoses between recipient site blood vessels and the major vessels that supply the flap. The vascular pedicle may contain functional nerves, yielding sensory flaps to provide protective

sensation or motor flaps to restore function. Bone and joints may be transplanted as free flaps, as in the case of toe-to-thumb site transfers.

Procedural Considerations. The perioperative nurse should consult with the surgeon in advance of the procedure to determine the donor site, the patient's position(s), and the surgical sequence of the procedure. Generally the surgical site and flap area are marked preoperatively with the patient in a functional position because landmarks and aesthetics are influenced by surgical positioning. If marking is undertaken on the anesthetized and surgically positioned patient, inaccuracies in tissue placement could occur. Flap procedures may involve two teams of surgeons working simultaneously: one raising the flap and closing the resulting defect, and the other preparing the site, repositioning the flap in its new site, and, in the case of a free flap, microscopically reanastomosing the blood vessels. For any lengthy procedure, a Foley catheter, sequential compression devices, warming units, and positioning aids that are safe for the skin will be needed. Skin grafts are sometimes used to achieve closure of the flap donor site; if this is anticipated then the nurse and surgical technologist should add appropriate instrumentation for harvesting a skin graft.

A basic plastic instrument set is required, plus the following:

- ESU
- Sterile marking pen
- Extra hemostats
- Dermatome of choice
- Skin mesher
- Microvascular instruments (as appropriate)

Operative Procedure—Advancement, Transpositional, Rotational, Island, and Pedicle Flaps

1. The recipient site is prepared in the same manner as for a skin graft.
2. Patterns matching the recipient and donor sites are drawn/marked.
3. The surgeon incises, elevates, and transfers the flap to the recipient site.
4. The edges of the flap are sutured to the periphery of the recipient site.
5. The flap donor site is repaired by approximating the skin edges directly or by covering the defect with a skin graft or another flap.
6. Drains are usually placed under flaps.
7. Dressings are applied with particular attention given to immobilization of the flap, which may require a stockinette, padding, or plaster of paris.
8. NOTE: Before a pedicle flap is detached from the donor site, the surgeon may want to determine the adequacy of circulation within the flap. One method to check circulation involves placing rubber-shod clamps across the base of the pedicle and injecting sodium fluorescein intravenously. After 10 minutes have elapsed, all lights in the OR are turned off and a Wood's lamp is held over the flap to determine the presence or absence of fluorescence within the flap. Fluorescein may be injected locally for the same purpose.

Operative Procedure—Free Flaps. See Operative Procedure for free TRAM flap described under Reconstructive Breast Surgery.

RECONSTRUCTIVE BREAST SURGERY

The loss of a breast because of cancer may have a devastating effect on a woman. Fortunately, the option of breast reconstruction is available to virtually any woman who loses her breast to cancer (ASPS, 2009c). Reconstruction has the ability to offer hope and a return to wholeness and normalcy. Normal, of course, is subjective, and although breasts may be reconstructed, there is a wide range of outcomes, and it must be stressed that breast reconstruction is not a one-time surgery. Revisions are the rule and not the exception. Techniques and options continue to evolve and improve, and women have many options. Breast reconstruction may be offered at one of many times during this process—initially, at the time of mastectomy; before or after adjunct therapy; or even many years later. The important fact is that each woman and her oncologic status are individual, so the decision for reconstruction must be made according to the woman's wishes coupled with her most favorable circumstances. Reconstruction has no known effect on the recurrence of breast cancer (ACS, 2009). Breast reconstruction options include alloplastic (artificial materials), autogenous (flaps), or a combination of both. Flaps may be pedicle-based or free flaps, requiring microsurgical techniques for their reconstruction.

Breast Reconstruction Using Tissue Expanders

Mastectomy may leave a shortage of skin that prevents creation of a breast mound. For these patients, extra tissue can be created locally with the use of tissue expanders (Figure 21-15). Tissue expansion is a technique used to stretch normal tissue that is adjacent to a defect, mechanically creating redundancy of normal tissue to correct the defect. For breast reconstruction, the expander resembles the shape of a breast prosthesis. The expander has a metal-backed, self-sealing silicone valve at its dome. Another type of expander used less frequently has a small, dome-shaped reservoir with a fill tube that is positioned subcutaneously at a distance from the expander but connected to it. Following surgery, the tissue expander is gradually filled with percutaneous injections of normal saline during routine office visits. The expander may be filled as often as weekly, or it may remain unused until chemotherapy or radiation is completed. Once the tissue expander is filled to the appropriate volume, it may be removed and replaced with a permanent reconstructive mammary prosthesis, either saline or silicone, as an ambulatory surgical procedure. Silicone can be used for breast augmentation for patients older than 21 years. If silicone is chosen, both the surgeon and the patient must participate in an adjunct clinical study at this time; the patient may opt out. Another option is the use of combination tissue expander and breast prosthesis, which remains in place once the desired amount of saline has been sequentially added. The benefit of this prosthesis is the ability to add or remove saline in case an adjustment proves necessary. The recent introduction of allografts helps to achieve better shape and fast expansion and is less painful.

Procedural Considerations. A basic plastic set may be used with the addition of fiberoptic breast retractors. Positioning is usually supine with both arms extended on armboards. Both inframammary folds are marked preoperatively, and both sides of the chest should be prepped and draped. The breast shape

FIGURE 21-15 Tissue expanders are inflatable plastic reservoirs of various shapes and volumes that are implanted under the skin. The skin over the expander is stretched during a period of several weeks as the expander is gradually filled by percutaneous injection of saline into an incorporated part of the remote-fill port. Expanders are useful for breast reconstruction.

expander is supplied in a sterile package from the manufacturer and is available in a variety of sizes. Meticulous sterile technique is required, and the expander should be handled as little as possible. This procedure may be performed immediately following mastectomy or at a later date. Drains are usually placed to prevent hematoma and seroma formation, the latter of which could cause rotation or malposition of the tissue expander. If a surgical bra is used, care must be taken that it is not too tight and does not compromise circulation to the skin flaps.

Operative Procedure

1. Skin flaps are assessed for adequate blood supply, and then the pectoralis fascia is incised along its lateral border. The surgeon creates a submuscular pocket for the temporary expander by undermining the muscle over the sternal attachments and down over the lower ribs.
2. Recently, allograft material is being used to bridge the gap created from the elevated pectoral and serratus muscles to the inframammary fold.
3. The tissue expander is tested before insertion for watertight integrity.
4. After hemostasis is achieved, the surgeon checks the expander for integrity and then inserts it into the pocket. Muscle coverage is assessed, and if adequate the reservoir is positioned subcutaneously and connected, the wound is closed, and the expander is filled with sterile saline solution until slight blanching of the skin is achieved. The amount is recorded on the patient record.

Second-Stage Tissue Expander Breast Reconstruction

Once the tissue expander has been expanded to the desired size, the patient is taken back to surgery for the next stage of her breast reconstruction. This is a relatively minor procedure in which the tissue expander is deflated and replaced with a permanent mammary prosthesis (Figures 21-16 and 21-17, *A* and *B*). At this time, if there is asymmetry of the contralateral breast, surgery may be performed to create bilateral symmetry. The patient may require correction of breast ptosis through mastopexy, with or without the addition of a breast implant; alternatively, a reduction mammoplasty may be needed on the opposite breast. This procedure is usually performed on an outpatient basis in which the patient is administered a general anesthetic.

FIGURE 21-16 While discussing options in surgeon's office, samples of tissue expanders, textured and smooth saline and silicone implants, are shown to patients for their selection.

Breast Reconstruction Using Myocutaneous Flaps

Flaps are described by the types of tissue they contain, the blood supply of the tissues, and the method by which the flaps are moved from the donor site to the recipient site. The latissimus

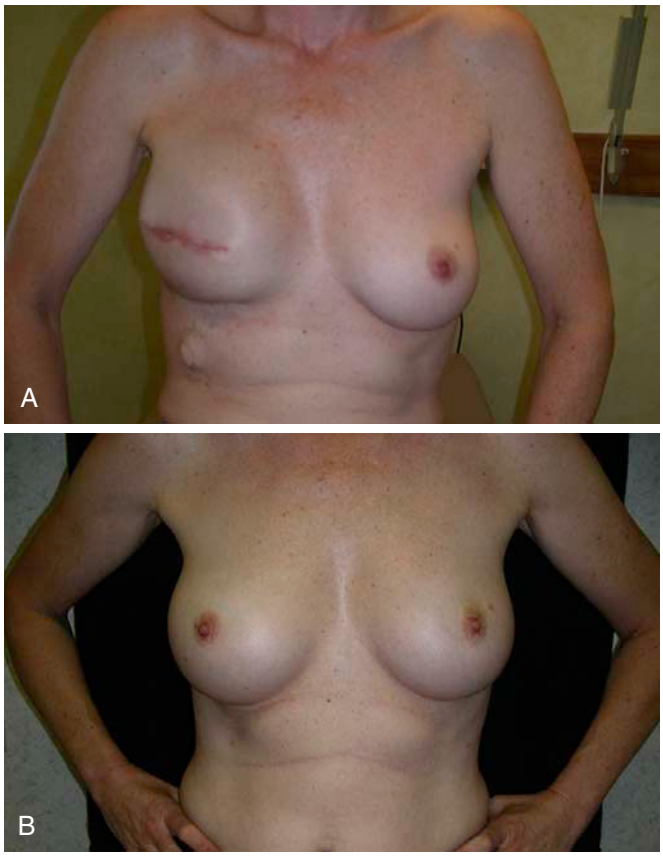


FIGURE 21-17 **A**, Tissue expander is used to create extra tissue after mastectomy so a breast mound can be created. **B**, Postoperative result after tissue expander replaced with breast prosthesis.

dorsi myocutaneous flap is used during reconstruction of the breast after mastectomy. This procedure may be staged. Because the flap consists of skin combined with muscle, it is described as *myocutaneous*. This flap is used when significant tissue deficiency occurs after a mastectomy or when abdominal flap (transverse rectus abdominis myocutaneous [TRAM]) reconstruction is not an option. The latissimus dorsi muscle is a wide, flat muscle extending over the midthoracic portion of the back and inserting into the humerus. Its blood supply comes from the thoracodorsal artery and from perforators of the upper lumbar arteries and intercostal vessels. This rich vascularity allows the surgeon flexibility in orienting and positioning the flap to the pattern of the deficit on the anterior chest wall. Latissimus dorsi flaps are usually used in conjunction with a reconstructive breast prosthesis, in order to create a more natural breast mound.

According to the U.S. Department of Labor, The Women's Health and Cancer Rights Act of 1998 (WHCRA) mandates financial coverage of all breast reconstruction related procedures. One other option is the superior gluteal artery perforator (SGAP) flap, which is becoming more refined recently. Some women choose to use their own tissue for reconstruction, as they prefer what they consider more realistic, supple breasts that would not need to be replaced or removed as is possible with implants. The SGAP flap does require microsurgical skills and is not offered at all institutions. Factors for choosing reconstructive options include the patient's size and availability of appropriate abdominal or gluteal tissue. Even very thin patients generally have enough skin and fat for the SGAP procedure, and the consistency of the buttock fat (thicker than abdominal) provides the more supple result. Positioning is especially challenging, and some operative efficiency may be achieved by using two OR beds (Edwards et al, 2009).

Procedural Considerations. The surgeon marks the donor site of the latissimus dorsi with its skin island, along with the intended recipient site, before surgery with the patient in a sitting position. In the OR, the patient is placed in a lateral position, donor side up, with the arm extended and safely supported. The perioperative nurse should assemble extra padding and positioning aids in preparation for the patient's arrival. Once the donor muscle has been mobilized and exteriorized through the area of defect, the back incision is closed and the patient repositioned supine with the arm extended on an armboard. Instrumentation should include a basic plastic instrument set, fiberoptic breast retractor, vascular instruments, sterile marking pens, suction, and long tissue forceps and scissors, and a Doppler probe should be available.

Operative Procedure

1. Initially the island of skin is incised transversely across the back, being careful to ensure that a bra or bathing suit will cover the resulting scar (Figure 21-18, *A*).
2. The surgeon frees the muscle, subcuticular fat, and fascia from the overlying skin by undermining so that part or all of the muscle may be mobilized (Figure 21-18, *B*).
3. The skin island and the muscle are then tunneled under the axilla to the chest wall (Figure 21-18, *C*). The insertion of the muscle on the humerus and accompanying blood vessels are left undisturbed. The latissimus dorsi muscle fills the space left by the missing pectoralis muscle.
4. The island of skin is oriented to the recipient site, and the surgeon sutures both into place (Figure 21-18, *D*).
5. A mammary prosthesis is placed under the muscle before suturing to reconstruct the breast mound.
6. The wound is drained by closed-wound drains.
7. The nipple-areola complex may also be reconstructed by sharing the nipple on the unaffected side or by using groin, adjacent tissue, thigh, or auricular tissue. This can be done at the time of reconstruction or at a later date as a minor procedure with the patient administered a local anesthetic (Figure 21-18, *E*).
8. If a surgical bra is used, care must be taken not to compromise blood supply to the flap.

Transverse Rectus Abdominis Myocutaneous Flap

TRAM flaps are the most common pedicle-based flaps used for breast reconstruction. The rectus muscle is the broad, wide abdominal muscle that reaches from under the ribs to the pubis, and either one or both sides of the muscle may be used for reconstruction. The blood supply (superior epigastric artery and vein) is carried within the muscle pedicle. The muscle along with its pedicle is severed at its most distal origins and pulled through a subcutaneous tunnel to the chest to form a breast. Although this procedure has the added benefit of an abdominoplasty, if there is inadequate abdominal tissue the patient may require a small mammary prosthesis.

The several types of TRAM techniques are based on blood supply, but the procedure still follows a basic format. As with

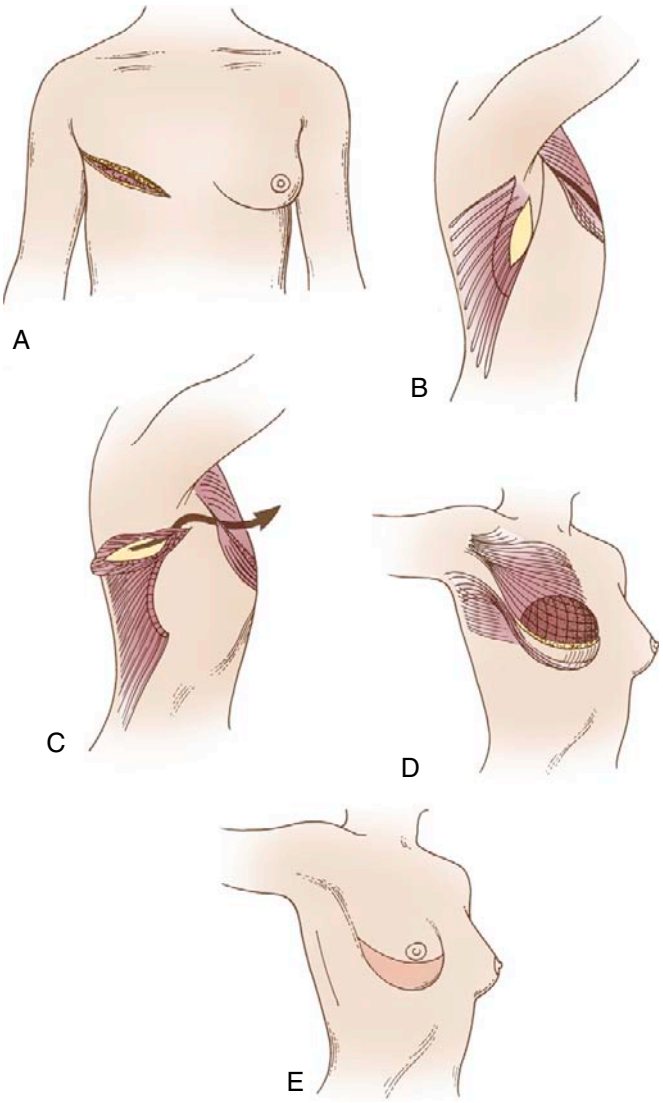


FIGURE 21-18 Latissimus dorsi flap for reconstruction after mastectomy (see text for procedure).

other types of breast reconstruction, TRAM flaps may be performed immediately following mastectomy or planned for a later stage in the patient's recuperative phase.

Procedural Considerations. The surgeon marks the surgical landmarks preoperatively with the patient in a standing position. A basic plastic instrument set is used as for the latissimus dorsi flap. The patient is positioned supine with arms extended on armboards. Positioning the patient for this procedure is particularly difficult because of the need to promote closure of the abdominal wound, support circulation to the flap, and protect the patient from injury. The OR bed is often flexed; additional padding of the lower extremities may be required. The skin prep should extend from the lower neck to midthigh.

Operative Procedure

1. The surgeon excises the skin from the mastectomy scar and makes the abdominal incision. The abdominal flap is dissected with care being taken not to shear the skin and subcutaneous tissue from its underlying muscle attachments (Figure 21-19, *A*).
2. The transverse rectus abdominis muscle is divided from its inferior-most attachment (Figure 21-19, *B*).
3. The flap is rotated and passed through to its new location on the chest wall (Figure 21-19, *C* and *D*) and sutured medially; the thinnest portion of the flap is superior and medial, and the thickest portion is inferior and lateral.
4. Because of the amount of tissue available, an implant is often unnecessary (Figure 21-19, *E*).

Free Transverse Rectus Abdominis Myocutaneous Flap

The free TRAM flap is indicated when there is concern about the absence of one or both of the rectus muscles following the procedure or when there are concerns about vascularity, either with the pedicle used in the standard TRAM flap with any other factors that may compromise vascularity of the flap. A newer technique of the free TRAM (deep inferior epigastric perforator procedure) has the advantage of not requiring the entire rectus muscle, because only a small portion of the rectus muscle that carries a segment of the deep inferior epigastric perforator vessels is needed to move with the fat and skin to its new location. It is also used when the buttock tissue (superior gluteal perforator flap) is planned to replace the absent breast or breasts.

Procedural Considerations. Care of the patient undergoing a free TRAM procedure is identical to that of patients undergoing pedicle TRAM flaps with the addition of the surgical microscope. Refer to the Procedural Considerations under Transverse Rectus Abdominis Myocutaneous Flaps (TRAM). Two surgical teams may be used, one for harvesting and one for site preparation. Meticulous attention must be paid to positioning and protection from pressure injuries because of the length of the procedure. During the preoperative verification process, the perioperative nurse should determine if the patient has made preoperative autologous blood donations and if the appropriate blood work has been performed.

Operative Procedure

1. The site is prepped, and the recipient site blood vessels are identified for anastomosis.
2. The surgeon dissects and isolates the recipient vessels.
3. Donor vessels are selected based on pedicle length, and the flap is prepared.
4. The anesthesia provider administers heparin to prevent clotting and vasospasm.
5. Once recipient vessels are ready, the surgeon severs the flap.
6. The microscope is positioned in place and draped with a sterile drape.
7. The free flap is transferred to the recipient site, and the surgeon anastomoses the blood vessels.
8. The breast mound is shaped and sutured in place.
9. The donor site is closed, covering with a skin graft if necessary.

Nipple Reconstruction

Although nipple reconstruction can be performed at the time of breast reconstruction or replacement of the tissue expander with a mammary prosthesis, some surgeons prefer to wait and let the new breast tissues "settle" and mature in order to

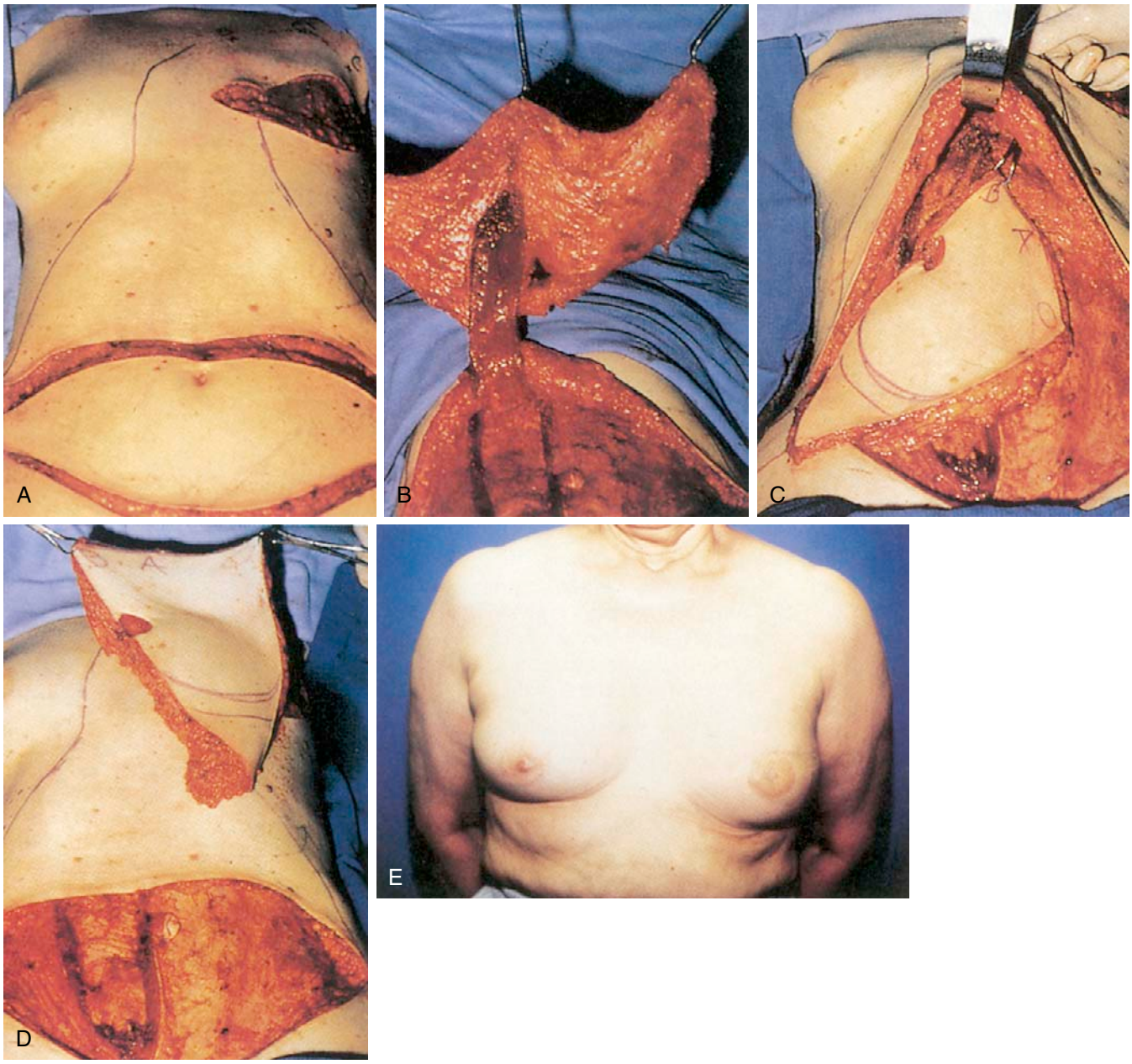


FIGURE 21-19 Transverse rectus abdominis myocutaneous (TRAM) flap for postmastectomy breast reconstruction (see text for procedure).

reconstruct the new nipple in the most accurate anatomic position. Generally this may take a minimum of 6 to 8 weeks. Tissue for the new nipple can be recruited locally by raising a flap or be grafted from the opposite nipple. The areola is reconstructed with skin grafting from the groin, buttock crease, or auricle (Figure 21-20). The areolar skin may be tattooed to create a very pleasing nipple-areolar complex (Figure 21-21, *A* and *B*).

MICROSURGERY

Microsurgery is a fundamental tool in reconstructive plastic surgery. It allows an almost unlimited choice of reconstructive methods, replacement of lost tissue with similar components, and optimal selection of donor sites with minimal morbidity (Wei and Suominen, 2006). Reconstructive microsurgical procedures include, but are not limited to, replantation of amputated body parts, repair of facial nerves, repair of lacerated nerves and blood vessels, treatment of extensive trauma to extremities and hands, reconstruction following removal of extensive cancers, and female to male transsexual reassignment. Today's physicians skilled in microsurgery can successfully anastomose the ends of a vessel measuring less than 1 mm in diameter. The surgeon's use of an operating microscope or loupes for microsurgical procedures depends on the procedure to be performed, condition of the tissue, and personal preference. Endoscopic harvesting of tissues for microsurgical grafting is possible in some circumstances. The success of microsurgery depends on several factors besides patient factors: (1) the individual

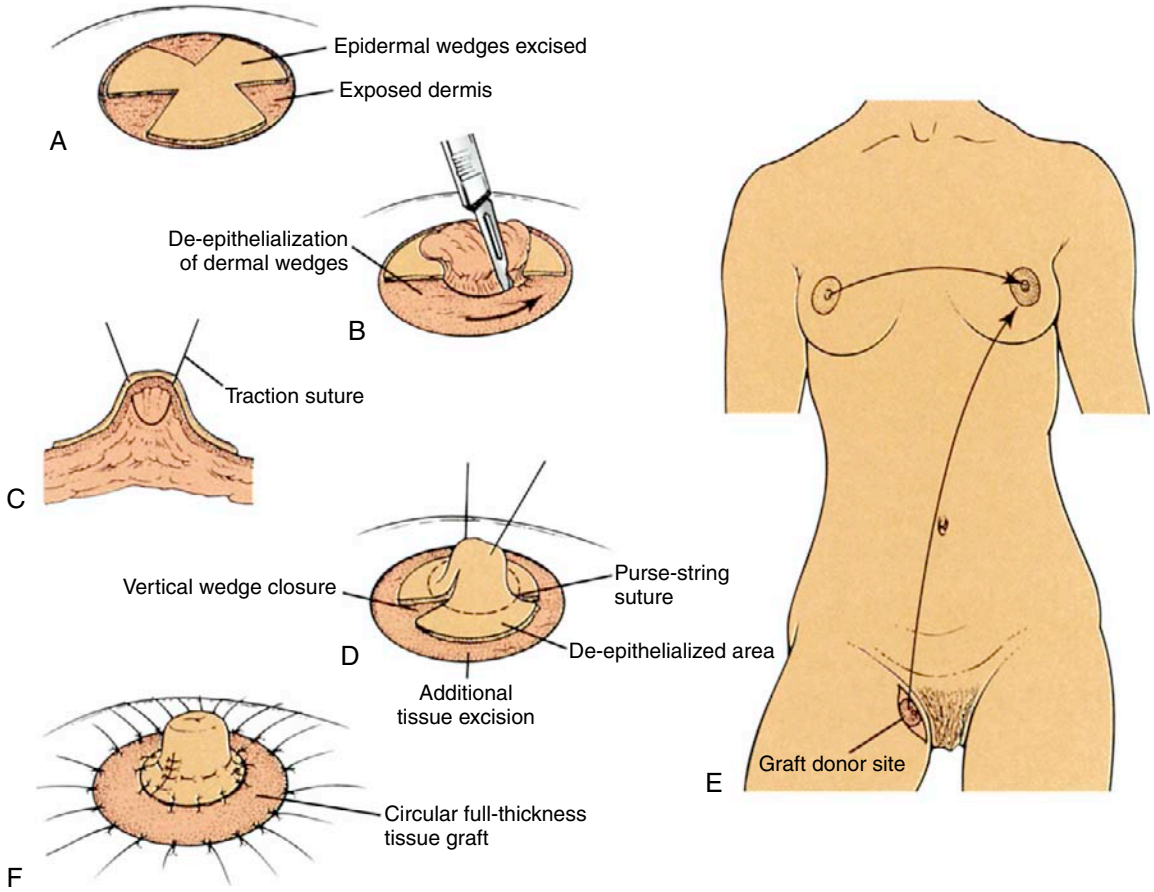


FIGURE 21-20 **A**, Circumferential demarcation of the nipple periphery with removal of dermal wedges. **B**, Dermal wedges are deepithelialized from the rim toward the center. **C**, A traction suture is used to elevate the central future nipple tip. **D**, Traction is applied to the future nipple tip as the wedges are approximated to create a permanent projected surface. A purse-string suture is placed, and excess tissue is excised. **E**, Possible full-thickness donor site areolar color match may be found in the labial folds. **F**, The donor graft is measured, cut, and secured to the dermal ring of the neonipple-areolar complex.

and collective experiences of the surgical team and the members' ability to work together, relieving each other as necessary during long operations; (2) the surgeon's knowledge of the physiology of the microcirculation; (3) many hours of practice in the laboratory by the surgical team; and (4) the availability of proper microscopes, microvascular instruments, and microvascular suture.

Replantation of Amputated Body Part

Replantation is an attempt to reattach a completely amputated digit or other body part. Revascularization is the procedure performed on incomplete amputations, when the part remains attached to the body by skin, artery, vein, or nerve. Good candidates for replantation are those with the following amputations: (1) thumb, (2) multiple digits, (3) distal portion of hand at palm level, (4) wrist or forearm, (5) elbow and above the elbow, and (6) almost any body part of a child.

The success of digital replantation depends primarily on the microsurgical repair of one digital artery and two digital veins. Replantation of an amputated part is ideally performed within 4 to 6 hours after injury, but success has been reported up to 24 hours after injury if the amputated part has been cooled. Proper care of the amputated body part or parts before surgery is vital to successful replantation. The ultimate aim of replantation is the restitution of function beyond that provided by a prosthesis.

Procedural Considerations. A regional anesthetic is usually given to replantation patients if the anticipated length of surgery permits. Because of the length of these surgeries (12 to 16 hours), positioning is important. The OR bed and armboards should be carefully padded with pressure-reducing materials to support the supine patient. The surgeon may request the room temperature increased before the patient arrives because the warm room will reduce vasoconstriction in the extremities. A warming device, such as a forced air warming blanket, is usually applied to maintain the patient's core body temperature. The surgeon usually brings the amputated part to the OR before the patient arrives to ensure ample time for preparation of the amputated part for replantation. The amputated body part should be maintained by wrapping it in saline-soaked gauze sponges, placing it in an occlusive bag, and immersing it in a container of iced saline. If radiographs of the amputated body part and amputation site have not been taken before the patient's arrival in the OR the

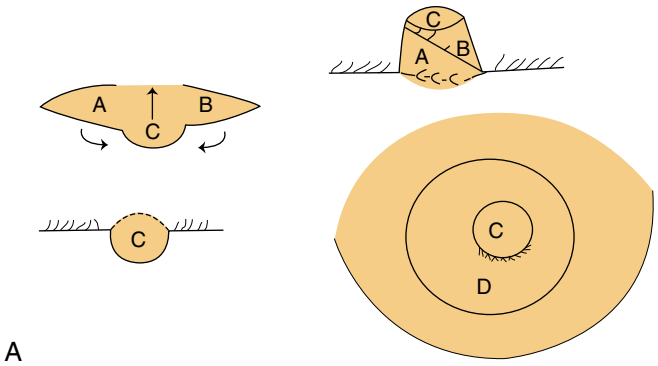


FIGURE 21-21 **A**, Breast nipple reconstruction. A and B represent wing flaps raised from side and wrapped around C; the central flap was raised superiorly. D represents areolar skin created with skin grafted either from pigmented groin skin or from opposite areolar skin by tattooing. **B**, Areolar tattoo.

perioperative nurse should arrange for these to be taken. Radiographic films are crucial to determine bone trauma and loss.

The hand drape (described later in this paragraph) can be applied to either upper or lower extremities, as required by the surgical procedure. Before a hand drape is placed, a pneumatic tourniquet cuff is often applied to the upper arm over padding. The patient is supine on the OR bed, with the affected arm extended and supported on a hand table. While an assistant holds the patient's arm with both hands around the tourniquet cuff, the skin prep solution is applied from fingertips to tourniquet cuff. Care is taken to keep the cuff dry and free of solution. Then two folded barrier sheets are used to cover the hand table. The first sheet is placed with the folded edge nearest the patient (thus forming a cuff). A double-thickness, 4-inch stockinette is used to cover the extremity, and the edge is rolled over the tourniquet. The upper arm and upper half of the body are covered by a folded sheet, with the folded edge placed across the part of the stockinette that covers the tourniquet cuff. A small, nonperforating towel clamp that grasps the edge of the folded top sheet, the stockinette, and the edge of the cuff of the bottom sheet is placed on each side of the arm. This excludes the tourniquet cuff from the sterile field. The remainder of the body is covered with one or two additional sheets. A commercially prepared extremity drape that has an aperture incorporated into the drape may also be used.

Instrumentation includes a plastic hand instrument set, microvascular instruments, a Kirschner wire driver, Kirschner wires, an operating microscope, and a bipolar ESU.

Operative Procedure

1. The surgeon shortens the bone ends to eliminate tension on vascular anastomoses to be done later; the bone is stabilized by means of internal fixation with Kirschner wires.
2. Flexor and extensor tendon repairs are usually performed next.
3. The digital nerves are repaired with the aid of loupes or the operating microscope.
4. With microsurgical instruments and techniques, two digital veins are repaired, followed by repair of one digital artery. If ischemic time has been prolonged, digital vessel repair may precede repair of tendons and nerves.
5. The skin is sutured.
6. A bulky supportive hand dressing is applied.

Toe-to-Hand Transfer

The reconstructive procedure of toe-to-hand transfer involves surgical removal of a single toe or multiple toes and anastomosis of the vessels of the toes to those on the hand to restore finger and thumb functions. It is lengthy surgery (12 to 16 hours) and entails a two-team approach; one team is at the foot for toe removal, and one team is at the recipient site—the hand.

Procedural Considerations. The patient is placed in the supine position on the OR bed. The patient is administered an anticoagulation regimen during the anastomosis procedure. Two tourniquets are needed—one on the thigh of the operative foot and one on the operative arm. Both extremities are separately prepped and draped. Instrumentation includes a plastic hand set, microvascular instruments, power Kirschner wire driver, and Kirschner wires. Additional equipment includes the operating microscope, two tourniquet power sources, two bipolar ESUs, a sterile marking pen, and an Esmarch bandage.

Operative Procedure

1. The surgeon preparing the hand determines adequate blood flow and vessel location on the thumb site (Figure 21-22, *A*). This may prevent a needless amputation of the toe.
2. Appropriate skin flaps are incised to expose the veins on the dorsum of the hand and clamped with vessel microclips.
3. The radial artery or its branches are dissected out and prepared for anastomosis.
4. The flexor and extensor pollicis longus tendons are located and transfixed.
5. The bone at the base of the thumb is prepared for the toe.
6. The nerves to the thumb are dissected out with adequate length for suturing without tension.
7. The toe is circumscribed with a racket-shaped incision (Figure 21-22, *B*), and the veins are isolated through the dorsal aspect and clamped with vessel microclips.
8. The extensor tendon is dissected proximally and transected over the base of the metatarsal.
9. The dorsalis pedis artery is dissected to the digital vessels with ligation of all branches of that vessel to prepare for the anastomosis.

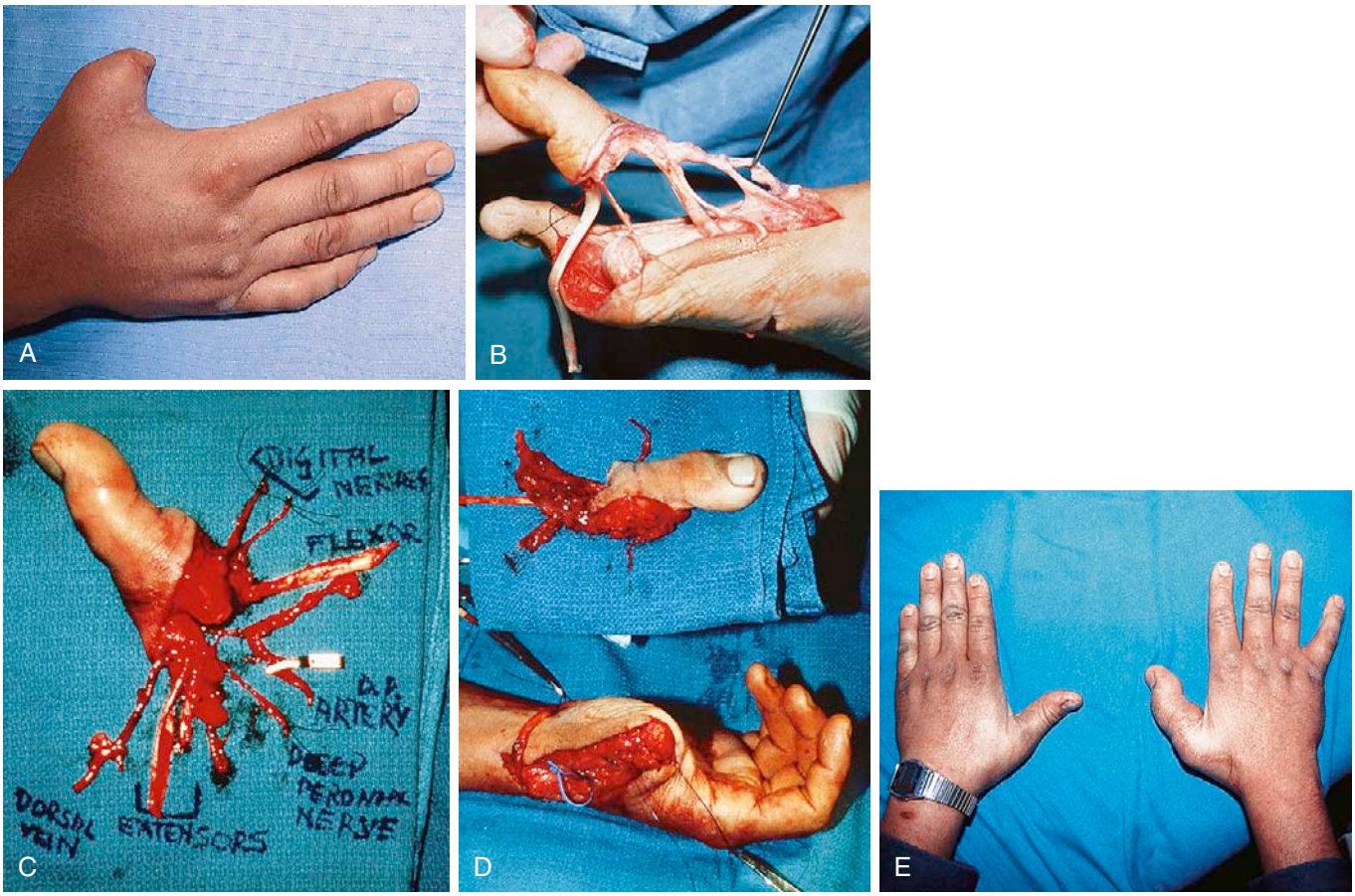


FIGURE 21-22 Toe-to-hand transfer. **A**, Preoperative appearance of hand. **B**, Harvest of toe. **C**, Identification of vessels and nerves. **D**, Transfer of toe to thumb site. **E**, Postoperative view of toe-to-thumb site transfer.

10. On the plantar surface, the digital nerves and flexor tendons are transected at levels of adequate length for anastomosis (Figure 21-22, *C*).
11. The toe is transected at the level previously determined for adequate length of the thumb.
12. The toe vessels are anastomosed microsurgically to the thumb vessels. The toe is attached to the thumb area by Kirschner wires (Figure 21-22, *D*).

An aesthetic and functionally effective hand can be achieved through this procedure (Figure 21-22, *E*).

RECONSTRUCTIVE MAXILLOFACIAL SURGERY

The need for maxillofacial surgery results from blunt or penetrating trauma, disease, or congenital anomaly. Regardless of the cause, the principles are the same: establishment of preinjury/predisease/normal anatomic dental occlusion, anatomic reduction, stabilization of the fracture, and healing for functional results (Pfiedler Enterprises, 2007). The technique and approach must be individualized to optimize the visual reduction (or reconstruction) of the procedure as well as minimize facial scarring and nerve injury, whether it be a mandibular free flap tissue and bone reconstruction or open reduction and internal fixation of any number and combination of facial fractures. In addition to midface fractures, other common facial fractures include nasal, orbital (blow-out) floor, zygomatic, and mandibular fractures.

Procedural Considerations for Maxillofacial Surgery

The perioperative nurse should ask the surgeon about the precise injuries and the expected surgical treatment plan: open or closed reduction; intraoral or extraoral approach; the order of multiple procedures; need for intraoperative x-rays; and type, number, and sizes of screws and compression plates to be placed if rigid fixation is to be employed. Orbital fractures may require alloplastic implant material. Wire is used less frequently for immobilization because of the greater degree of stability afforded by plating systems. The head should be immobilized and stabilized in a gel-type head ring; the position is almost always supine. Both eyes should be protected, and care must be taken not to displace endotracheal tubes. Instrumentation needs include a plastic surgery set, periosteal elevators, power drill for plating systems, bone hooks, Rowe disimpaction forceps (for maxillary fractures), the ESU, sterile marking pens, and suction. For application of arch bars, the nurse should assemble arch bars, wires, elastics, wire cutters, wire twisters, and dull retractors for good exposure of the teeth.

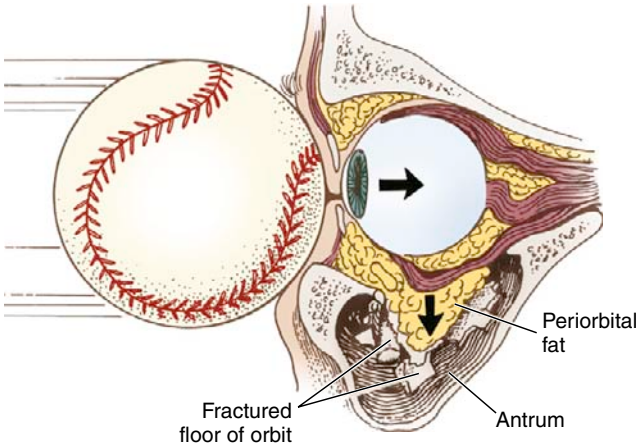


FIGURE 21-23 Ball has struck rim of orbit and has pressed orbital contents backward, displacing fragments of bone into maxillary sinus. Inferior rectus muscle is incarcerated in fracture. Inferior oblique muscle may also be involved.

Reduction of Nasal Fracture

Usually a closed reduction of the bony nasal fragments is performed by digital and instrumental manipulation. Occasionally an open reduction with interosseous wire fixation of nasal bone fragments is necessary. A nasal fracture may involve a fracture of the nasal bones or cartilage (including the septum). Closed reduction of a nasal fracture is most often performed with the patient administered topical and local anesthetics. Procedural considerations and the surgical intervention are described in Chapter 18.

Reduction of Orbital Floor Fractures

The orbital floor is the eggshell-thin bone on which the eye and periorbital tissues rest. It separates the orbit from the maxillary antrum. Orbital floor fractures usually occur in combination with fractures of the infraorbital rim (maxillary and zygomatic fractures). An isolated depressed orbital floor fracture with an intact infraorbital rim is called a *blow-out* fracture.

Fractures of the walls of the orbit may be caused by direct blows or by extension of a fracture line from adjacent bones. Isolated orbital floor, or blow-out, fractures usually occur after injury to the region of the eye by an object the size of an apple or an adult's fist (Figure 21-23). Orbital contents herniated into the maxillary sinus, and the inferior rectus or inferior oblique muscle, may become incarcerated at the fracture site. A Caldwell-Luc antrostomy may be done with reduction of the fracture from below, or the fracture site may be approached directly through the lower lid along the orbital floor; the prolapsed tissue is reduced, the orbital floor is reduced, and the orbital floor defect is bridged with bone grafts, molded metal implants, or plastic material.

Procedural Considerations. A graft set may be used for implantation of autogenous graft or synthetic graft materials of various sizes and thicknesses, along with a flexible narrow-width retractor. Interosseous wiring may be required for fractures of the frontozygomatic junction. Microplates and screws to stabilize fractures involving the fragile facial and orbital bones may also be used. A general anesthetic is usually administered.

Operative Procedure

1. The surgeon tests the maximum ocular rotation by exerting traction with a forceps on the tendon of the inferior rectus muscle to determine if the inferior muscle sling is trapped in the fracture.
2. To distribute tension over the lower lid and stretch the orbicularis muscle, the surgeon inserts a traction suture through the lower lid margin.
3. With a #3 knife handle and a #15 blade, the surgeon incises the lower lid in the lid fold above the orbital rim.
4. The skin is separated from the orbicularis muscle, and the orbital septum is identified by blunt dissection. Dissection is continued down to the periosteum of the orbital rim by means of scissors, loop retractors, elevators, and forceps.
5. The periosteum of the orbital rim is incised with a #15 blade. With periosteal elevators, the floor of the orbit is exposed and explored. When the fracture site is identified, bone spicules (needle-shaped bone fragments) are removed and the herniated contents are freed from the maxillary antrum. The contents of the orbit are elevated by means of narrow-width, flexible retractors. A 4-0 traction suture is placed around the tendon of the inferior rectus muscle.
6. An autogenous graft is taken from the iliac crest, or an alloplastic material of proper size is used to repair the bony defect. The material may or may not be anchored to the orbital rim by wire sutures.
7. The periosteum is carefully closed with 4-0 absorbable sutures.
8. The skin is closed with 6-0 nonabsorbable sutures, and a pressure dressing is applied.

Reduction of Zygomatic Fractures

Fractures of the zygoma (the cheek or malar bone) are corrected by either closed or open reduction. The two most common types of zygomatic fractures are depressed fractures of the arch and separation at or near the zygomaticofrontal, zygomaticomaxillary, and zygomaticotemporal suture lines, which constitutes a trimalar fracture. Although fractures of the zygoma can interfere with the ability to open and close the mouth properly, their chief consequence is a flattening of the cheek on the involved side, which results from a depressed trimalar or zygomatic arch fracture. Treatment is directed toward elevating the depressed fracture and maintaining the reduction. Closed reduction is the procedure used for treatment of zygomatic arch fractures, whereas most trimalar fractures are reduced by means of open reduction with internal fixation.

Procedural Considerations. A plastic instrument set, a Suraci zygoma hook-elevator, and a jaw hook are required for a closed reduction. A basic plastic instrument set, along with the following instruments and supplies, is required for an open reduction: a Hall II air drill; stainless-steel wires (#26, #28, and #30); the Suraci zygoma hook-elevator; a jaw hook; a Kerrison rongeur; two Blair retractors; the bipolar ESU; a sterile marking pen; epinephrine 1:200,000 for injection; and a miniplating rigid fixation set. The patient is placed in the supine position on the OR bed. The head drape is used.

Operative Procedure. Closed reduction is performed by elevating the depressed fracture with a percutaneous bone hook. Stabilization of a trimalar fracture may then be achieved by

inserting a transantral Kirschner wire from the fractured side to the normal side.

The technique of open reduction of a trimalar fracture is as follows:

1. Incisions are marked along the lateral area of the eyebrow and lower eyelid over the zygomaticofrontal suture line and zygomaticomaxillary suture line (infraorbital rim) fractures, respectively.
2. After injection with epinephrine 1:200,000 for hemostasis, the surgeon incises along the premarked lines down to bone, and suture lines are identified and exposed.
3. The depressed zygoma is elevated with a Kelly hemostat or periosteal elevator placed behind the body of the zygoma through the lateral eyebrow incision. Bone hooks placed percutaneously or at the fracture sites may be used instead.
4. The surgeon drills holes into bone on each side of the fracture lines. Stainless-steel wires are passed through the hole and twisted down tightly to maintain the reduction. (Reduction and stabilization of two of the three fractures are sufficient.) Alternative methods of stabilization of the fractures are interosseous wiring of the zygomaticofrontal fracture and placement of a transmural Kirschner wire or stabilization with micro/mini plates and screws.
5. Using a subcuticular technique, the surgeon closes the incisions.
6. An eye-patch dressing may be applied.

Reduction of Maxillary Fractures

Midface fractures are usually classified according to a system developed in the early 1900s by Dr. Rene Le Fort: (1) Le Fort I, or transverse maxillary, fracture—this horizontal fracture includes the nasal floor, septum, and teeth; (2) Le Fort II, or pyramidal maxillary, fracture (unilateral or bilateral)—this type often involves the nasal cavity, hard palate, and the orbital rim; and (3) Le Fort III, or craniofacial dysjunction, fracture—this type includes fractures of both zygomas and the nose (Pfiedler Enterprises, 2007) (Figure 21-24). Like a mandibular fracture, a maxillary fracture also produces malocclusion. In addition, depending on the severity of the fracture, it may produce considerable deformity of the middle of the face, usually perceived as a flattening or smashed-in appearance.

Closed reduction with intermaxillary fixation suffices for treatment of Le Fort I and some Le Fort II fractures. The more severe Le Fort II and all Le Fort III fractures require open reduction in addition to intermaxillary fixation.

Procedural Considerations. The basic plastic instrument set is required as well as an air drill; stainless-steel wires (#25, #26, and #28); Rowe maxillary forceps, right and left; a Brown fascia needle; polyethylene buttons (for suspension wire pull-through for Le Fort III repair); a small, foam-rubber pad; a sterile marking pen or methylene blue; the ESU; epinephrine 1:200,000 for injection; periosteal elevators; and a rigid fixation system. A separate Mayo setup for the application of arch bars is required, as described for reduction of mandibular fractures. The patient is placed in the supine position on the OR bed. The head drape is used.

Operative Procedure. Arch bars are applied before or after the open reduction, or they may be the only mode of treatment in closed reduction. In addition to ligating the maxillary arch bar to the teeth, it must also be suspended from stable bones superior to the fractured maxilla (which is unstable). In Le Fort I fractures, suspension may be around both zygomatic arches by passage of percutaneous wires. In Le Fort II and Le Fort III fractures, suspension wires are placed through holes drilled bilaterally into the zygomatic process of the frontal bone. This requires incisions into both lateral eyebrow areas. The following description pertains to open reduction of Le Fort II and Le Fort III fractures:

1. After injection of epinephrine 1:200,000 for hemostasis, the surgeon makes bilateral incisions to expose the infraorbital rims and zygomaticofrontal suture lines.
2. The surgeon applies Rowe maxillary forceps intranasally and intraorally to disimpact and reduce the maxilla. Holes are drilled into bone on each side of fracture lines along the infraorbital rim (and zygomaticofrontal area for Le Fort III fractures, after reducing the zygomatic fractures).
3. Stainless-steel wires are passed through these holes and twisted down tightly to maintain the reduction.
4. Suspension wires are passed from the eyebrow incisions, behind the zygomatic arches, and into the mouth with the Brown fascia needle. A pullout wire is looped through each suspension wire within the eyebrow incision, brought out through the skin near the hairline, and tied down over a polyethylene button and foam-rubber padding. Self-tapping screws, mini compression plates, and bone grafts may also be used, based on the surgeon's preference. Incisions are closed.
5. When indicated, reduction of a nasal fracture is then performed.

FIGURE 21-24 Practice skulls are provided in seminars to practice fixation techniques. See text for Le Fort classification of fractures.

FIGURE 21-25 Teeth in occlusion with arch bars in place. Tongs on arch bars will accept latex bands, which maintain occlusion for several weeks (wires around tongs are shown).

Reduction of Mandibular Fractures

The purpose of treatment for a mandibular fracture is to restore the patient's preinjury dental occlusion. With some types of fractures, a closed reduction with immobilization by means of intermaxillary fixation is sufficient for treatment. With a majority of mandibular fractures, however, an open reduction with wire fixation is necessary, plus supplemental intermaxillary fixation to achieve adequate immobilization for healing.

Intermaxillary fixation is most often accomplished when arch bars are applied to the maxillary and mandibular teeth. Stainless-steel wires (#24 or #25) are placed around the necks of the teeth and are ligated around the arch bars to hold the latter in place. Latex bands are attached to the tongs on the maxillary and mandibular arch bars to fix the teeth in occlusion (Figure 21-25). If the patient is edentulous, arch bars are attached to dentures or specially fabricated dental splints. The dentures or splints are held in place by means of wires placed around the mandible (for the mandibular arch bar) and through the nasal spine and around the zygomatic arches (for the maxillary arch bar). Scissors or wire cutters must be sent with the patient to the PACU and the postoperative patient care unit to prevent aspiration if the patient vomits or chokes.

Procedural Considerations—Open Reduction. In addition to a basic plastic instrument set, the following instruments and supplies are needed for an open reduction of a fractured mandible: a Hall II air drill, two Dingman bone-holding forceps, a nerve stimulator, a sterile marking pen, stainless-steel wires (#24, #26, and #28), the ESU, epinephrine 1:200,000 for injection, and a rigid fixation system.

For the application of arch bars or other types of interdental wiring techniques, a separate Mayo setup with the following instruments and supplies is required: a set of coil arch bars and latex bands; stainless-steel wire (#25 or #26); two Mayo-Hegar needle holders, 8 inch; a wire suture scissors, 4¾ inch; a wire twister; a Yankauer suction tube; two Wieder tongue depressors, large and small; six mosquito hemostats, curved, 5¼ inch; a Brown fascia needle (if dentures or splints are used); a Freer septal elevator; and a small drain.

If arch bars are applied before the open reduction is performed, this former setup must be kept completely separate from the instruments used for the open reduction. Because the mouth is a contaminated area, a complete change of gowns, gloves, and drapes is necessary after the intraoral procedure.

Operative Procedure

1. Arch bars may be applied before or after the open reduction.
2. A line inferior and parallel to the lower border of the mandible at the fracture site is marked, and the area is infiltrated with epinephrine 1:200,000 for hemostasis.
3. The surgeon places the incision to expose the inferior border of the mandible. The nerve stimulator may be used to aid in identification of the marginal mandibular branch of the facial nerve in fractures of the posterior body and angle of the mandible.
4. The fracture is reduced by manipulation. Holes are drilled into the mandible on each side of the fracture line with the Hall II air drill while an assistant holds the reduced fracture with the aid of Dingman bone-holding forceps.
5. Stainless-steel wire is inserted through the holes and twisted tightly to secure the fracture fragments in anatomic alignment.
6. In the event that rigid fixation is desired with the use of plates and screws, the appropriate drill bit, tap, and depth gauge are chosen. With these items, the proper-size prosthesis is placed and the fracture is approximated, aligned, and placed in anatomic position.
7. A small drain is sometimes placed into the wound, and the wound is closed in layers (periosteum, platysma muscle, and skin).
8. The latex bands may be applied to the arch bars at this time but more frequently are applied later, after the patient is fully awake and reactive.
9. A moderate compression dressing is applied to cover the submandibular wound and drain.

Elective Orthognathic Surgery

A large number of patients have either acquired or congenital facial defects that affect the maxilla, the mandible, or both. The condition of many of these patients can be improved dramatically with orthodontic care; however, many also require surgical rearrangement of the maxilla or mandible.

Procedural Considerations. Psychosocial and functional deficits are related to abnormalities of the maxilla and mandible. Surgical correction of these defects can improve patients' quality of life. Surgery is usually delayed until an adequate number of permanent teeth are in place for postoperative immobilization. Coordinated preoperative planning is of great importance to the success of these procedures.

Operative Procedure

1. Arch bars are applied for postoperative immobilization.
2. Intraoral incisions provide exposure.
3. The maxilla or mandible is cut as indicated by the preoperative workup.
4. Bone is advanced or set back to a predetermined position.
5. Bones are wired in place, with grafts placed in defects as needed.

GENDER REASSIGNMENT

Transsexualism is defined as the condition in which an individual with chromosomes and internal and external organs normal to one gender identifies psychologically and socially with attributes of the opposite gender. Reassignment of gender by means of surgery is the last step to be taken in treatment of transsexuals. It is performed only after the patient has been treated with hormones of the opposite gender, has experienced a period of cross-gender living, and has had intensive psychiatric evaluation. Most institutions performing this type of surgery have gender-identity teams who evaluate and treat transsexuals. These teams usually include a variety of professionals: psychiatrist, psychologist, endocrinologist, plastic surgeon, urologist, gynecologist, and social worker.

The surgical techniques for assignment of male to female are technically easier. A breast augmentation may be performed if hormone therapy has not sufficiently changed breast size. Construction of the neovagina includes radical penectomy, bilateral orchiectomy, urethroplasty, perineal dissection, creation of a neovaginal vault, vaginoplasty, and vulvoplasty.

The surgical technique for female to male is technically more difficult and requires multiple surgical procedures. Considerations that must be addressed are twofold: the neophallus must be constructed to (1) allow the patient to stand to void and (2) permit stimulation of a sexual partner during intercourse. This may require a radial artery forearm free flap with a later-stage surgical insertion of a penile prosthesis for attaining an erection.

AESTHETIC SURGERY

Aesthetic surgery may be performed after induction of general anesthesia, monitored anesthesia care, or local anesthesia with moderate sedation. The perioperative nurse must be qualified and prepared to monitor the patient during the procedure according to AORN recommended practices (AORN, 2009). Baseline vital signs should be recorded in the OR record. A blood pressure cuff, pulse oximeter, and cardiac monitor electrodes should be placed (with staff capable of interpreting cardiac data). IV fluids should be administered. The OR should be kept quiet and patient privacy protected. Care should be taken to avoid conversation that could be misinterpreted by the patient.

Scar Revision

Scar revision involves the rearranging or reshaping of an existing scar so that the scar is less noticeable. The simplest form of scar revision is excision of an existing scar and simple resuturing of the wound. This may improve scars that are wide.

The Z-plasty is the most widely used method of scar revision (Figure 21-26). It breaks up linear scars, rearranging them so that the central limb of the Z lies in the same direction as a natural skin line. Scars that are parallel to skin lines are less noticeable than scars that are perpendicular to skin lines. A contracted scar line can also be lengthened with a Z-plasty.

Procedural Considerations. A plastic local instrument set and a sterile marking pen are required. The procedure may be performed with the patient administered a local or general anesthetic. The patient is positioned, prepped, and draped so that the scar that is to be revised is well exposed.

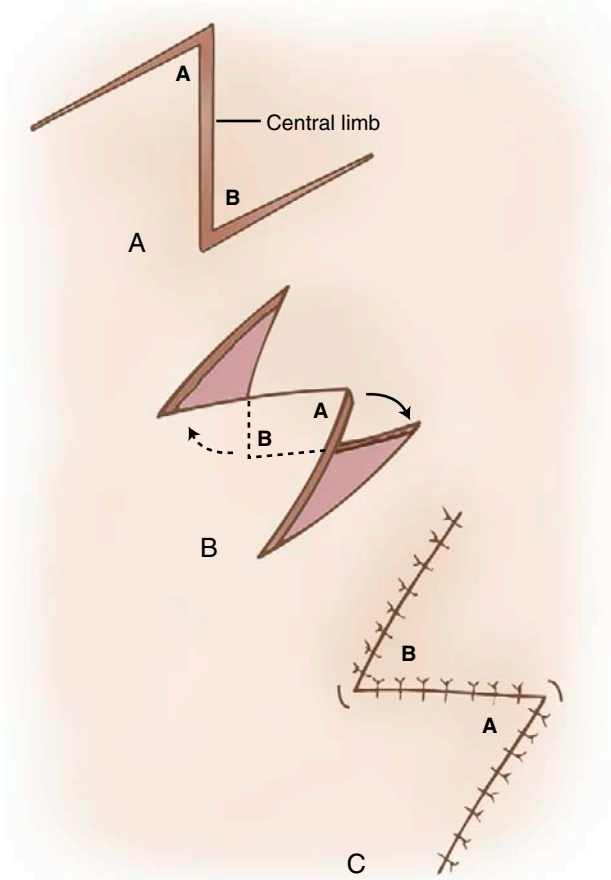


FIGURE 21-26 Z-plasty for scar revision. **A**, The central limb of the Z-plasty is over the scar that needs to be revised. **B**, Two other limbs are incised—each equal in length to the central limb and diverging from it at an equal angle. The flaps are then transposed. **C**, Flaps transposed, and original Z rotated 90 degrees and reversed.

Operative Procedure

1. The surgeon marks the pattern for the planned revision.
2. The scar is excised.
3. The surrounding tissue is undermined, and the wound edges are approximated according to the surgeon's markings.
4. Dressings may or may not be applied.

Endoscopic Brow Lift

The aging process affects the area above the eyes and brows in several ways. Loss of skin elasticity can cause the appearance of a heavy brow and emphasize hooding of the upper eyelids. Repetitive muscle action results in horizontal forehead lines and furrows as well as creases between the brows. The goal of endoscopic brow/forehead surgery is to minimize the heaviness of the brow and improve the frown lines of aging, reduce upper eyelid hooding, reposition the eyebrows if necessary, and create a more youthful, refreshed appearance of the forehead and brow area, all through multiple, short incisions in the scalp.

Procedural Considerations. Positioning the patient at the very top of the OR bed is necessary for good utilization and mobility of the endoscopic instruments. For patients with medium to long hair, the hair may be sectioned and tied with

FIGURE 21-27 **A**, Preoperative and **B**, postoperative rhytidectomy.

sterilized rubber bands to minimize interference with the planned incision. The surgeon marks the patient's incision lines and anatomic landmarks before the surgery. The entire head (scalp, face, ears, and neck) should be prepped and draped with impervious drape material. The patient's eyes may be protected with ointment and shields for the duration of the procedure; ear canals may also be protected from pooling of prep solution by using sterile cotton balls. During preparation of the room, the perioperative nurse and surgical technologist perform a check of all endoscopic equipment to ensure it is functioning properly. Endoscopic instrumentation includes elevators, scissors, clamps, needle holders, camera, and light sources. Depending on the method of fixation, screws and accompanying instrumentation may be necessary.

Operative Procedure

1. The surgeon injects a local anesthetic and places three to five small scalp incisions (one midline and one or two paramedian).
2. Using blunt dissection, the surgeon elevates the forehead skin.
3. The endoscope is placed to allow visualization of muscles, vessels, nerves, and tissues.
4. Using endoscopic instruments the surgeon dissects the corrugator and procerus muscles and soft tissues. The area is redraped to produce a smoother appearance and desired repositioning of brows.
5. Screws are placed in the outer table of the cranium at designated points, and sutures are placed through the galea and tied around screws to facilitate elevation of the brow and forehead.
6. The surgeon staples or sutures the scalp incisions for closure.

Rhytidectomy (Facelift)

As the aging process progresses, the skin of the face and neck becomes loose and redundant. This is particularly noticeable in the "jowl" areas and just beneath the chin. A facelift is performed to correct the sagging skin. A common misconception is that a facelift involves only the face. Actually, one of the most common complaints of aging is the appearance of the neck and submental skin. The typical facelift treats the face and neck and involves removal and redraping of excess skin of the face and neck once repositioning of the underlying muscle and platysma has been performed. The result is a smooth, rested appearance, without unnatural tightness or distortion of facial features (Figure 21-27). Rather than excising the redundant skin directly, incisions adjacent to or within hairlines are used so that the scars are virtually indiscernible.

Procedural Considerations. The perioperative nurse assists with positioning the patient supine with the head and shoulders slightly elevated. Attention should be given to safety by using proper positioning to prevent pressure injuries, using sequential compression devices (SCDs), maintaining normothermia, and preventing eye injuries by using shields. Depending on the complexity of the procedure and planned surgical time, the nurse may insert an indwelling urinary catheter.

Specialized scissors of varying lengths should be available, along with smooth and toothed tissue forceps and various sizes of needle holders. A fiberoptic lighted retractor is standard for facelifts. To avoid flash sterilization, contact with the surgeon or office staff should be initiated before the day of surgery to discuss special requests.

There are numerous techniques for rhytidectomy, and a well-prepared perioperative nurse will ask the surgeon about the specific technique in order to have the appropriate suture material and special needles available. The underlying superficial muscular aponeurotic system (SMAS) may be repositioned, the cheek may be elevated independently, the midface may be lifted, and there may or may not be accompanying liposuction. Facelift procedures are customized specific to the anatomic needs of the individual patient. The entire head, neck, ears, and scalp are prepped and draped.

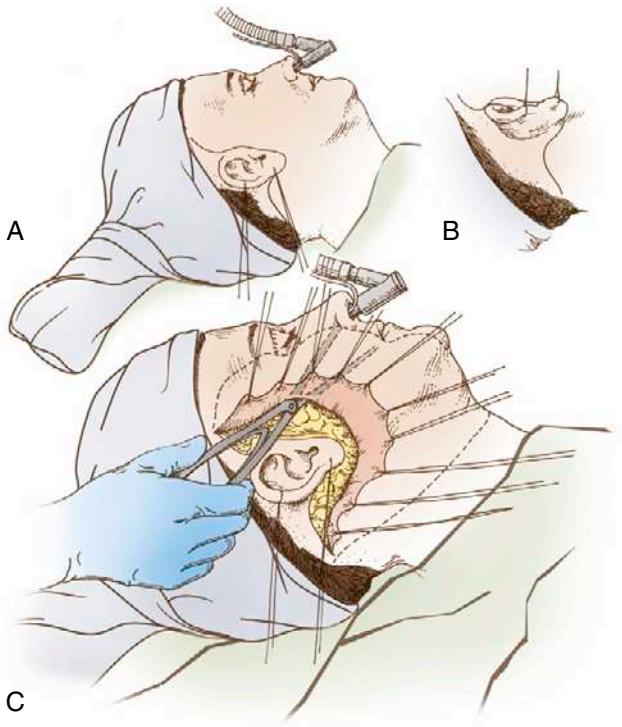


FIGURE 21-28 Rhytidectomy: line of incision and undermining. **A**, Traction sutures of 4-0 silk placed into auricle; temporal incision curved posteriorly for better support of upward pull. **B**, Incision carried under earlobe and then curved posteriorly upward and then caudad toward midline. **C**, Skin undermined almost to nasolabial fold, to area of mental foramen, and to midline of neck as far down as thyroid cartilage. Care is taken to avoid injury to submandibular branches of facial nerve and facial artery.

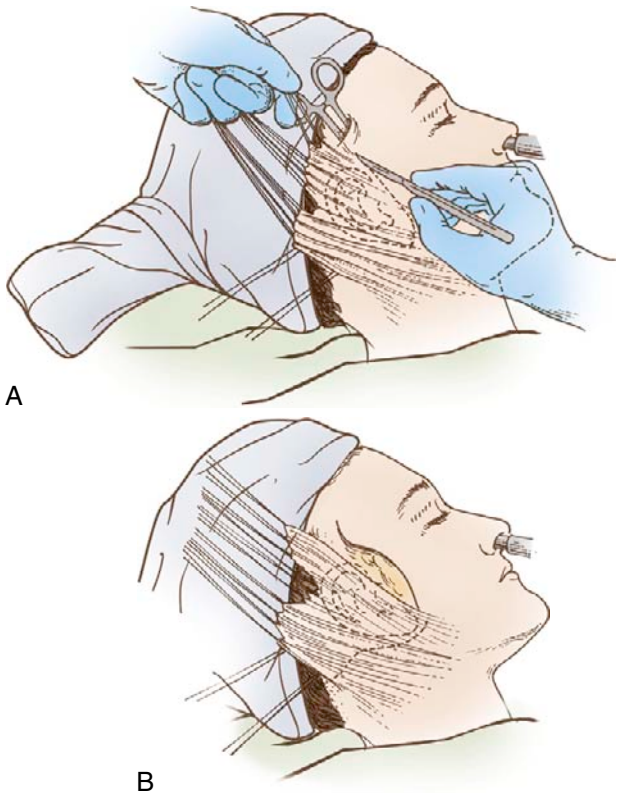


FIGURE 21-29 Rhytidectomy: removal of superfluous skin. **A**, Skin drawn upward to proper degree of tension, and incision made along posterior margin of clamp. **B**, Incision continued upward around posterior margin of auricle and then backward to excise skin specimen.

Operative Procedure

1. The surgeon marks bilateral incision lines from the temporal scalp, around the earlobe, around the posterior margin of the auricula, and into the occipital scalp (Figures 21-28 and 21-29).
2. The incision lines, both temples, cheeks, upper neck, and the submental area are injected with the local anesthetic agent.
3. The surgeon may use liposuction on the neck, jowls, or cheeks before placing the incisions.
4. After the incisions are made, the surgeon elevates the temporal and cheek skin. The SMAS is plicated cephalad and caudally, elevating and tightening the SMAS and platysma.
5. The surgeon elevates and repositions the malar pad; it is then anchored with suture.
6. The facial skin flap is then elevated in a superior and slightly posterior direction and tacked, and excess skin is trimmed at the flap edges.
7. Through a submental incision, the surgeon undermines the neck, and identifies and plicates the plastysmal bands. Excess tissue is trimmed and tacked postauricularly. Small drains are placed beneath the skin flaps and secured.
8. Incisions are closed in one or two layers.
9. A moderate pressure dressing is applied.

Blepharoplasty

The aging process causes a sagging or relaxation of eyelid skin and the orbital septum. As the latter becomes weaker, it allows periorbital fat to bulge. These changes are perceived as baggy eyelids, which give the patient a chronically tired appearance. The goal of blepharoplasty is to improve the patient's appearance by removing excess eyelid skin, removing or repositioning bulging periorbital fat, and tightening and smoothing the muscles under the eye (Figure 21-30). The upper eyelid skin can be so redundant that it encroaches on the patient's field of vision, and removal of excessive hooding of the upper eyelid skin may even improve peripheral vision. The upper eyelid crease may also be enhanced. Not all patients need removal of skin; for selected individuals, CO_2 skin resurfacing may be the procedure of choice to achieve a smoother appearance of the lower eyelid skin. Incisions in the subconjunctival mucosa of the lower lids are sometimes used for this group of patients if resection or repositioning of the periorbital fat is also indicated. Blepharoplasty is often performed with rhytidectomy. Blepharoplasty may be performed on both the upper and lower lids, upper lids only, or lower lids only.

Procedural Considerations. A plastic local instrument set is required. Delicate, short instruments are used, with special attention to scissors (curved Kaye blepharoplasty); fine

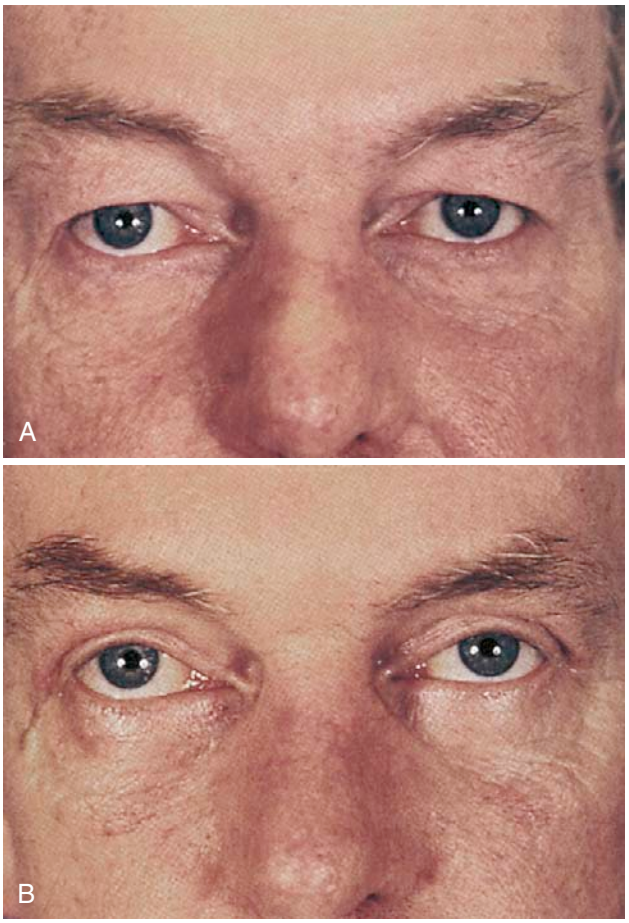


FIGURE 21-30 **A**, Preoperative and **B**, postoperative blepharoplasty.

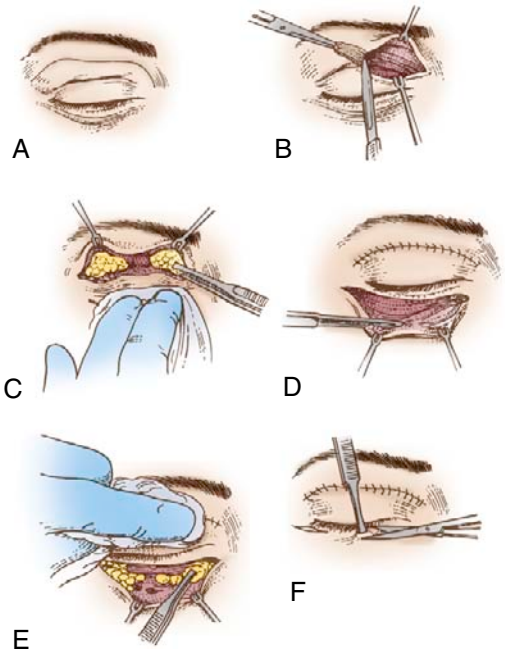


FIGURE 21-31 Blepharoplasty for baggy eyelids. **A**, Areas of proposed skin excision marked with methylene blue or a sterile marking pen. **B**, Strip of skin excised from upper lid; fat pad shining through orbital fascia and orbicular muscle of eye. **C**, Orbital fascia opened in two places (medially and laterally). Pressure on eyeball causes fat pads to bulge. They are eased out meticulously. **D**, Upper lid incision sutured with continuous 6-0 suture material of choice. Orbital muscle fibers of lower lid are separated from skin. **E**, Orbital fascia opened; fat pads bulge because of digital pressure and are teased out meticulously. **F**, Skin tailored to fit and sutured.

Adson forceps with teeth; calipers; and fixation forceps. Webster needle holders are frequently desired. A bipolar ESU unit may be used. A needle tip for the active electrode may be requested if the monopolar ESU is used. (With the monopolar ESU, a lower setting is used. The perioperative nurse should verbally repeat back the settings requested by the surgeon.) Blepharoplasty is usually performed using a local anesthetic with monitored anesthesia care. The patient is in the supine position on the OR bed. The face is prepped, and the head drape is used. Corneal shields may be used to protect the cornea.

Operative Procedure—Upper Lids

1. The surgeon marks the lines of incision and injects local anesthetic.
2. The incision is placed, and excess skin is removed. Hemostasis is obtained (Figure 21-31, *A* to *C*).
3. The surgeon trims the orbicularis oculi muscle and identifies and excises the septum orbitale. Excess periorbital fat is trimmed and coagulated.
4. Upper lid incisions are closed; and the procedure is repeated for the opposite upper lid.
5. Finely crushed ice on moist gauze 4 × 4 pads may be applied to the periorbital region; other means of reducing swelling, such as cold compresses or a mechanical cold mask, may be similarly applied. Compresses are changed as often as they become warm.

Operative Procedure—Lower Lids

1. The surgeon marks the lines of incision and injects local anesthetic.
2. A subciliary incision (1 mm below eyelashes) is made and brought out in a natural line in the outer canthal skin.
3. The skin-muscle flap is raised, leaving a 3-mm strip of muscle attached to the tarsus (Figure 21-31, *D*).
4. The skin-muscle flap is dissected down below the level of the orbital rim.
5. The surgeon incises the arcus marginalis, and redundant fat with the overlying septum orbitale is draped over the orbital rim (Figure 21-31, *E*) and sutured.
6. Hemostasis is obtained. Skin is redraped in an upward and outward fashion with attention to prevention of ectropion.
7. Excess skin is trimmed (Figure 21-31, *F*).
8. Lateral muscle is sutured to periosteum.
9. The surgeon closes the lower lid incision, and repeats the procedure for the opposite lower lid.
10. Compresses are applied as described in the upper lid procedure.

Rhinoplasty

Deformities of the external nose and nasal septum may be congenital or secondary to previous trauma. The goal of rhinoplasty is to improve the appearance of the external nose. This is accomplished by reshaping the underlying framework of the nose, which allows the overlying skin and subcutaneous

tissue to redrape over the new framework. Reshaping the nasal skeleton usually includes use of a rasp for dorsal hump reduction, partial excision of lateral and alar cartilages, shortening of the septum, and osteotomy of nasal bones. A procedure to alter the nasal septum—septoplasty, or submucous resection (SMR)—often accompanies rhinoplasty. The goal of SMR is to improve the nasal airway by resecting a segment of septal cartilage. Septoplasty reshapes the existing septal cartilage; it may aid in altering the appearance of the nose or in improving the airway. Rhinoplasty may be performed as an open procedure by making an external incision across the base of the columella, or it may be performed entirely through the nostrils by using internal incisions. Small external incisions at the alar bases are used to narrow the nostrils, and internal incisions placed alongside the base of the nasal bones are used to narrow the entire nose once the hump is removed or dorsum is incised. A full description of rhinologic procedures may be found in Chapter 18.

Laser Surgery

Several different types of lasers are commonly used in plastic and reconstructive surgery (Box 21-3). One of the most popular types of laser is the skin resurfacing, or CO_2, laser. The laser is attracted to the water in the skin cells and ablates the cells at a predetermined depth. The collagen material is also heated, resulting in smoother and slightly tighter skin. This treatment has virtually replaced dermabrasion, because it is much more consistent in terms of depth of penetration and less dependent on user technique or skill.

Tattoo removal and destruction of vascular lesions, such as facial telangiectasias, spider veins, and hemangiomas, may be achieved with the use of other types of lasers. Whether using lasers for skin resurfacing or tattoo removal procedures, the areas must first be numbed with a local anesthetic. Use of sedation depends on the anxiety level of the patient as well as the total surface area to be treated. Vascular lesions may be treated without local anesthesia, although there is some temporary discomfort with each pulse of the laser.

Procedural Considerations. Laser safety and procedures are described in great detail in Chapter 7.

Liposuction

Liposuction is a surgical technique designed to remove excess deposits of fat and improve the contour of the body (Figure 21-32). It is not a treatment for obesity or simply a weight reduction procedure; rather, the ideal candidate is of normal weight and desires to remove localized fat that has proved resistant despite diet and exercise. By extension, liposuction patients must adhere to lifestyle changes (e.g., proper nutrition, adequate exercise) to maintain optimal results (Logan and Broughton, 2008). Although most often associated with contour correction, liposuction may also be used for treatment of gynecomastia or to remove lipomas. Areas that may be suctioned include face, neck, back, breasts (not a replacement for reduction mammoplasty, only contour correction), waist, abdomen, midriff, flanks, upper arms, hips, medial and lateral thighs, knees, and ankles (Figures 21-33 and 21-34).

Multiple techniques have been developed to enhance the final results as well as ease the removal of the fat. These techniques are not always used in isolation of each other; rather, some may be combined both to achieve the best possible outcome and to address the surgeon's preferences. Each procedure has specific equipment needed for that technique and often has highly specific cannulae and other instrumentation. Since multiple areas are usually treated, the perioperative nurse should determine the sequence of liposuction the surgeon prefers to be prepared for positioning.

Procedural Considerations. Immediate preoperative preparation includes asking the patient to stand while the area of deformity is outlined. The surgeon usually draws two lines on the skin surface—one delineating the major area of defect and the other placed a short distance outside the first area. These lines make it easier for the surgeon to make a smooth transition toward the normal tissue by adjusting the amount of fat removed from the center to the periphery of the

BOX 21-3

Lasers in Plastic Surgery

Common uses for lasers in plastic surgery include exfoliation, treatment of vascular malformations, removal of hair and tattoos, and tightening of collagen fibers in aging skin. A variety of lasers are available; selection of the appropriate laser is dependent on the patient's diagnosis because the effect of the laser on the skin tissue is dependent on its wavelength. The types of lasers and their common uses are described below.

Laser	Use
CO_2	Desiccation of benign lesions of skin, skin resurfacing, cutting tissue
Excimer	Eye surgery, psoriasis
Argon	Hemangiomas, telangiectasias
Nd:YAG	Benign pigmented lesions and red tattoos
Candela dye	Tattoos, pigmented benign lesions, hemangiomas
Helium-neon	Biostimulation, wound healing alleviation, acupuncture
Diode	Hair removal, tattoo removal
Ruby	Nevi removal, dark tattoos
Erbium:YAG	Rhytides
Q-Switch	Benign pigmented lesions and dark tattoos

BOX 21-3

Lasers in Plastic Surgery—cont'd

A, Laser removal of large facial telangiectasia. **B**, Laser removal of photoaging and lentigines on hands of woman in her sixties. **C**, Laser removal of multicolored tattoo on the posterior shoulder.

Continued

BOX 21-3

Lasers in Plastic Surgery—cont'd

D, Laser hair removal. E, Laser skin resurfacing and wrinkle tightening.

Modified from Choi JE et al: Treatment of Becker's nevi with a long-pulse alexandrite laser, *Dermatol Surg,* April 27 [Epub ahead of print], 2009; Kono T et al: Long-pulsed neodymium:yttrium-aluminum-garnet laser treatment for hypertrophic port-wine stains on the lips, *J Cosmet Laser Ther* 11(1):11-13, 2009; Krupashankar DS: Standard guidelines of care: CO_2 laser for removal of benign skin lesions and resurfacing, IADVL Dermatosurgery Task Force, *Indian J Dermatol Venereol Leprol* 74(suppl):S61-S67, 2008; Mendonca DA et al: Venous malformations of the limbs: the Birmingham experience, comparisons and classification in children, *J Plast Reconstr Aesthet Surg,* Dec 27 [Epub ahead of print], 2008; Onesti MG: Surgical and laser treatment of Sturge-Weber syndrome, *Aesthet Plast Surg,* Mar 19 [Epub ahead of print], 2009.

deformity. The patient may remain standing and be prepped circumferentially with a spray bottle of antimicrobial skin solution. The perioperative nurse provides for the patient's privacy and uses appropriate measures to protect the patient from hypothermia.

Preoperative patient education should include a discussion of the compression garment, which is typically worn for 2 to 4 weeks postoperatively. Patients should also be informed about the likelihood of the puncture sites leaking tumescent solution during the first 24 hours of the postoperative period. Absorbent dressings are required to minimize soiling of clothing and bedding during this period as well as to maintain the cleanliness of the compression garment.

Depending on the areas targeted for liposuction, draping may require a good deal of innovation. Minimal instrumentation is necessary—knife handle, towel clips, tissue forceps, scissors, clamps, and needle holder are used along with the suction cannulae specific to the proposed liposuction technique. A general anesthetic, moderate sedation, or epidural anesthetic may or may not be used. However, the surgeon

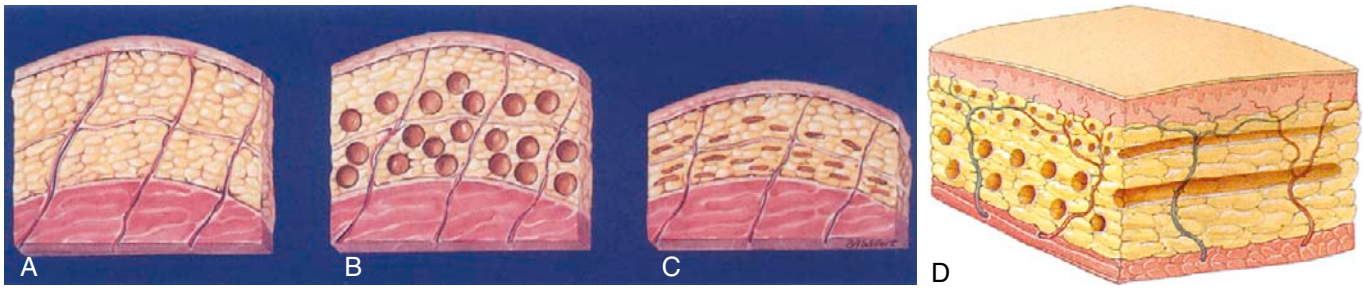


FIGURE 21-32 **A**, Normal appearance of excess fat. **B**, Removal of deep fat by larger-diameter cannulae. **C**, Corrected contour following removal of excess fat by liposuction. **D**, Removal of superficial fat involves using narrower-gauge cannulae.

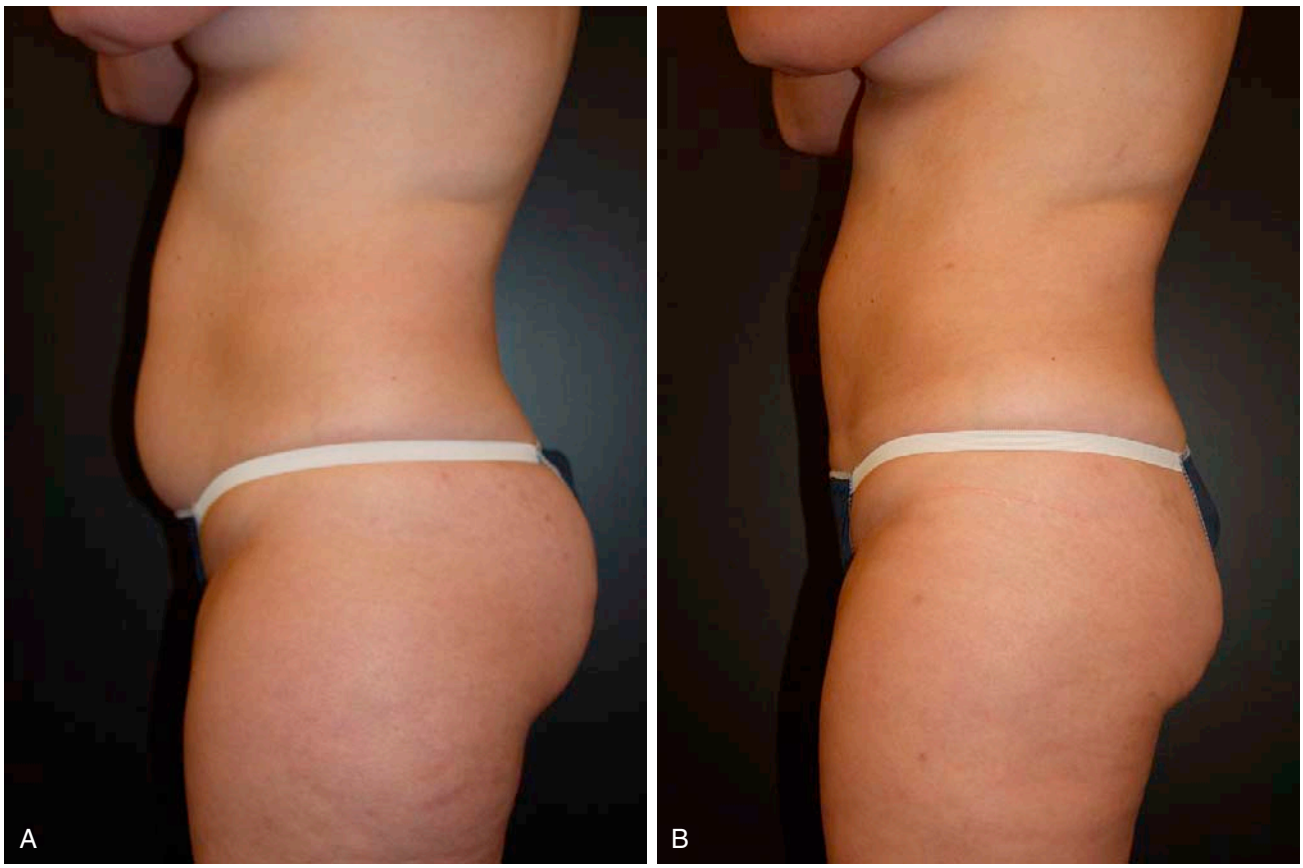


FIGURE 21-33 Female 43-year-old patient. **A**, Before and **B**, 6 months after liposuction of the abdomen and buttocks.

typically injects a medicated solution into the fatty areas before removal because of concerns about large fluid volume shift and blood loss after lipectomy. The solution contains IV solution (e.g., lactated Ringer's), lidocaine, and epinephrine. Using more than 70 ml/kg of wetting solution for infiltration can lead to fluid overload; this may present as increased blood pressure, jugular vein distention, bounding pulses, cough, dyspnea, lung crackles, and pulmonary edema. For safety issues, the nurse needs to communicate and verify with the surgeon the total lipoaspirate and volume of wetting solution used. Additionally, it is imperative that warmed wetting solution be used for suction-assisted lipectomy (Logan and Broughton, 2008).

In the tumescent technique, large volumes of this solution are administered. The "super-wet" technique uses less solution; usually the amount of fluid injected approximates the amount of fat to be removed—thus the name, which refers to the swollen and firm ("tumesced") state of the tissues when they are filled with solution. The perioperative nurse should inquire if the surgeon will be infiltrating tumescent solution and, if so, what ingredients are used for his or her technique. Also, the nurse should ask whether the surgeon uses internal or external ultrasound (sound waves that liquefy fat) or power-assisted liposuction. One of the newer techniques is the use of Vaser-Assisted LipoSelection, which incorporates thermal energy to liquefy the fat, thus aiding greatly in its removal.

FIGURE 21-34 Submental liposuction. **A**, Preoperative. **B**, Postoperative.

Operative Procedure

1. The surgeon places stablike incisions in concealed areas to access sites to be liposuctioned.
2. Tumescent solution is infused.
3. Depending on technique, at this point either internal or external ultrasound or the Vaser technique is performed at predetermined settings and length of time.
4. Liposuction is performed with the use of various sizes and lengths of cannulae. The cannula is attached to large-bore, firm suction tubing and connected to an aspirating unit. The high vacuum pressure caused by the unit causes the fat cells to emulsify so that they can be suctioned through the vacuum opening near the rounded tip of the cannula. Areas are usually cross-suctioned to achieve the best outcomes. Stab wounds may be closed with absorbable suture or left open to drain.
5. The patient's skin is cleaned, and bulky dressings and compression garments are applied.

Abdominoplasty

Abdominoplasty is particularly useful in improving the appearance (and to a certain extent, function) of persons who have lost a great deal of weight or who suffer from laxity of abdominal skin following pregnancy. Obesity produces distention and stretching of the skin of the abdomen. Weight loss reduces the volume of the underlying fat; however, it does not produce concomitant reduction in the excess surface area of the overlying skin, which results from destruction or insufficiency of elastic fibers in the skin. The rectus abdominis fascia is also stretched in obese patients, and weight loss does not restore its integrity.

There are several versions of the abdominoplasty procedure and the choice of which technique to use depends upon the degree of deformity of the abdominal skin and muscle. All techniques are designed to improve the appearance of the abdomen by tightening the abdominal area (abdominal wall/rectus muscles) and removing excess skin or fullness.

If there is minimal to no laxity of the skin and mostly fullness of the lower abdomen, then a "mini-abdominoplasty" may be indicated. With this technique it is not necessary to relocate or incise the umbilicus and a short incision, resembling a Pfannenstiel, may be effectively utilized. However, if there is laxity of the periumbilical and upper and lower abdominal skin accompanied by protrusion of the abdominal wall with diastasis (separation) of the rectus muscle, then full abdominoplasty is the procedure of choice. This version requires relocation of the umbilicus and an incision that stretches from hip to hip. Endoscopic abdominoplasty is another option if only muscle repair (correction of the diastasis deformity or shortening of the rectus muscles) is needed.

Procedural Considerations. A basic plastic instrument set is required, as well as extra retractors and clamping instruments, an ESU, and a sterile marking pen. Frequently tumescent anesthetic solution will be added to minimize bleeding, reduce postoperative discomfort, and aid in dissection. The perioperative nurse should ask the surgeon about the use of tumescent as well as preference for ingredients. A lighted fiberoptic retractor should be available. Sequential compression devices or antiembolism hose are usually in place or applied in the OR. The patient is in the supine position with slight flexion at the hips. Draping is such that the entire abdomen, lower costal margins, upper thighs, and both anterior iliac spines are exposed.

Operative Procedure

1. The surgeon makes a low transverse abdominal incision across both inguinal areas laterally and the superior border of the mons pubis in the midline down to fascia.
2. A large flap of skin and subcutaneous tissue is elevated away from the fascia of the anterior abdominal wall.
3. The umbilicus is circumscribed and left in its normal position.
4. The surgeon elevates the abdominal flap until the xiphoid process of the sternum and the lower costal margins are reached.

FIGURE 21-35 Belt lipectomy and thigh liposuction. The patient was a 40-year-old woman 40 months after gastric bypass surgery with a weight loss of 269 pounds.

5. If diastasis of the rectus abdominis fascia is present, the surgeon plicates it with suture from the xiphoid process to the mons pubis.
6. The flap of abdominal skin and subcutaneous tissue is pulled inferiorly, and excess tissue is excised.
7. A small incision is made in the midline of the flap to accommodate the umbilicus, which is then sutured peripherally to the flap.
8. Drains are inserted, followed by closure of the lower abdominal incision in layers.
9. Postoperatively the patient is placed in the hospital bed in high-Fowler position.

Post–Bariatric Surgery Body Contouring

Successful bariatric surgery produces significant weight loss. The weight loss may result in a trunk that lacks waist and hip definition; ptosis of the mons pubis; and various degrees of skin, fat, and abdominal wall laxity. Upper and lower back rolls accompany the anterior truncal deformities; the buttocks are lower and lack fullness. Upper arms and thighs exhibit similar deformities.

Treatment is aimed at removing the excessive skin and creating a desirable body contour. Most patients are candidates for some form of circumferential recontouring (belt lipectomy) (Figure 21-35) in combination with any number of other recontouring procedures: brachioplasty (Figure 21-36), thigh lifts (Figure 21-37), and mastopexy. For the perioperative nurse, these surgeries offer a logistical challenge because of the combination of procedures and positioning required. The malabsorptive effects of the original bariatric surgery may compromise postoperative wound healing after body contouring procedures. The perioperative nurse must be familiar with the complications relating to post–bariatric surgery body contouring to provide comprehensive care for this unique group of patients.

Procedural Considerations. Any form of body contouring will begin in the preoperative area, where extensive measuring and marking are performed by the plastic surgeon. The perioperative nurse should inquire about the ordering of the procedures and positioning if more than one is planned. Sequential compression devices and a Foley catheter should be used once the patient arrives in the OR. During prepping and draping, attempts should be made to preserve the patient's body temperature. Repositioning is a standard part of these procedures. Pressure points should be well padded with appropriate positioning aids to maintain functional alignment and stable positioning. With each repositioning activity, the patient must be reassessed for safety in terms of skin and nerve compression and competence of the grounding pad, Foley catheter, and all monitoring devices (Ide et al, 2008). A basic plastic surgery instrument set with additional towel clamps is used. Other supplies include a stapler for skin approximation, multiple drains, and the ESU. The surgeon may choose to use tissue adhesive products in

FIGURE 21-36 Brachioplasty.

FIGURE 21-37 Thigh lift.

combination with suture material to reduce the incidence of seroma. Compression garments may be applied, but care must be taken not to compromise the vascularity of the skin flaps.

Operative Procedure—Belt Lipectomy

Sites addressed are the abdomen, including mons pubis, upper and lower back, lateral trunk skin, buttocks, and lateral upper thighs.

1. The surgeon infuses dilute tumescent solution to aid in hemostasis and facilitate undermining of flaps.
2. Incisions are made and taken down to the level of the fascia, and flaps are elevated to previously marked margins. Liposuction cannulae without vacuum attachments may be used for undermining.
3. Liposuction is used if indicated for contouring only.
4. Muscle plication is performed when indicated.
5. The surgeon approximates and sutures the superficial fascia with permanent sutures.
6. Skin flaps are approximated, and excess skin is excised.
7. Closed-wound suction drains are inserted and secured with suture.
8. The patient is repositioned; depending on position at the start of the procedure, this could be lateral decubitus or supine.
9. Similar techniques are used for defects in areas presented by the new position and repeated until all areas are addressed, including relocation of the umbilicus.
10. The patient is cleaned, incisions are dressed, and a garment is applied at the surgeon's preference.
11. The patient is transferred to a stretcher or bed and placed in the flexed position.

Breast Surgeries

A variety of surgical procedures are available to enhance the aesthetic appearance of the breasts. Patients may choose to enlarge, reduce, and change the position of their breasts.

Augmentation Mammoplasty. Breast augmentation is performed for correction of hypomastia, to correct breast asymmetry, and to recreate the breast after mastectomy. A prosthesis is inserted to enlarge or form the breast mound.

Breast Implants. The two basic types of breast implants are saline filled and silicone gel filled. Both are now approved by the FDA for elective breast augmentation; in November 2006 the FDA approved the use of silicone gel filled breast implants for breast augmentation and breast reconstruction and revision surgeries (Gladfelter and Murphy, 2008). Of the total breast implants performed in 2008, 53% used saline and 47% used silicone (ASPS Stats, 2009).

Implants are configured into round or teardrop (also known as anatomic) shapes and may have a smooth or textured

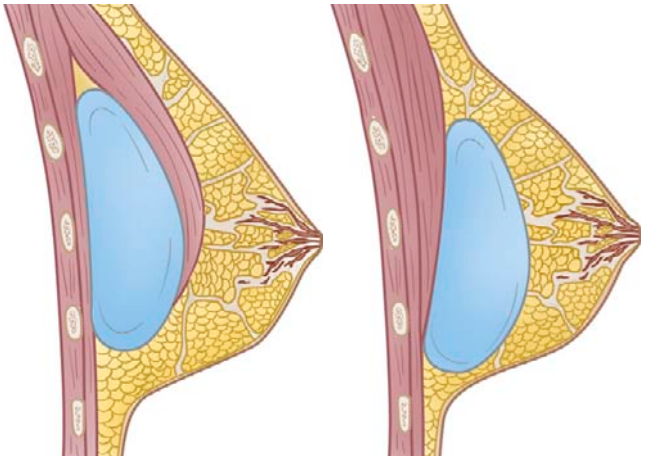


FIGURE 21-38 A, Augmentation mammoplasty implant under muscle. B, Implant under breast tissue.

surface. The surfaces are designed to minimize capsular contracture and migration. The choice to use a round or an anatomic implant is based on the shape and form of the existing breast.

PROCEDURAL CONSIDERATIONS. The perioperative nurse verifies style and size of implant and handles the implant according to the manufacturer's recommendations. Handling implants as little as possible assists in efforts to reduce the potential for implant contamination. A basic plastic instrument set is used, plus lighted fiberoptic retractors. The breast implants are packaged in sterile containers from the manufacturer and given to the scrub person when breast size is determined. Breast implants should only be filled with sterile injectable saline using a closed system designed for that purpose. The patient is supine. The arms may be extended on armboards to approximately 60 degrees. Prepping and draping are carried out in the routine manner to expose the operative site.

OPERATIVE PROCEDURE. The surgeon may perform augmentation mammoplasty through circumareolar, inframammary, axillary, or transumbilical incisions using an open or endoscopic approach. Depending on the anatomy of the patient and the surgeon's preference, breast implants may be placed subglandularly, subpectorally (Figure 21-38), or biplanar (partial muscle coverage).

OPERATIVE PROCEDURE—UNFILLED SALINE IMPLANTS

1. The surgeon may inject local anesthetic to decrease bleeding and provide analgesia.
2. An incision is made, the pocket is dissected, and hemostasis is achieved.
3. The surgeon may utilize breast implant sizers (gel or saline) to evaluate the size of the pocket and determine the size of the final implant.
4. With the sizers in place, the anesthesia provider elevates the patient to the 90-degree position so the surgeon can evaluate the appearance from various angles and plan for any adjustments or revisions to the pocket.
5. The sizers are removed, and the surgeon finalizes the pocket.
6. The perioperative nurse verifies the implant type and size again with the surgeon and dispenses it to the sterile field.
7. The surgeon rolls the implant into a cylindric shape in preparation for insertion.
8. The pocket is irrigated with saline or antibiotic solution.
9. The surgeon inserts the implant and unrolls it, and once it is properly positioned, the surgeon inflates the implant with an appropriate amount of saline.
10. The procedure is repeated for the opposite breast.
11. The incision is closed in two layers.
12. The patient is cleaned, and bandages and a surgical bra are applied.

Capsulotomy. Capsule contracture results from an exaggerated scar response to a foreign prosthetic material. All surgical implants undergo some degree of encapsulation, but clinical problems arise when this scar formation becomes excessive (Maxwell and Hartley, 2006). Depending on the extent of the contracture, an open capsulotomy may be used to release the constrictive tissue, or a capsulectomy may be indicated to actually remove the tissue (A Board Certified Plastic Surgeon Resource [ABCPSR], 2009).

PROCEDURAL CONSIDERATIONS. The patient is prepared and positioned in the same manner as for breast augmentation. Although patients receive education about capsule contracture as part of the informed consent process for breast augmentation, the actuality of the event may cause emotional distress for the patient. The patient may verbalize disappointment over the results and express fear related to additional postoperative changes in the appearance and functioning of the breast. In addition, the patient now faces the surgical and anesthetic risks associated with a second surgical procedure and may also be struggling with a possible financial burden because these procedures may not be covered by the patient's health plan. An empathetic and understanding approach is paramount to easing the patient's anxiety.

OPERATIVE PROCEDURE

1. The surgeon incises the skin and exposes the capsule.
2. The capsule is scored in multiple areas to achieve the desired release. Depending on the degree of contracture, circumferential incisions may be necessary to release the contracture.
3. If capsulotomy is not effective in releasing the capsule, a partial or full capsulectomy may be required to physically remove all or a portion of the capsule.
   a. The capsule is excised, and the breast implant is removed.
   b. The breast implant may be replaced in the same area, exchanged and replaced, or placed in a new pocket.
4. The site is irrigated with antibiotic solution. Drains are placed if a capsulectomy was performed.
5. The surgeon closes the incision in two layers.
6. The patient's skin is cleaned, and dressings are applied.

Reduction Mammoplasty. Reduction mammoplasty is indicated for the patient with macromastia with resulting back pain, intertrigo (chronic skin infection), or deep grooving in the shoulders from the bra straps because of the weight of the breasts (Patient and Family Education) (Research Highlight) (Figure 21-39, *A*). The procedure may also be performed to achieve symmetry after a mastectomy on the contralateral side. Excessive breast tissue and its overlying skin are excised, with reconstruction of the breast contour, size, shape, and symmetry (Figure 21-39, *B*).

PATIENT AND FAMILY EDUCATION

Patient Education for Breast Reduction

GENERAL INFORMATION

Women with very large, pendulous breasts (a condition known as macromastia) can experience a number of physical and emotional problems. Macromastia is generally defined as excessive breast size, usually a bra cup size of D or larger. This condition is seen in young girls to middle-aged women. The condition probably is caused by hormonal factors but is also associated with obesity. Often there is a family pattern of large breasts.

COMMON SIGNS AND SYMPTOMS

- Breast size that is out of proportion to the torso and larger than the accepted norm
- Upper back and neck pain
- Shoulder pain
- Arm pain
- Breast pain
- Rashes and sometimes infections of the skin under the breasts
- Shoulder grooving from bra straps
- Hyperpigmentation (dark marks) in the bra strap lines
- Difficulty in finding bras or clothing that fits
- Possibly shyness or other personality changes because of appearance and the effects of excessively large breasts

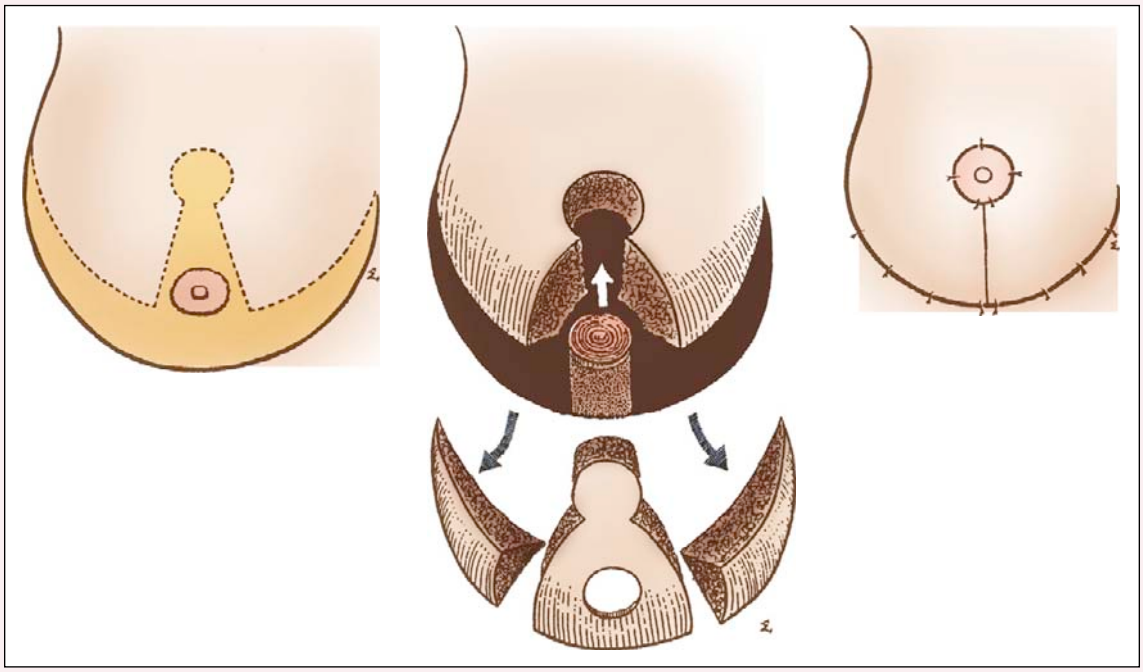
DIAGNOSIS

The surgeon will confirm the diagnosis of macromastia by examining the breasts carefully and relating the findings of the patient's history.

TREATMENT

- Women with large breasts have often tried custom bras and weight loss as a way of reducing breast size or adding support. Physical therapy and pain medications may also be used in an effort to relieve symptoms. After trying these methods without success, many women seek surgical help in the form of breast reduction surgery. Technically, breast reduction surgery is known as reduction mammoplasty.
- The best candidates for breast reduction usually have at least two of the symptoms listed in the aforementioned Common Signs and Symptoms category.
- Breast reduction surgery should be delayed if the breasts are still growing; also, if the patient is gaining or losing weight, they should consider delaying breast reduction until their weight has stabilized.
- The aims of the operation are the following:
  - To remove enough breast tissue to be able to construct a normal-appearing breast mound
  - To reposition the nipple-areola complex in a suitable position in the "new" breast

There are many operations to reduce large breasts. A common technique is shown in the figures.



PATIENT AND FAMILY EDUCATION

Patient Education for Breast Reduction—cont'd

PREPARING FOR THE OPERATION

- The surgeon will examine and measure the breasts and will probably photograph the patient for reference during the surgery and afterward.
- A mammogram may be ordered if patient is 35 years or older.
- If patient smokes, they should avoid smoking completely for at least 1 month before surgery. Smoking affects the blood vessels in the skin and can slow healing.
- The surgeon may instruct patient to avoid taking aspirin, nonsteroidal antiinflammatory drugs (ibuprofen [Motrin]), vitamin E, fenfluramine, or phentermine at least 2 weeks before surgery. These substances may interfere with normal blood clotting or with the ability to heal after surgery.
- Before surgery patient may want to do the following:
  - Wash hair (will not be able to shower or bathe immediately after surgery).
  - Arrange for temporary care for any house pets that may jump on him.
  - Move "daily use" items within arm's reach.
  - Fill any prescriptions from the surgeon.
- Following are common after this operation:
  - The sensation in the nipples probably will be decreased.
  - Patient may not be able to breastfeed.
  - Reading the mammogram may become more difficult for the physician because of the scarring inside the breast.
  - The scars from the operation may be prominent.
- On the day of the operation, the places where the incisions will be made on the breasts and the new position of the nipple-areola complex will be marked with dissolving ink while patient is in a sitting position.
- Patient may be given medicine that will make them feel drowsy before they are brought to the OR.

THE OPERATION

- Most women have general anesthesia (going to sleep) for breast reduction. Some surgeons may perform the procedure with a local anesthetic and sedation.
- The operation generally takes 3 to 4 hours.

AFTER YOUR OPERATION

- Patient will be taken to a recovery room and observed. When blood pressure, pulse, and breathing are stable, they will be taken to a regular hospital room.
- Patient will be wrapped in elastic bandages or a surgical bra over gauze. Small plastic tubes will be coming from the breast incisions and will be connected to small plastic bulbs. They drain any extra fluid that needs to come out.
- Many breast reduction surgeries are done as outpatient procedures, in which case the patient will go home after they wake up from the anesthesia and the pain is under good control. In some cases they may stay in the hospital after surgery for a short period (1 or 2 days).
- Recovery is different for every patient, but bed rest may only be needed for 1 or 2 days after the procedure. Even in the first 24 to 48 hours after surgery it is important for them to get out of bed and walk around every 2 hours during the day and early evening. Continuous bed rest after surgery may increase your risks for pneumonia or blood clots.
- As with any operation, complications are always possible. With this type of operation, they can include bleeding, infection, delayed wound healing, abnormal scarring, and shape irregularities.

HOME CARE

Patient will want to take it easy at first, but may walk about as they wish, even climb stairs, but should not overdo things. Avoid heavy exercise, heavy lifting, or stress on the upper body for 1 month. Items that can be helpful as you recover include the following:

- A body or sitting support pillow
- Cordless phone
- Variety of easy-to-cook or precooked meals
- Two or three loose-fitting robes or housedresses with snaps in the front and large pockets
- Slip-on shoes
- Soft sponge for bathing before showering is allowed
- Small containers for drinks (gallon containers are very heavy)
- A listing of physicians, pharmacy, and caregivers/helpers with telephone contact information. The patient should call the surgeon if any of the following occurs:
  - The incisions become red or swollen, or there is drainage from them.
  - The patient develops a temperature higher than 37.8° C (100° F).
  - The patient has any questions.

Modified from *Consumer's guide to breast reduction,* available at www.plasticsurgery.org/Patients_and_Consumers/Procedures/Reconstructive_Procedures/Breast_Reduction/Consumers_Guide_to_Breast_Reduction.html. Accessed July 5, 2009; Jones G: Breast reduction. In Mathes SJ, editor: *Plastic surgery,* vol 6, ed 2, Philadelphia, 2006, Saunders.

RESEARCH HIGHLIGHT

A Phenomenologic Study in Breast Reduction Patients

Researchers explored women's perception of life after breast reduction surgery in an effort to understand subjective issues for these patients. A limitation of this study was the use of a small convenience sample of nine patients interviewed at follow-up visits; in addition, one of the researchers was a novice in this field. However, the data collected gave a qualitative aspect to an event that had been studied for surgical technique or physical symptoms. The study intended to gather detailed, descriptive information to reflect women's experiences after this surgery.

After obtaining informed consent data were collected in a private exam room in the office. Open-ended questions were asked, such as "What is life like following your breast reduction?" Prompts (e.g., "tell me more") were also used in an unstructured interview. Field notes were taken and interviews audiotaped for later analysis.

Findings revealed the following themes; explanations through patient quotes were listed in the article:

- Enhanced physical health
- Improved body image
- Increased self-esteem
- Increased self-confidence
- Dissatisfaction with the postoperative recovery period/though pleased overall with above aspects (this may be due to method, in that patients requiring follow-up care 5 months to 3 years after surgery may have more issues than a typical patient)

Implications for nursing and future research emphasize the need for adequate patient education for realistic expectations. As patient advocates, nurses should encourage communication with the plastic surgery team to facilitate referral for possible breast reduction surgery when patients verbalize issues commonly seen with breast hypertrophy. Nurses working in plastic surgery should ensure preoperative education includes important surgical and postoperative findings based on the evidence. Future research includes determining whether patients are receiving adequate information prospectively to have realistic expectations following surgery. Understanding the rationale for postoperative difficulties or for the extended time in making the decision to have breast reduction surgery could lead to new nursing interventions. Finally, this research should be replicated in patients who did not need to return to the plastic surgeon's office following the routine 90-day postoperative period.

Modified from Woodman R, Radzyminski S: Women's perception of life following breast reduction: a phenomenological study, *Plast Surg Nurs* 27(2): 85-95, 2007.

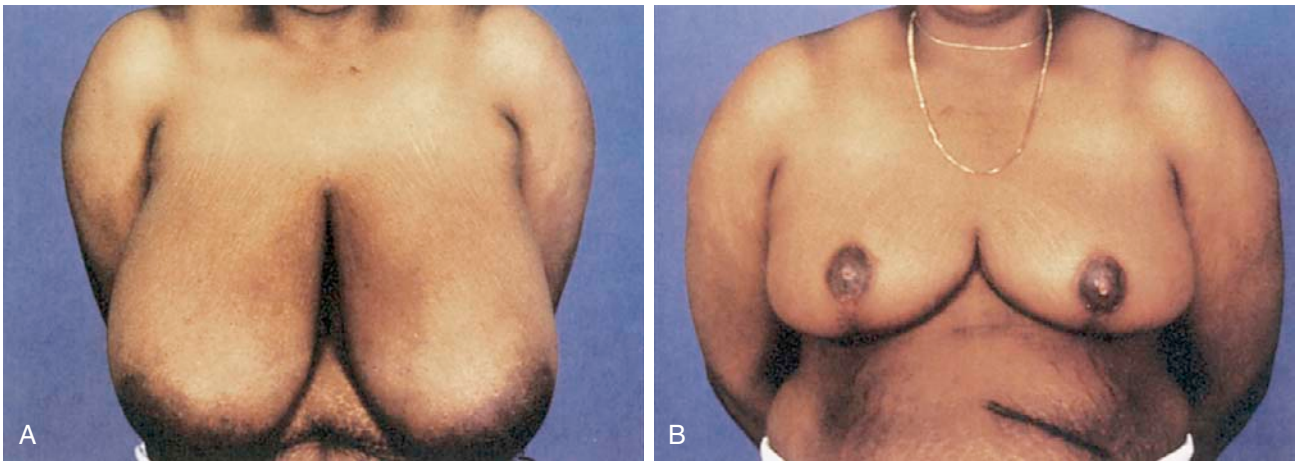


FIGURE 21-39 A, Preoperative view of reduction mammoplasty. B, Postoperative view.

PROCEDURAL CONSIDERATIONS. A basic plastic instrument set is used with the addition of a "cookie cutter" areola marker or a "keyhole" pattern marker, a sterile marking pen, skin stapler, tape measure, baby Deaver retractors, and two closed-wound suction systems. The ESU and a scale for weighing specimens should also be available, and tissue from each side should be carefully weighed and marked appropriately. The perioperative nurse should ensure the scale is calibrated correctly before weighing any tissue. Numerous blades will be used if deepithelializing breast skin. If the nipple is removed and placed as a free nipple graft, extra suture will be necessary for tie-over bolsters. There are numerous choices in the reduction mammoplasty technique; therefore before opening suture or other supplies, the perioperative nurse should ask the surgeon which technique will be employed. The surgeon will mark the skin to be excised and the new site for the nipple preoperatively with the patient in a sitting position.

The patient is supine with arms slightly extended on padded armboards. The hips should be positioned at the break in the OR bed so that the patient may be raised to a sitting position if necessary. Standard prepping and draping are done. Care should be taken not to remove the preoperative markings.

OPERATIVE PROCEDURE. The standard reduction mammoplasty procedure is described below. If the surgeon is using the "short scar" technique, the breast tissue is incised and removed according to the technique chosen. The nipple pedicle technique, wherein the nipple is mobilized and secured in a new position, may be chosen, or a free nipple graft may be utilized.

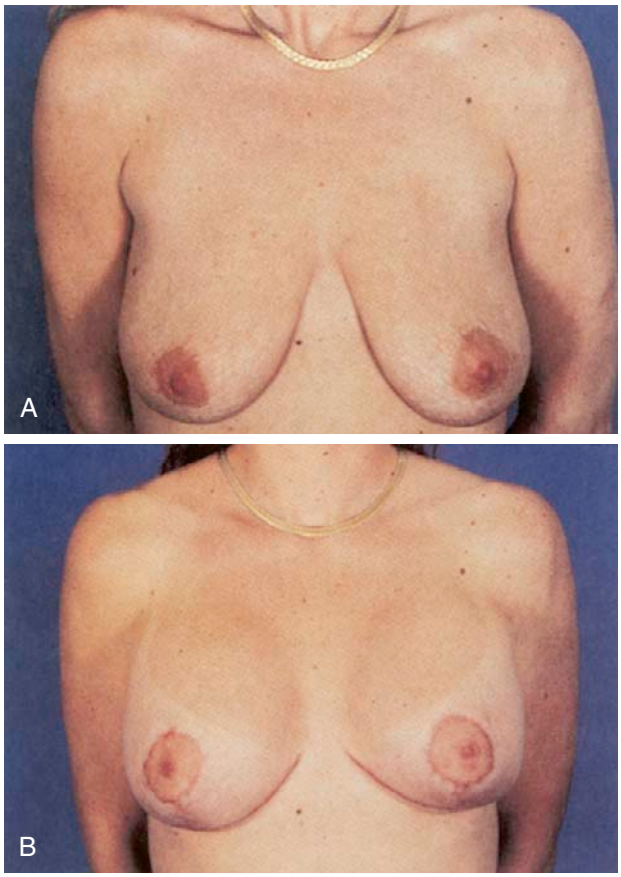


FIGURE 21-40 Mastopexy. **A**, Preoperative view. **B**, Postoperative view; ptosis corrected.

1. The surgeon incises and removes the skin between the new and the old nipple sites, with the nipple remaining attached to the underlying breast tissue. On patients with very large breasts, the nipples are removed and then reapplied as free grafts when the reduction is complete.
2. The redundant segment of breast tissue inferior to the nipple is excised through an inverted-T incision. Tissue from each breast is weighed and kept separate.
3. The surgeon mobilizes the nipple and adjacent tissue and sutures them in place.
4. The medial and lateral skin edges are approximated in a vertical suture line inferior to the nipple.
5. The inframammary elliptic incision is trimmed and closed transversely. Closed-wound suction catheters may be placed. The wound is dressed.

Mastopexy. Breast ptosis is corrected by moving the nipple to a more normal position and removing excess breast skin (Figure 21-40). With mastopexy surgery there is usually minimal to no removal of breast tissue, although it may be necessary to add a breast implant to achieve the desired result.

PROCEDURAL CONSIDERATIONS. The surgeon will mark the patient before surgery. Positioning is similar to that used for breast augmentation. Skin incision choices are periareolar only; periareolar combined with a vertical (known as a short scar or vertical mastopexy); the classic inverted T, which adds an inframammary incision to the previous incision; or the horizontal inframammary, which combines the periareolar and inframammary, leaving out the vertical component. Mastopexy may involve reduction of the skin envelope only or combine skin removal with glandular reshaping and placement in a more desirable position.

OPERATIVE PROCEDURE

1. Incisions are placed; one or more of the following techniques are used:
   a. Excess skin is removed.
   b. The breast cone is reshaped by invagination of lower midbreast tissue.
   c. The lower submammary breast tissue pedicle is advanced below the breast tissue and tacked superiorly to the pectoral muscle.
   d. Lower midbreast tissue is incised and overlapped.
   e. A superiorly based (on the nipple-areolar complex pedicle) wedge tissue flap is created, turned under, and superiorly attached.
   f. The upper pole of breast tissue is mobilized and advanced superiorly and tacked to the pectoral muscle fascia.
2. The breast may be sutured entirely at this time or approximated, and the same procedure is applied to the opposite breast, closing both at the end of the procedure.
3. The operative area is cleaned, dressings of choice are applied, and a surgical bra is applied.

Excision of Gynecomastia. Gynecomastia is a relatively common pathologic condition that consists of bilateral or unilateral enlargement of the male breast. It occurs primarily during puberty or after the age of 40 years. Although it may be produced by a variety of diseases or be the result of side effects related to certain medications, it is usually related to excessive hormone production or alterations in hormonal balance. It may also be seen in elderly men and in men after excessive use of marijuana. All subareolar fibroglandular tissue is removed, and the resultant defect is surgically closed (Figure 21-41). The patient may be positioned in a supine position or semi-Fowler position, according to the surgeon's preference. Supplies and equipment needed are the same as those for a simple mastectomy, plus a basic plastic instrument set. Because suction-assisted lipectomy (SAL) may be used for contouring, suction cannulae, associated supplies, and an aspirator should also be available. All breast tissue removed should be weighed and then sent for pathologic examination. Although infrequent, men are not immune from breast cancer.

OPERATIVE PROCEDURE

1. The surgeon instills local anesthetic and makes a stab wound incision for introduction of the liposuction cannula.
2. Liposuction is performed. If satisfactory removal of breast tissue is accomplished, the incision is closed and a compression garment applied.
3. If additional surgery is required, the surgeon makes a periareolar incision. Through this incision, the fibrous and ductal attachments of the underlying glandular tissue to the nipple are divided.
4. A cuff of fatty tissue is left attached to the underlying nipple surface to protect the blood supply.
5. The breast tissue mass is dissected. Carrying the dissection to the pectoralis fascia is usually necessary to remove the entire mass.
6. Hemostasis is achieved.
7. Closure is performed, the area cleaned, and a compression garment applied.

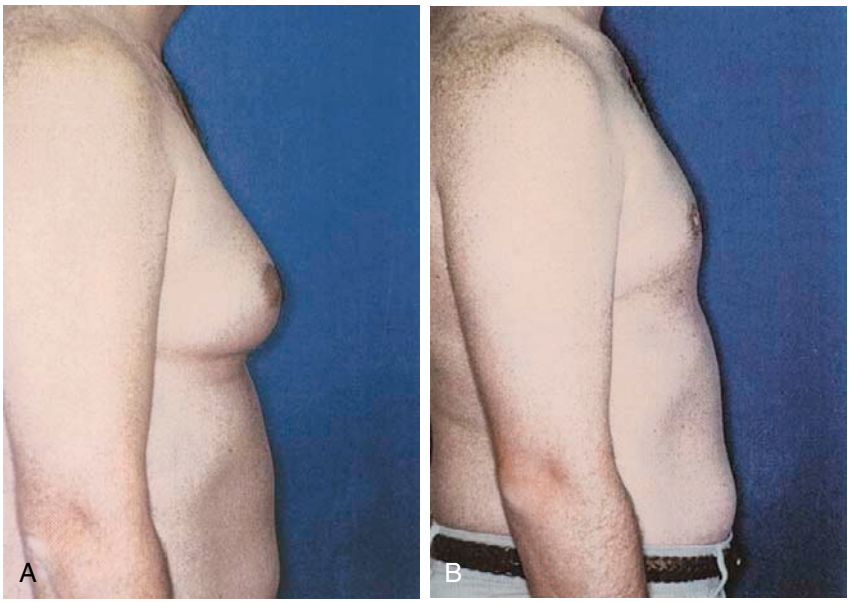


FIGURE 21-41 **A**, Preoperative view of gynecomastia. **B**, Postoperative view after excision of gynecomastia.

REFERENCES

A Board Certified Plastic Surgeon Resource (ABCPSR) (2009): Capsular contracture, available at www.aboardcertifiedplasticsurgeonresource.com/breast_augmentation/capsular_contracture/index.html. Accessed June 28, 2009.

American Burn Association (ABA): Burn incidence and treatment in the US: 2007, available at www.ameriburn.org/resources_factsheet.php. Accessed June 27, 2009.

American Cancer Society (ACS): Breast reconstruction after mastectomy, 2009, available at www.cancer.org/docroot/CRI/content/CRI_2_6X_Breast_Reconstruction_After_Mastectomy_5.asp?sitearea=. Accessed Nov. 21, 2009.

American Society of Plastic Surgeons (ASPS): Quick facts: percentage change 2008 vs. 2007, available at www.plasticsurgery.org/media/stats/2008-quick-facts-cosmetic-surgery-minimally-invasive-statistics.pdf. Accessed June 11, 2009.

American Society of Plastic Surgeons (ASPS) Stats, 2000/2007/2008 National plastic surgery statistics: Cosmetic and reconstructive procedure trends 2009, available at www.plasticsurgery.org/media/stats/2008-cosmetic-reconstructive-plastic-surgery-minimally-invasive-statistics.pdf. Accessed June 20, 2009.

American Society of Plastic Surgeons (ASPS) 2009a: Patients and consumers: planning your surgery: plastic surgery and total patient care, available at www.plasticsurgery.org/Patients_and_Consumers/Planning_Your_Surgery/Plastic_Surgery_and_Total_Patient_Care.html. Accessed June 19, 2009.

American Society of Plastic Surgeons (ASPS) 2009b: Patients and consumers: planning your surgery: psychological aspects: your self-image and plastic surgery, available at www.plasticsurgery.org/Patients_and_Consumers/Planning_Your_Surgery/Psychological_Aspects_Your_Self-Image_and_Plastic_Surgery.html. Accessed June 26, 2009.

American Society of Plastic Surgeons (ASPS) 2009c: Breast reconstruction, available at www.plasticsurgery.org/public_education/procedures/BreastReconstruction.cfm. Accessed July 8, 2009.

Association of periOperative Registered Nurses (AORN): In Peterson C, editor: *The perioperative nursing data set: the perioperative nursing vocabulary, revised*, 2nd ed, Denver, 2007, The Association.

Association of periOperative Registered Nurses (AORN): Recommended practices for managing the patient receiving local anesthesia. In *Perioperative standards and recommended practices*, Denver, 2009, The Association.

Barberio JA: *Nurse's pocket drug guide 2007*, New York, 2007, McGraw-Hill.

Clayton JL: Special needs of older adults undergoing surgery, *AORN J* 87(3):557–570, 2008.

Cuzzell J, Workman ML: Interventions for clients with skin problems. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care*, ed 6, St. Louis, 2010, Saunders.

Denholm B: Tucking patient's arms and general positioning, *AORN J* 89(4):755–757, 2009.

Department of Defense (DOD): Patient safety program: about TeamSTEPPS (2009), available at http://dodpatientsafety.usuhs.mil/index.php?name=News&file=article&sid=31. Accessed June 26, 2009.

Edwards C et al: The SGAP flap for the postmastectomy patient, *OR Nurse* 3(3):28–34, 2009.

Gladfelter J: Compression garments 101, *Plast Surg Nurs* 27(2):73–77, 2007.

Gladfelter J, Murphy D: Breast augmentation motivations and satisfaction: a prospective study of more than 3,000 silicone implantations, *Plast Surg Nurs* 28(4):170–174, 2008.

Gutierrez KJ, Peterson PG: Alterations in integumentary function. In *Saunders nursing survival guide, Pathophysiology*, St Louis, 2007, Saunders.

Hagan KF: Clinical photography for the plastic surgery practice-the basics, *Plast Surg Nurs* 28(4):188–192, 2008.

Health Stream: *Infection prevention for surgical site care, (study guide). (Grant funds provided by Enturia). (Health Stream is accredited as provider of continuing nursing education by the American Nurses Credentialing Center's Commission on Accreditation)*, Denver, 2007, Health Stream, p. 13.

Ide P et al: Perioperative nursing care of the bariatric surgical patient, *AORN J* 88(1):30–54, 2008.

Lehne RA: Local anesthetics. In Lehne RA, editor: *Pharmacology for nursing care*, ed 4, St Louis, 2007, Saunders.

Lenth A: AORN offers patient handoff tool kit. In Management connections, June 2007, available at www.aorn.org/Managers/June2007Issue/PatientHandOffToolKit/. Accessed June 26, 2009.

Logan JM, Broughton G: Plastic surgery: Understanding abdominoplasty and liposuction, *AORN J* 88(4):587–600, 2008.

Marler JJ, Upton JJ: Tissue engineering. In Mathes SJ, editor: *Plastic surgery*, vol 1, ed 2, Philadelphia, 2006, Saunders.

Maxwell GP, Hartley RW: Breast augmentation, In Mathes SJ, editor: *Plastic surgery*, vol 1, ed 2, Philadelphia, 2006, Saunders.

National Cancer Institute, U.S. National Institutes of Health (NCI): Skin cancer, available at www.cancer.gov/cancertopics/types/skin. Accessed June 27, 2009.

Pfiedler Enterprises: Maxillofacial injuries: Perioperative patient care, 2007, CECredit booklet [Pfiedler Enterprises is approved as an Authorized Provider by the International Association for Continuing Education and Training (IACET), Washington, DC] and was offered through AORN for ANCC credit, (grant funds provided by Stryker Craniomaxillofacial).

Sladden MJ et al: Surgical excision margins for localised cutaneous melanoma (Protocol). Cochrane Database of Systematic Reviews 2004, Issue 3. Art. No.: CD004835. DOI: 10.1002/14651858.CD004835, available at http://mrw.interscience.wiley.com/cochrane/clsysrev/articles/CD004835/frame.html. Accessed May 13, 2009.

Song DH et al: Plastic and reconstructive surgery essentials for students, 2007, available at www.plasticsurgery.org/d.xml?comp=x1504. Accessed June 27, 2009.

Wei F, Suominen S: Principles and techniques of microvascular surgery. In Mathes SJ, editor: *Plastic surgery*, vol 1, ed 2, Philadelphia, 2006, Saunders.

Zgonis T et al: Surgical management of diabetic foot infections and amputations, *AORN J* 87(5):935–946, 2008a.

Zgonis T et al: Plastic surgery reconstruction of the diabetic foot, *AORN J* 87(5):951–965, 2008b.

CHAPTER 22

Thoracic Surgery

BRIAN BLANCHARD

Thoracic surgery, like other specialties, has evolved with the development of surgical techniques and treatments, such as blood transfusion, anesthetic delivery, and screening procedures. During the past 50 years the understanding of pathophysiology and improved techniques have expanded the field of thoracic surgery. The thoracic specialty extends beyond the surgical arena into infectious disease, trauma, and oncology. Improved technology and the determination to treat diseases previously considered untreatable with operative and other invasive procedures continue to improve the recovery rate for patients experiencing thoracic diseases. As the ability to treat thoracic disease has improved, the responsibilities of the perioperative nurse have expanded, resulting in accomplishments throughout the years that have provided an extensive knowledge base and specialized perioperative practitioners.

Surgical Anatomy

The skeletal framework of the thorax is formed anteriorly by the sternum and costal cartilages, laterally by the 12 pairs of ribs, and posteriorly by the 12 thoracic vertebrae (Figure 22-1). This airtight compartment is enclosed in the root of the neck by Sibson's fascia and is separated from the abdomen by the diaphragm.

The sternum forms the anterior thoracic wall in the midline. It consists of three parts: (1) the upper part, or manubrium; (2) the body, or gladiolus; and (3) the lower cartilage, or xiphoid process. The manubrium articulates with the clavicles and the first two ribs on each side; the gladiolus articulates with the remaining true ribs by separate costal cartilages; and the xiphoid fuses with the gladiolus in early development and is attached to the diaphragm by the substernal ligament.

Normally the lateral walls of the thorax are formed by the 12 pairs of ribs. Posteriorly, each pair of ribs articulates with its corresponding thoracic vertebrae. Anteriorly, the first seven ribs articulate with the sternum. The eighth, ninth, and tenth ribs articulate with the costal cartilages of the rib above; however, the eleventh and twelfth ribs are not fixed to the costal arch (see Figure 22-1).

The muscles of each hemithorax (Figures 22-2 and 22-3) include the 11 external and 11 internal intercostal muscles, which fill the spaces between the ribs. An intercostal artery, vein, and nerve accompany each intercostal muscle. The arteries communicate with the internal thoracic artery anteriorly and arise from the aorta posteriorly. The intercostal veins follow the course of the arteries and communicate with the mammary veins anteriorly and with the azygos and hemiazygos veins posteriorly.

During surgery, great care is taken to prevent injury to the intercostal nerve, which passes forward and alongside the posterior intercostal artery and shares with the superior branch of the artery the intercostal groove on the inferior edge of the corresponding rib. When the nerve must be disturbed, an anesthetic agent may be injected to prevent postoperative pain.

The thoracic outlet is a junction bound anteriorly by the manubrium, anterolaterally by the first ribs, and posteriorly by the first thoracic vertebrae and posterior angles of the first ribs of the space. The great vessels of the head, neck, and arm pass through this space. Compression of these structures causes thoracic outlet syndrome.

The mediastinum is divided into anterior, middle, and posterior compartments. The anterior mediastinum is bound anteriorly by the sternum and posteriorly by the pericardium and great vessels. It contains the thymus gland, lymph nodes, and pericardial fat. The middle mediastinum is bound anteriorly by the pericardium and great vessels and posteriorly by the anterior border of the vertebral bodies. The posterior mediastinum is bound anteriorly by the vertebral bodies and extends posteriorly to the chest wall.

The chest cavity is subdivided into the right and the left pleural cavities, which contain the lungs separated by the mediastinum, which lies medially between the two pleural membranes. The parietal pleura, the membrane that lines the inner surface of each hemithorax, is adjacent to the inner surfaces of the ribs posteriorly and the mediastinum medially and covers the surface of the diaphragm except at the central portion. Part of the parietal membrane is reflected back at the root of each lung to form a sac around it. This reflection is called the *visceral pleura.* The pleural space holds about 50 ml of pleural fluid, a serous secretion that provides lubrication between these two membranes to minimize friction during inspiration and expiration (Coughlin and Parchinsky, 2006).

The lungs are the essential organs of respiration. The base of each lung rests on the diaphragm, whereas its apex (upper end) projects into the base of the neck at a level above the first rib. The bronchus, the nerves, the lymphatics, and the pulmonary and bronchial vessels enter and leave the lung on the mediastinal surface in a structure known as the *hilum,* or *root,* of the lung. Deep fissures divide the spongy, porous lung into lobes. The primary bronchi divide and then subdivide into each lobe and eventually become bronchioles. The right lung has an upper, a middle, and a lower lobe; the left lung has only an upper and a lower lobe (Figure 22-4). However, the lungs are similar in that each is composed of 10 major segments

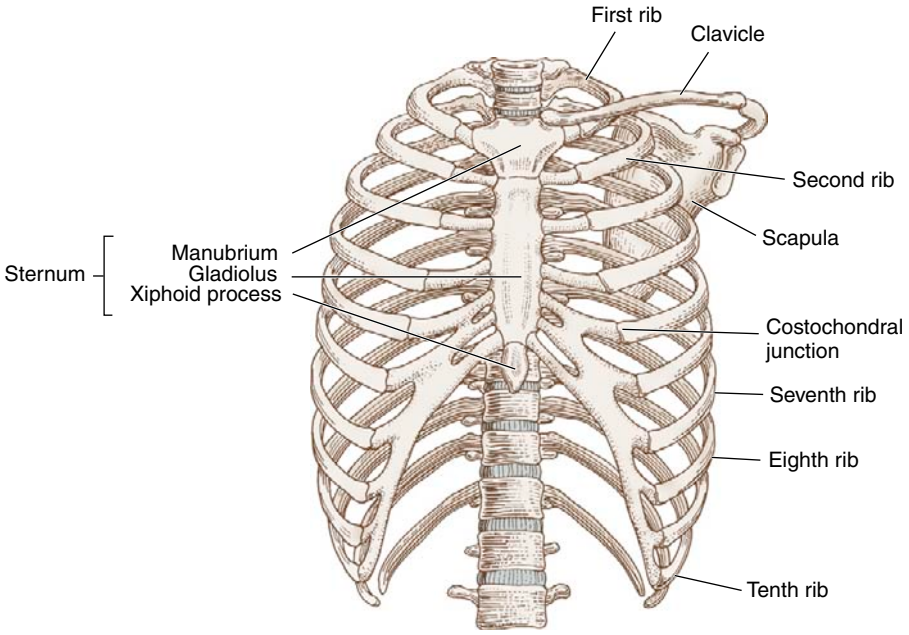


FIGURE 22-1 Bony thorax.

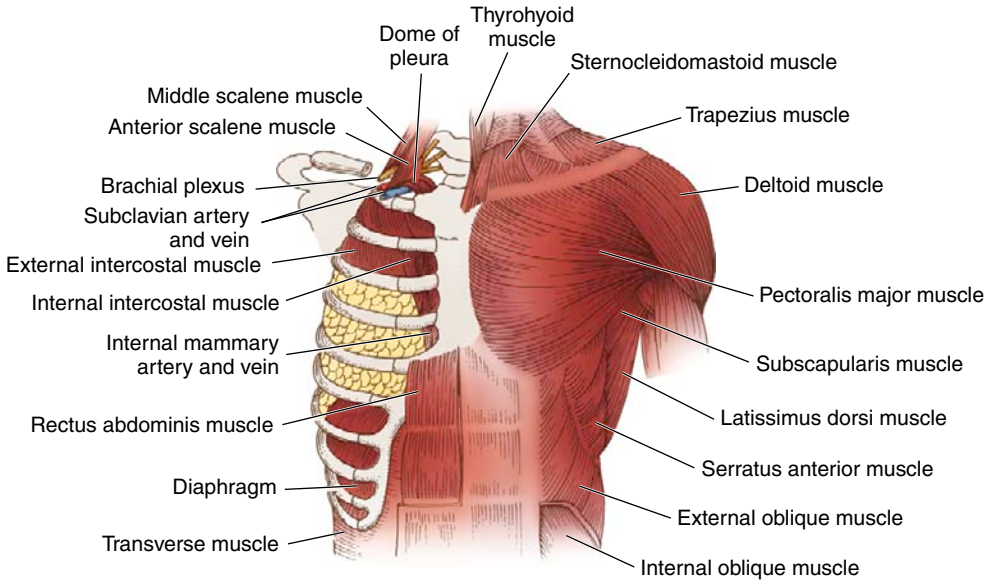


FIGURE 22-2 Anterior view of thorax and contiguous portions of base of neck and anterior abdominal wall. *Right half,* Superficial layer of muscles and fascia; *left half,* relations of deep muscles of neck and abdomen to rib cage, intercostal muscles, diaphragm, and internal mammary vessels; relations of muscles, nerves, and vessels with first rib; and anterior relations of lung.

(Figure 22-5). Each segment extends to the pleural surface, expanding in volume from its center to its peripheral edges. Each segment also has its own bronchus and branches of the pulmonary artery and vein.

The bronchial arteries, arising from the aorta, supply nourishment to the lungs. They vary in their number and course. The arrangement may include two branches to the left lung and one branch to the right lung, which later branches into two, or there may be one or two branches for each lung. The pulmonary arteries carry the blood to the pulmonary parenchyma, and the pulmonary veins transport the oxygenated blood to the left atrium.

The nerves of the lungs are a part of the autonomic nervous system (see Chapter 20). They regulate constriction and relaxation of the bronchi and of the blood vessels within the lungs.

Although the thoracic cavity is an airtight space, the lungs receive outside air through the nasal passages, trachea, and bronchi. The main function of the lungs is to exchange carbon dioxide for oxygen. Normally, as the thorax expands, the lungs also expand as air is drawn in; during expiration, the

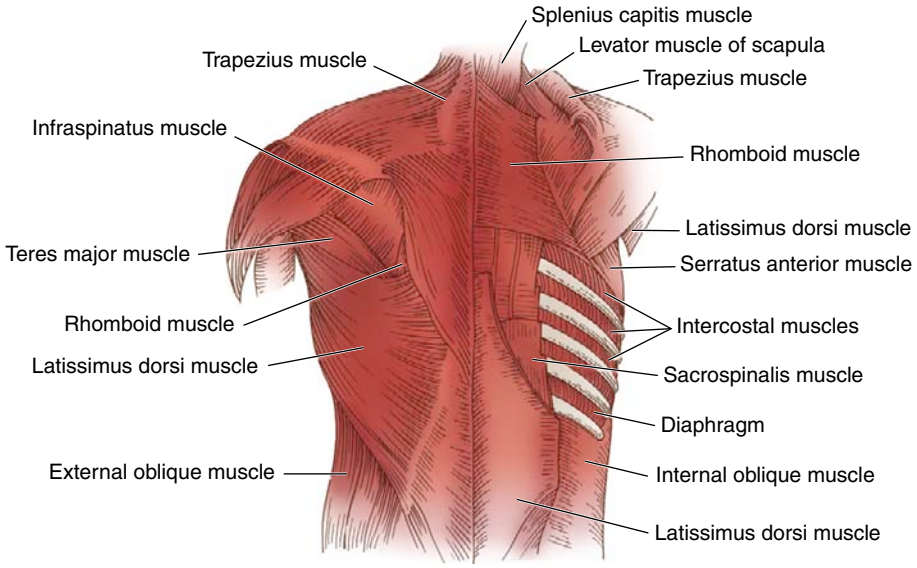


FIGURE 22-3 Posterior view of thorax and contiguous portions of neck and abdominal wall. *Left half,* Superficial muscles; *right half,* deeper muscles.

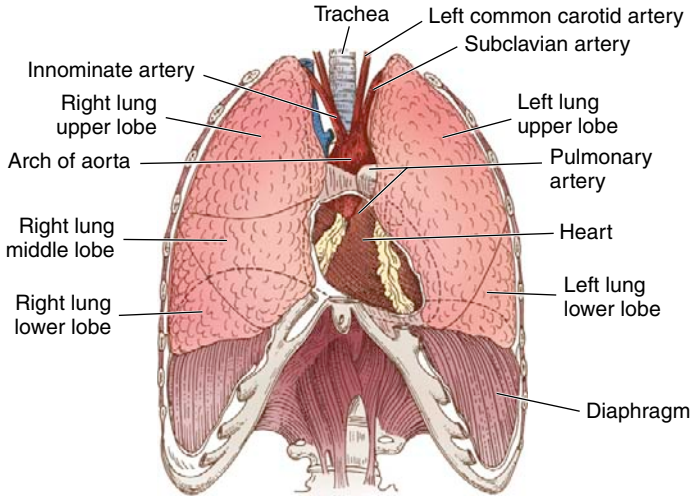


FIGURE 22-4 Organs of thoracic cavity. Part of pericardium has been removed to expose heart.

thorax relaxes and the lungs passively contract as air is forced out. Inspiration normally takes place when the intrathoracic pressure is slightly below atmospheric pressure (76 cm Hg, or 760 mm Hg) and when a partial vacuum exists between the parietal and visceral pleural (intrathoracic) surfaces. As the muscles of inspiration contract to enlarge the chest cage, the lungs passively follow the diaphragm and chest wall because of decreased intrathoracic pressure. The acts of inspiration and expiration are the result of air moving in and out of the lung, causing pressure to equalize with that of the atmosphere at the end of expiration.

The normal intrapleural pressure varies from –9 to –12 cm H_2O during inspiration and from about –3 to –6 cm H_2O during expiration. The greatest amount of air that can be expired after a maximum inspiration is termed the *vital capacity,* and the volume of gas remaining in the lungs after maximal expiration is *residual volume.* Size, age, gender, and pulmonary disease of the patient influence vital capacity. Any condition that interferes with the normally negative intrapleural pressure affects respiratory function.

Perioperative Nursing Considerations

Assessment

During assessment, the perioperative nurse gathers information that is important to planning patient care. Signs and symptoms demonstrated by the patient are confirmed by the perioperative nurse during the admission assessment. The nurse may begin data collection by identifying the patient (Patient Safety) and confirming the correct surgical site. A thorough review of the patient's medical record, including

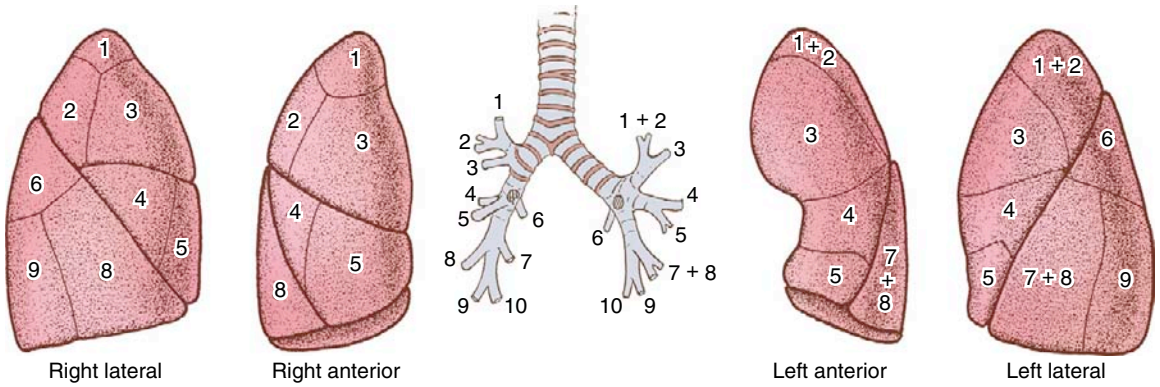


FIGURE 22-5 Segments of the pulmonary lobes. *RLL*, Right lower lobe.

PATIENT SAFETY

Patient Identification

Like the hospital gown, the wrist identification band is a traditional part of the "patient" persona and is linked to the routine of verification before administering medications, treatments, or procedures. When the wristband is present and has correct information, it can be a reliable identifier.

Patients undergoing thoracic procedures are at risk for identification errors because their wristbands are often removed to provide access for starting intravenous (IV) and other invasive monitoring lines or may be inaccessible because of positioning or draping. Correctly identifying the patient is an important Joint Commission National Patient Safety Goal. Research from The Joint Commission found that incorrect patient identification was involved in 13% of surgical errors and 67% of transfusion errors. The nurse must be familiar with the institutional policy regarding patient identification and the methods and procedures used to accomplish it. If a band is removed it should never be retaped in a new location or taped or pinned to the patient's gown. The band that is retaped or repaired may not maintain its integrity. A band pinned to a gown is easily lost if the gown is removed or replaced. The nurse should anticipate that identification bands may need to be removed for access purposes and ensure replacement bands are available. If the patient's arms are not accessible, the nurse should consider placing the new band on the patient's ankle.

Some organizations use color-coded identification bands to indicate allergies, blood type, or do-not-resuscitate (DNR) orders. Nurses must be familiar with the color coding used by the institution to avoid misidentification.

Technology is available to support the patient identification process. Many identification bands include bar codes that can be read with handheld bar code readers. Bar codes allow nurses to verify identity and capture other important data. A bar code identification band meets the American Hospital Association's guidelines for a tamperproof, nontransferable identification band.

Newer technology uses radiofrequency identification (RFID) systems for accurate patient verification. RFID remotely collects information and stores it on a system consisting of tags (transponders) and readers (interrogators). Microchips inside the tags contain more than 100 times the information of bar codes. The chip can contain patient information such as name, blood type, allergies, and medications.

The Joint Commission has updated their Patient Safety Goals for 2009. In these new goals a two-patient identifier, a pre-procedural identification, and a time-out procedure are added. First, the two-patient identifier simply means that the nurse must use more than one method of identification to identify the patient. Using the wristband alone is not enough. Second, the pre-procedural identification is performed, usually, in the postanesthesia care unit, by the surgeon and a nurse. This is used to correctly identify each patient just before going into the operating suite. Lastly, the time-out procedure is performed in the operating suite by the surgeon and the perioperative team—time is taken to properly identify the patient, procedure, and site of surgery. This is the final identifier before the actual operation is performed.

Regardless of the system used, the perioperative nurse plays a key role in identifying the patient and reinforcing subsequent verification procedures as necessary throughout the surgical experience to provide a safe environment of care.

Modified from The Joint Commission International Center for Patient Safety: *Using identification bands to reduce patient identification errors,* available at www. jcipatientsafety.org/show.asp?durki=12346. Accessed April 11, 2009; The Joint Commission: *2009 National Patient Safety Goals (NPSGs),* available at www. jointcommission/NR/rdonlyres/31666E86-E7F4-423E-9BE8-F05BD1CB0AA8/0/HAP_NPSG.pdf. Accessed May 7, 2009; Inglesby JM, Inglesby T: Automatic identification barcoding and RFID, *Patient Safety Quality HealthCare,* available at www.psqh.com/sepoct05/barcodingrfid2.html. Accessed May 7, 2009.

results of the history, physical examination, laboratory tests, other diagnostic workups, and the nursing history and assessment, is critical for subsequent care planning. It is valuable to assess the patient's understanding of the disease process and of the anticipated procedure. In addition to assessing the patient's knowledge and understanding of the proposed surgical procedure and outcomes, the perioperative nurse ensures that the patient has adequate support to assist the patient through the surgical experience and recovery. The nurse should also assess emotional status, since patients with a possible diagnosis of carcinoma may be very anxious. A focused assessment of the respiratory system should be included during the physical assessment. The nurse questions the patient or otherwise confirms the presence of an increased frequency of cough, increase in sputum production, recurrent hemoptysis, malaise, shortness of breath, substernal chest discomfort, weight loss, poor appetite, status of nutrition, and hypoxia. The results of the physical examination of the chest should be reviewed; the perioperative nurse may auscultate the chest and confirm the presence of crackles or wheezes on inspiration or expiration, which should be documented on the medical record.

The review of diagnostic and laboratory tests may include the chest x-ray films, sputum analysis obtained during bronchoscopy, cytology reports, arterial blood gas (ABG) results, and pulmonary function studies (Table 22-1). Laboratory tests including the complete blood count (CBC) should be within normal limits but can indicate anemia. The chest x-ray film remains an indispensable diagnostic tool and will be needed in the OR. This film outlines the lesion, if any is present, and defines its shape and space-occupying nature (e.g., tracheal shift). The presence of air in the hilar region, pleural effusion, or atelectasis may also be confirmed by radiologic evidence. Sputum analysis for culture and sensitivity may alert the perioperative nurse to an infectious process; cytologic examination may confirm a malignancy. The patient may have already undergone diagnostic bronchoscopy or mediastinoscopy; if so, the findings for acid-fast bacillus smear, culture, bronchial washing, and biopsy should be reviewed. A three-dimensional image reconstruction and display technique—virtual bronchoscopy—may have been undertaken for noninvasive airway evaluation (Amdo, 2009). Pulmonary function tests with a forced expiratory volume in 1 second (FEV_1) less than 1.0 L indicate the patient is at extremely high risk for pulmonary complications in the postoperative period. Computed tomography (CT) scans of the chest, as well as of the brain, liver, and abdomen, may reveal the presence or absence of metastasis, pleural calcification, thickening, or plaque. Radioisotope scans may have been done for similar reasons as the CT. Magnetic resonance imaging (MRI) detects vascular relationships to masses or vascular lesions. Positron emission tomography (PET) is a noninvasive study demonstrated to be highly accurate in diagnosing malignant pulmonary nodules and lymphadenopathy. MRI and PET are sometimes performed to rule out metastasis of the lesion. Transbronchial needle aspiration is useful in diagnosing mediastinal lymphadenopathy and staging lung cancer. Ventilation and perfusion studies show the distribution of each function in the lung. These results assist the perioperative nurse in collaborating with the surgical team to maintain effective gas exchange during the surgical intervention. The results are also valuable in predicting postoperative respiratory function and metabolic responses. Patients hospitalized for surgery related to carcinoma may have received chemotherapy or radiation therapy before surgery. Assessment of the skin and the patient's general condition is important in preventing perioperative complications. The nurse should also assess the patient's pain tolerance to determine necessary teaching or tools that will assist in achieving positive postoperative outcomes.

The nurse should assess the patient's smoking history (including the use of cigars, pipes, tobacco, or controlled substances) and any exposure to secondhand smoke within the home and/or workplace and reinforce the need to abstain following surgery (Rees, 2010). Patients might be sensitive about smoking history because of the assumed relationship between smoking and lung disease. The nurse should phrase questions in a way that will not result in guilt about smoking habits or assumptions that the diagnosed condition is associated with smoking.

After a general and focused review of the patient's medical record and patient interview, the perioperative nurse formulates nursing diagnoses. These statements reflect problems that will require perioperative nursing intervention, either independently or collaboratively with other members of the surgical team. Nursing diagnoses should be individualized and prioritized for each patient.

Nursing Diagnosis

Nursing diagnoses related to the care of patients undergoing thoracic surgery might include the following:

- Impaired Gas Exchange related to surgical intervention
- Risk for Impaired Skin Integrity related to surgical positioning, length of surgical intervention, or use of chemical antimicrobial agents on the skin
- Risk for Imbalanced Fluid Volume related to decreased surface area of the lung for perfusion and to administration of intravenous (IV) fluids during surgery
- Risk for Infection at surgical site related to inadequate secondary defenses (presence of existing disease process) and surgical disruption of tissues
- Impaired Comfort related to pain following surgical intervention

Outcome Identification

Outcomes identified for the selected nursing diagnoses could be stated as follows:

- The patient will experience adequate gas exchange during the surgical procedure.
- The patient's skin integrity will be maintained.
- The patient will maintain appropriate fluid balance.
- The patient will be free from postoperative surgical site infection.
- The patient's pain will be monitored and managed.

Planning

A Sample Plan of Care for a patient undergoing thoracic surgery is included on pp. 942-943.

Implementation

During implementation of the plan of care, the perioperative nurse is concerned with both preparatory patient considerations (e.g., procedure explanation and teaching for the patient; verification of the patient, surgical procedure, and site; positioning; presurgical diagnostic interventions; draping) and the requirements of the surgical intervention (e.g., medication

TABLE 22-1

Laboratory Studies and Tests for Assessment of Patients Undergoing Thoracic Procedures

Laboratory Study	Normal Results	Significance of Abnormal Findings
PERFUSION STUDIES—ARTERIAL BLOOD GASES (ABGS)		
pH	7.35-7.45	Changes indicate metabolic or respiratory acidosis.
$Paco_2$	35-45 mm Hg	Elevations indicate possible COPD, asthma, pneumonia, anesthetic effects, or use of opioids (respiratory acidosis). Decreased levels indicate hyperventilation/respiratory alkalosis.
HCO_3^-	21-28 mEq/L	Elevations indicate possible respiratory acidosis as compensation for primary metabolic alkalosis. Decreased levels indicate possible respiratory alkalosis as compensation for primary metabolic acidosis.
Pao_2	80-100 mm Hg	Elevations may indicate possible excessive oxygen administration. Decreased levels indicate possible COPD, asthma, chronic bronchitis, cancer of bronchi and lungs, respiratory distress syndrome, or any other cause of hypoxia.
O_2 saturation	95%-100%	Decreased levels indicate possible impaired ability of hemoglobin to release oxygen to tissues.
COMPLETE BLOOD COUNT		
RBCs	*Male:* 4.7-6.1 million/mm^3 *Female:* 4.2-5.4 million/mm^3	Elevated levels may be due to excessive production of erythropoietin, which occurs in response to a hypoxic stimulus, such as COPD. Decreased levels may indicate anemia, hemorrhage, or hemolysis.
Hemoglobin	*Male:* 14.8 g/dl *Female:* 12-16 g/dl	Same as for RBCs.
Hematocrit	*Male:* 42%-52% *Female:* 37%-47%	Same as for RBCs.
WBCs	5000-10,000/mm^3	Elevations indicate possible acute bacterial infections or inflammatory conditions (smoking). Decreased levels may indicate overwhelming infection or immunosuppression.

Pulmonary Function Tests

Test	Purpose
FVC (forced vital capacity): Records maximum amount of air that can be exhaled as quickly as possible after maximum inspiration	Provides an indication of respiratory muscle strength and ventilatory reserve. Often reduced in obstructive disease (because of air trapping) and in restrictive disease.
FEV_1 (forced expiratory volume in 1 sec): Records maximum amount of air that can be exhaled in first second of respiration	Effort dependent and declines with age. Reduced in certain obstructive and restrictive disorders.
FEV_1/FVC: Ratio of expiratory volume in 1 sec to FVC	Provides a more sensitive indicator of obstruction to airflow. Ratio is normal or increased in restrictive disease.
$FEF_{25-75\%}$: Records forced expiratory flow over 25%-75% volume (middle half) of FVC	This measure provides a more sensitive index of obstruction in smaller airways.
FRC (functional residual capacity): Amount of air remaining in lungs after normal expiration	Increased FRC indicates hyperinflation or air trapping, which may result from obstructive disease.
TLC (total lung capacity): Amount of air remaining in lungs at end of maximum inhalation	Increased TLC indicates air trapping associated with obstructive pulmonary disease. Decreased TLC indicates restrictive disease.
RV (residual volume): Amount of air remaining in lungs at end of a full, forced exhalation	RV is increased in obstructive pulmonary disease, such as emphysema.
DL_{co} (diffusion capacity of carbon monoxide): Reflects surface area of alveolocapillary membrane	DL_{co} is reduced when alveolocapillary membrane is diminished, such as in emphysema, pulmonary hypertension, and pulmonary fibrosis.

COPD, Chronic obstructive pulmonary disease; *HCO_3^-*, bicarbonate ion; *$PaCO_2$*, partial pressure of arterial carbon dioxide; *PaO_2*, partial pressure of arterial oxygen; *RBC,* red blood cell; *WBC,* white blood cell.

From Pagana KD, Pagana TJ: *Mosby's diagnostic and laboratory test references,* ed 9, St Louis, 2009, Mosby; Rees HC: Assessment of the respiratory system. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care*, ed 6, Philadelphia, 2010, Saunders.

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Impaired Gas Exchange related to surgical intervention

OUTCOME
The patient will experience adequate gas exchange during the surgical procedure.

INTERVENTIONS
- Determine the preoperative status of gas exchange by reviewing laboratory results and assessing the patient; report deviations from preoperative laboratory values and patient assessment findings.
- Obtain chest x-ray films for the intraoperative period.
- Verify that a double-lumen endotracheal tube with a soft, inflatable cuff is available for the anesthesia provider.
- Collaborate in obtaining equipment for and monitoring arterial blood gases (ABGs); document results.
- Obtain equipment for and assist with patient preparation for hemodynamic monitoring: electrocardiogram (ECG), CO_2 analyzer, pulse oximeter, arterial pressure line, and central venous pressure line; collaborate with the anesthesia provider in evaluating results provided by these monitoring devices during the procedure.
- Apply thermal unit (forced-air warming device or other device as available in institution); check equipment before procedure; monitor and note patient temperature during procedure.
- Collaborate in positioning the patient to provide access to the endotracheal tube, enable efficient ventilatory function, and prevent injury.
- Obtain and label specimens (e.g., ABG, blood count) to be sent to laboratory; document specimens sent, and evaluate results. Report abnormal values to the anesthesia provider and surgical team.

NURSING DIAGNOSIS
Risk for Impaired Skin Integrity related to surgical positioning, length of surgical intervention, or use of chemical antimicrobial agents on the skin

OUTCOME
The patient's skin integrity will be maintained.

INTERVENTIONS
- Assess skin integrity and condition of the skin preoperatively. Document findings; report the presence of any lesions, rashes, cuts, nicks, or reddened areas.
- Determine presence of preexisting conditions that could compromise skin integrity (e.g., age, obesity, diabetes, allergies, radiation therapy).
- Apply principles of positioning for efficient circulatory function for lateral or supine position during the procedure; pad and protect vulnerable neurovascular bundles and dependent pressure areas:
  - *Lateral position:* ear, acromion process, iliac crest, greater trochanter, medial and lateral condyles, malleolus
  - *Supine position:* occiput, scapula, olecranon, sacrum, ischial tuberosity, calcaneus
- Position the patient in the best possible body alignment to allow visualization of the operative field.
- Assess for preexisting conditions (e.g., joint implants, arthritis, restricted movement) to prevent patient injury during positional maneuvers.
- Stabilize the patient in lateral position (e.g., beanbag, sandbag, soft shoulder roll, pillows between knees); check for tape sensitivity if adhesive tape is used. Flex the upper arm slightly (not exceeding 90-degree extension) above the head on a raised, padded armboard or supported on padding.
- Use adequate number of individuals to position the patient for the lateral position.
- Assess the area where the electrosurgical dispersive pad will be placed; clip the area if necessary. Document assessment and pad placement on the intraoperative record.
- If hair must be removed from the operative site, use clippers or a depilatory (check patient sensitivity); shave the patient with wet shave if a razor must be used.
- Prevent pooling of skin prep solutions at the bedline, site of ECG electrodes, and electrosurgical dispersive pad.
- Decrease surgical time by anticipating needs of the patient and surgical team.
- Observe and document skin integrity and condition postoperatively; compare with preoperative status.

NURSING DIAGNOSIS
Risk for Imbalanced Fluid Volume related to decreased surface area of the lung for perfusion and to administration of intravenous (IV) fluids during surgery

OUTCOME
The patient will maintain appropriate fluid balance.

INTERVENTIONS
- Insert indwelling urinary catheter; use aseptic technique.
- Position drainage bag off floor, where it is readily observable.
- Monitor urinary output hourly during the procedure; report output less than 30 ml/hr.
- Provide access for administration of IV fluids; assist with fluid administration and insertion of lines. Keep lines protected and patent during positional changes.
- Monitor results of hemodynamic parameters; document and report appropriately.
- Monitor blood loss during the procedure; document and report appropriately.
- Provide blood (including autologous) or blood products for fluid replacement; assist in replacement therapy and patient monitoring.
- Observe for signs of shock (e.g., hypotension, abnormal ECG); report signs, and initiate corrective nursing actions.
- Observe for signs of excess blood loss (e.g., rapid, weak pulse; rapid respirations; cool, moist skin; early, slight rise in blood pressure); report signs, and initiate corrective nursing actions.
- Observe for signs of fluid excess (e.g., tachycardia, increased blood pressure); report signs, and initiate corrective nursing actions.
- Have available and administer furosemide (Lasix) and other diuretic agents as prescribed; monitor for therapeutic results.

NURSING DIAGNOSIS
Risk for Infection at surgical site related to inadequate secondary defenses (presence of existing disease process) and surgical disruption of tissues

OUTCOME
The patient will be free from surgical site infection.

INTERVENTIONS
- Create and maintain a sterile field immediately before use; monitor the sterile field, and take corrective action if breaks in technique occur.
- Administer preoperative antibiotics at least 1 hour before the procedure.
- Do not remove hair preoperatively unless the hair at or around the incision site will interfere with the surgical procedure. If hair must be removed, it should be done immediately before the surgical procedure, preferably using a means other than a razor.

SAMPLE PLAN OF CARE—cont'd

INTERVENTIONS—cont'd

- Practice aseptic technique when opening supplies, moving around the sterile field, catheterizing the patient, inserting IV lines, completing skin preparation, and draping the surgical site.
- Complete skin preparation at the incision site and point of insertion of monitoring lines to decrease microbial contamination. Use an appropriate antiseptic agent, applied in concentric circles moving toward the periphery. The prepped area should be extensive enough to extend the incision or create new incisions or drain sites.
- Monitor traffic patterns; limit the number of persons entering and leaving the OR.
- Administer prescribed antibiotics for irrigation and IV administration; check for patient allergies; record all medications administered by the perioperative nurse or scrub person at the sterile field.
- Decrease surgical time by anticipating patient and surgical team needs.
- When visible soiling with blood or other body fluids of surfaces or equipment occurs during the procedure, use an Environmental Protection Agency (EPA)–approved hospital disinfectant to wipe the affected area (confine and contain).
- Correctly classify the surgical wound according to the institution's wound classification system on completion of the surgical procedure.
- Using sterile gloves, apply sterile dressings to the surgical site before the drape is removed.

NURSING DIAGNOSIS

Impaired Comfort related to pain following surgical intervention

OUTCOME

The patient's comfort will be assessed, monitored, and managed.

INTERVENTIONS

- Teach the pain assessment scale preoperatively.
- Provide education to the patient regarding the physiology of pain and the importance of treating pain before it becomes unmanageable.
- Discuss pain management techniques and options (i.e., oral, intramuscular [IM], IV medications, patient-controlled analgesia [PCA], epidural use, intercostal blocks).
- Assist anesthesia provider in initiating pain control methods (i.e., epidural placement, nerve blocks).
- Assess pain before and following administration of pain medication or use of comfort measures (e.g., repositioning, applying support devices).
- Monitor the effects of pain management strategies and document.
- Assess verbal and nonverbal cues during procedures requiring monitored anesthesia care and administration of local anesthesia.
- Teach pain control methods and medication uses and side effects before discharge.

delivery; instrument, equipment, and supply availability). These patient care needs are coordinated with the other nursing interventions identified in the specific patient's plan of care.

Positioning. The type of position used in thoracic surgery is determined by the operative procedure planned. Bronchoscopy is performed in the supine position with a shoulder roll. Thoracotomy can be performed with the patient in one of three common positions: (1) lateral for the posterolateral approach, (2) semilateral for the anterolateral approach (Figure 22-6), and (3) supine for the median sternotomy approach. Arms are placed on padded armboards with the palms up and fingers extended. Armboards are maintained at less than a 90-degree angle to prevent brachial plexus stretch. If there are surgical reasons to tuck the arms at the side, the elbows are padded to protect the ulnar nerve, the palms face inward, and the wrist is maintained in a neutral position (Denholm, 2009). A drape secures the arms. It should be tucked snuggly under the patient, not under the mattress. This prevents the arm from shifting downward intraoperatively and resting against the OR bed rail.

The prone position can also provide access in some procedures (see Chapter 5 for safe positioning interventions). Adequate padding and safe transfer should be implemented to prevent pressure injury.

Draping. Draping may be minimal for bronchoscopic procedures. The principles of draping for other procedures (see Chapter 3) are followed in all other thoracic procedures. Drapes may consist of a fenestrated sheet or single sheets surrounding the incision site. To prevent instruments from falling from the field, the surgical technologist may place a magnetic pad on the drapes below the incision site when the patient is placed in lateral position. The perioperative nurse ensures a forced-air warming blanket is placed on the patient before draping to maintain normothermia. Sequential compression devices are often applied also to prevent the development of deep vein thrombosis (DVT).

Instrumentation. Bronchoscopy instruments are designed to directly inspect and observe the larynx, trachea, bronchi, or mediastinum; to remove secretions; to obtain washings or tissue for bacterial and cytologic studies; or to remove tissue. They are also designed to remove foreign bodies. Instrumentation for thoracic surgery includes the laparotomy instrument set (see Chapter 10) and specialty items. Instruments used for a thoracotomy or chest procedure include a combination of delicate and heavy instruments. Stapling equipment commonly is used as suturing devices and requires staplers and reload staples of appropriate sizes. The delicate instruments are used to cut tissue and vessels or to clamp tissue in an atraumatic manner. The heavier instruments are used for bone cutting, dissecting, or retracting. Instrumentation must also be available for hemostasis and suturing of all types of tissue.

The surgical technologist should determine the arrangement of items on the instrument table and Mayo stand; this arrangement should be an effective standard method that applies principles of work simplification and thorough knowledge of procedures. Lengthy incisions are often required for thoracic procedures; therefore it is critical that an instrument count be performed before closure.

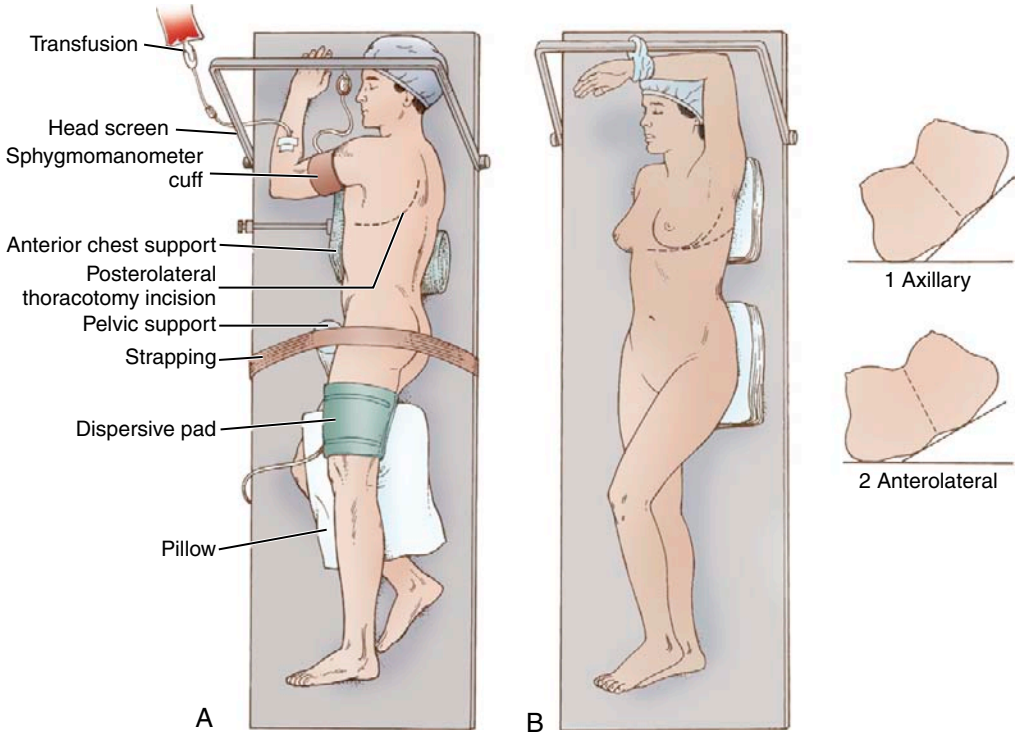


FIGURE 22-6 Positions for thoracotomy incisions. **A**, Lateral position for posterolateral incision. **B**, Semilateral position for axillary or anterolateral position.

Equipment. In thoracic surgery, a variety of equipment is used, including a forced-air warming unit, fiberoptic headlights, fiberoptic light sources, video equipment, sequential compression devices, and anesthesia supplies. Double-lumen endotracheal tubes are commonly used for thoracotomies.

The neodymium:yttrium-aluminum-garnet (Nd:YAG) or CO_2 laser can be used for treating tracheobronchial lesions with use of a bronchoscope. Obstruction of the mainstem bronchus and trachea caused by benign and malignant lesions can also be effectively treated with laser therapy. Use of laser equipment requires a thorough understanding of the equipment, the safety issues, the responsibilities (see Chapter 7), and the planned surgical procedure.

Monitoring. Monitored anesthesia care, local anesthesia, or topical anesthesia may be used during some bronchoscopic procedures. General anesthesia may also be used for bronchoscopic procedures and is used for other thoracic procedures. Team members work in cooperation to constantly monitor laboratory results (e.g., ABGs), oxygenation, temperature, blood loss, and urine output. Monitoring sequential compression device settings and patient position is also important in providing safe patient care. Results are communicated with other team members and documented for continuity of care.

Blood Replacement. Blood replacement therapy during or after the procedure may be required because of extensive tissue dissection in a highly vascular area. The patient may have autologous blood ordered; however, the diagnosis may prohibit patient donation of his or her own blood. The patient's blood type and amount of blood ordered should be noted before the procedure and its availability confirmed. During the procedure, every effort should be made to control and monitor bleeding. If blood collection or reinfusion systems are used, the manufacturer's instructions and institutional protocols should be followed. Bloodless surgery programs are available at some institutions and can prevent the need for allogeneic or autologous blood use (Fox et al, 2008).

Chest Drainage Systems. Chest tube and chest drainage system management represents an important intervention for perioperative nurses (Risk Reduction Strategies). In the presence of restrictive and obstructive pulmonary disease, the lung may not fully expand or contract, causing a reduction in alveolar ventilation with resultant hypoxia. Other conditions that interfere with respiratory function are excessive accumulation of mucus, pleural effusions, a foreign body in a bronchus, closed pneumothorax (simple and tension types), open pneumothorax, hemothorax, and multiple rib injuries that produce paradoxic motion of the thoracic cage, or flail chest (Figure 22-7).

The normal function of the lungs is supported by elasticity and negative intrapleural pressure. Collapse of the normal lung follows any condition that reduces or eliminates the negative intrapleural pressure if the lung is not adhering to the chest wall. When the pleural space is filled with air, reducing the negative pressure, the lung collapses. This action may cause complete collapse if the pressure within the intrathoracic (pleural) space becomes positive.

A diminished negative pressure or the occurrence of actual positive pressure in one pleural space may cause the mediastinum or trachea to shift toward the opposite side.

RISK REDUCTION STRATEGIES

Chest Tube Safety

The use of chest tubes is almost synonymous with thoracic surgery. Effective strategies for the management of chest tubes and chest tube drainage systems promote reduction of risk to patients for this aspect of thoracic surgery.

According to the U.S. Agency for Healthcare Research and Quality (AHRQ), major sources of adverse outcomes include breaks in sterile technique, inadequate anesthesia, incorrect insertion techniques, and inadequate self-protection by clinicians. The agency issued the following findings:

- Trying to perform multiple procedures concurrently is a major source of error.
- Equipment trays should be positioned near the surgeon's dominant hand.
- A patient's discomfort can make it difficult to perform a sterile procedure. While adequate anesthesia is important, the patient may also need verbal and physical comforting. If a patient's movements cannot be controlled, the anesthesiology team should be called.
- Correct techniques can prevent damage to the lung and surrounding tissue, contamination of the wound, and leakage of fluid.
- Universal Precautions against bloodborne infections are crucial to protect clinicians and their patients. In U.S. urban trauma centers, HIV rates among trauma patients are as high as 10%, and hepatitis C rates are as high as 15%; therefore Universal Precautions should be practiced for all chest tube insertions.

Additional management strategies include the following:

- Ensure that the dressing on the chest around the tube is tight and intact. Palpate the area for puffiness or crackling that may indicate subcutaneous emphysema.
- Assess for difficulty breathing.
- Assess breathing effectiveness by pulse oximetry.
- Check alignment of the patient's trachea.
- Keep the drainage system lower than the patient's chest.
- Keep the chest tube as straight as possible, avoiding kinks and dependent loops; do not "strip" the chest tube.
- Ensure the chest tube is securely taped to the connector and the connector is taped to the tubing that enters the collection chamber.
- Assess bubbling in the water-seal chamber; should be gentle bubbling on patient's exhalation, forceful cough, position changes.

The physician or rapid response team should be notified when the following are observed:

- Tracheal deviation
- Sudden onset or increased intensity of dyspnea
- Oxygen saturation less than 90%
- Drainage greater than 70 ml/hr
- Visible eyelets on the chest tube
- Chest tube falls out of the patient's chest or disconnects from the drainage system

Modified from Problems and Prevention: *Chest tube insertion. Patient safety: findings in action,* AHRQ Publ No. 06-P024, Sept 2006, Agency for Healthcare Research and Quality, Rockville, Md, available at www.ahrq.gov/qual/chesttubes.htm. Accessed May 12, 2009; Workman ML: Care of patients with noninfectious lower respiratory problems. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, Philadelphia, 2010, Saunders.

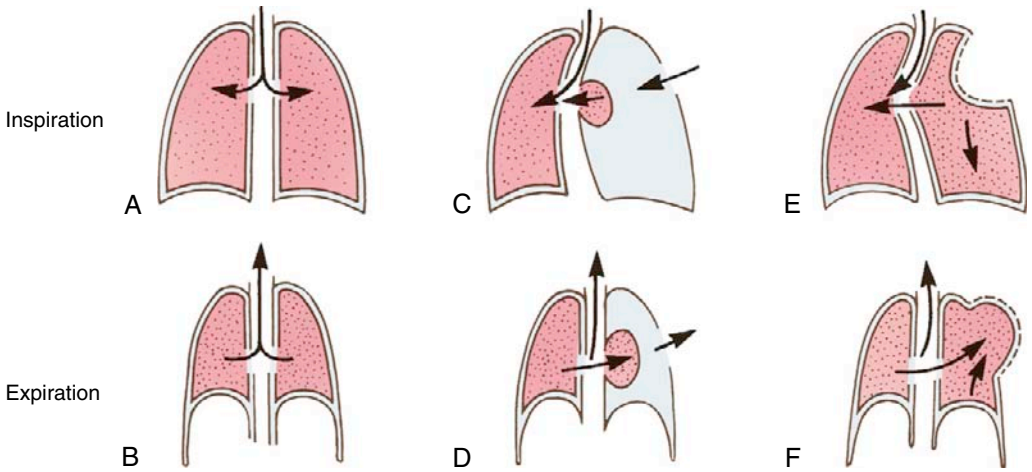


FIGURE 22-7 Pathophysiology of severe chest injuries. **A** and **B**, Normal physiology of inspiration and expiration. **C** and **D**, Open (sucking) wound of thorax. On inspiration, air at atmospheric pressure rushes in through defect (**C**), collapsing lung. Next, positive pressure causes mediastinum to shift, compressing opposite lung. On expiration (**D**), air from lung on uninjured side reenters collapsed lung and is rebreathed in next inspiration. Impaired cardiopulmonary function in presence of sucking wound of chest is caused by (1) collapse of lung on injured side, (2) partial collapse of opposite lung, (3) increased functional dead space caused by rebreathing of unoxygenated air from collapsed lung, and (4) diminished venous return to right side of heart. **E** and **F**, Primary effect of paradoxic motion resulting from flail or stove-in chest is diminution of pulmonary ventilation and extensive rebreathing from one lung to the other. Venous return to right side of heart is impaired. Appropriate treatment requires intubation of trachea and use of volume-limited ventilator.

When this occurs, not only the affected lung collapses because of a positive pressure in the pleural space but also the function of the lung on the opposite side may be impaired as a result of compression by the mediastinal shift. Tension pneumothorax can produce serious effects as air continues to escape from the lung into the intrapleural space. The air cannot return to the bronchi to be exhaled, thereby increasing the intrapleural pressure. When a large opening in the chest wall allows direct communication of the pleural space with atmospheric pressure, it may cause death if the mediastinum becomes mobile.

Paradoxic motion of the chest results from severe instability of the chest wall because of multiple and often bilateral rib fractures; with inspiration, partial collapse of the thoracic space occurs. The blunt injury that caused the multiple rib fractures also causes severe contusion of the lung itself. This contusion contributes to impairment of lung function by affecting gas exchange, which may result in severe, life-threatening hypoxia.

One or more chest catheters (tubes) may be inserted for postoperative closed-chest drainage. The chest tubes provide a conduit for drainage of air, blood, and other fluid from the intrapleural or mediastinal space and reestablishment of negative pressure in the intrapleural space. Drainage systems use three mechanisms to drain fluid and air from the pleural cavity: positive expiratory pressure, gravity, and suction. The chest tubes are connected to a sterile water-seal or gravity drainage system. Water-seal suction may be necessary when a persistent air leak cannot be controlled by drainage alone. Several compact, disposable units are available. The disposable units have three or four compartments for drainage, water seal, and suction. The first chamber collects the drainage from the intrapleural space, the second chamber provides the water seal, and the third provides the suction control determined by the level of water (Figure 22-8). If two chest tubes are inserted, they may be attached by a Y connector to a single drainage unit or may be attached individually to two separate units. Chest tubes are generally removed within 5 to 7 days.

FIGURE 22-8 Commercial chest drainage system.

Documentation. The nurse's documentation of perioperative care includes a summary of preoperative assessment information that supports formulated nursing diagnoses, nursing interventions, and postoperative evaluation. Documentation for a patient undergoing a thoracotomy specifically addresses patient assessment information related to position of the patient, positioning aids used, medications administered, results of laboratory tests completed, special equipment used, urine output, blood replacement, insertion of chest tubes and drainage systems, and postoperative evaluation of patient care outcomes.

Transfer Report. The patient is transferred from the OR to the postanesthesia care unit (PACU) after thoracotomy. The report to the PACU nurse is often a collaborative effort of the nurse and anesthesia provider. The perioperative nurse reports the procedure performed, particularly if it varies from the anticipated or scheduled procedure, and describes the patient's preoperative status, including anxiety level and understanding of the procedure, to assist the PACU nurse in meeting the emotional and educational needs of the patient. The nurse's description of the patient's position during the procedure provides criteria for assessment and evaluation of mobility. Results of immediate postoperative assessment, including skin integrity, location and type of dressing applied, location and type of drains, blood loss, fluid replacement, medications administered, and laboratory results obtained during the procedure, are reported by the nurse and anesthesia provider as a baseline control for assessment in the PACU. The perioperative care plan should be reviewed and patient outcomes reported.

Postprocedural Concerns. The patient's endotracheal tube may remain in place to maintain an adequate air exchange. Air exchange and effective ventilation are two immediate clinical needs after thoracotomy. Chest tubes are connected to suction except for postpneumonectomy procedures. The thoracotomy is considered a painful procedure and, when coupled with muscle injury, affects functional capacity. Anesthesia providers frequently use postprocedure epidural catheters for pain management to improve the comfort level of the patient as postoperative activities are encouraged.

Fluid volume overload can lead to acute life-threatening respiratory disease syndrome that should be avoided (Rapid Response Team box). Monitoring urine output is important, but postthoracotomy patients should be maintained in a state of hydration that does not require a fluid bolus for low urine output.

Patients are often anxious about their limitations, the environment, and the results of the procedure. Patients and families will benefit from preoperative teaching about pain management techniques and use of the institution's pain assessment tool. Patients and families should also be encouraged to discuss their feelings and needs both before and after the surgical procedure. The perioperative nurse should facilitate notification of the patient's status to the family members during and as soon as possible after the procedure.

RAPID RESPONSE TEAM

Surgical adverse events (SAEs) account for 50% to 75% of all adverse events in studies of healthcare complications. As the number and complexity of surgical procedures performed increase, the incidence and severity of SAEs are also likely to increase. Trigger Tool methodology employs a retrospective review of a random sample of inpatient hospital records, using "triggers" (or clues) to identify possible adverse events. This methodology is easy-to-use for identifying adverse events (harm) and measuring their rate of occurrence over time. Within the Institute for Healthcare Improvement's (IHI) Trigger Tool are 14 care process triggers, 1 of which is rapid response team (RRT) activation. The RRT may be activated for a code, cardiac or pulmonary arrest, or other condition/event requiring a rapid response. The IHI notes that cardiac or pulmonary arrest that occurs intraoperatively, in the postanesthesia care unit (PACU), or within the first 24 hours postoperatively should always be considered an adverse event. In 1 study undertaken within the IHI perioperative collaborative, 11 hospitals submitted data from surgical inpatient records. From record review, it was determined that the prevalence of SAEs was 14.6% and that 8.7% of the events required life-saving intervention. As more institutions use Trigger Tool methodology, it may be possible to investigate the effectiveness of RRT activation intraoperatively and improve the impact of interventions initiated in response to the RRT call.

Modified from Griffin FA, Classes DC: Detection of adverse events in surgical patients using the trigger tool approach, *Qual Saf Health Care* 17:253-258, 2008; Griffin FA, Resar RK: *IHI Global Trigger Tool for Measuring Adverse Events (Second Edition), IHI Innovation Series white paper,* Cambridge, Mass, Institute for Healthcare Improvement, 2009, available at www.IHI.org. Accessed May 19, 2009.

Evaluation

At the completion of the surgical procedure, perioperative nursing goals are evaluated. They may be restated as brief outcomes. For the goals identified for the patient undergoing thoracic surgery, outcomes could be stated as follows:

- The patient's gas exchange was unimpaired; ventilation/perfusion ratios were adequate as evidenced by laboratory results, and vital signs were within normal limits; skin, nailbeds, and mucosa were pink; lung fields were clear bilaterally; and chest excursion was normal.
- The patient's skin integrity was maintained; reddened or discolored skin and other signs of altered tissue perfusion were not present.
- Fluid balance was maintained; there were no fluid excesses or deficits; mental orientation was consistent with preoperative level; serum electrolytes and ABGs were within normal limits; urinary output was adequate.
- A postoperative surgical site infection will not be experienced; the incision site will remain approximated and dry, without redness, drainage, or undue tenderness. (This is a long-term goal, and its evaluation will require the collaboration of the nurse in the patient care unit.)
- Comfort will be managed and pain levels assessed.

Patient and Family Education and Discharge Planning

Discharge status will be determined by the type of procedure being performed. General patient concerns might include mobility and activity levels/restrictions, pain management, wound care, dietary recommendations, medication regimens, follow-up appointments, and any prescribed outpatient care or referrals. Both the patient and the family need specific instructions for discharge that relate to the specific procedure. The nurse should review this information verbally and provide it in written form, with verification of understanding and time for questions and concerns.

After a bronchoscopy, patients will be discharged within hours of the procedure. Their main concerns might be the results of biopsy and diagnosis. The patient and family should be aware of the length of time until results will be available and the method used to obtain those results. Patients should also be reminded of the need to rest for 2 to 3 days after the procedure. Side effects might result from medications used for moderate sedation or untoward intraoperative outcomes (e.g., the patient may experience bloody sputum, difficulty breathing). In addition, patients should be reminded that their throats might feel numb 2 to 3 hours after the procedure and difficulty with swallowing will subside (Ambulatory Surgery Considerations).

After a surgical procedure such as thoracoscopy or thoracotomy, vigorous pulmonary toileting is encouraged, including use of a spirometer, deep breathing, and turning and coughing every 1 to 2 hours while awake. Patients will transfer to the chair or ambulate on the day of surgery; length of time until discharge might be a few days to 1 week or more. Patients who progress without difficulty after a thoracoscopy or thoracotomy will be monitored for drainage from the chest tubes and for pain management or complications. Postoperative air leaks or pulmonary infections will delay discharge from the healthcare setting.

In-home nursing care may be initiated to monitor oxygen levels, wound care needs, and pain management. The patient may be discharged with supplemental oxygen (Patient and Family Education). This will require that the patient be weaned and demonstrate satisfactory ambulatory Sao_2 (i.e., percent saturation of arterial oxygen) rates of 88% to 90%, which will most likely be supervised by homecare nurses.

Surgical Interventions

ENDOSCOPY (DIAGNOSTIC OR THERAPEUTIC)

Endoscopy refers to examination of hollow body organs or cavities with instruments that permit visual inspection of their contents and walls. The endoscopic procedures pertinent to thoracic surgery are bronchoscopy, mediastinoscopy, and thoracoscopy. Each endoscopist has preferences regarding the type of endoscope, positioning of the patient, type of anesthetic, and equipment. Invasive diagnostic or therapeutic measures enhance the decision to pursue surgical intervention by providing information related to the disease process, including histologic characteristics, location of the lesion, and lesion extent. Therapeutic endoscopy provides treatment by removal of the lesion or foreign body.

AMBULATORY SURGERY CONSIDERATIONS

Ambulatory Thoracic Surgery

The concept of ambulatory surgical procedures is not new to the thoracic specialty; patients undergoing bronchoscopy or endoscopic sympathectomy have often completed their procedures on an outpatient basis. With the increased trend towards more minimally invasive procedures and improved technology to accomplish those procedures, the indications for ambulatory thoracic surgery are growing. Proper patient selection is key to the success of an ambulatory thoracic program. The surgeon must weigh the risks and benefits of performing surgery on a patient and allowing a discharge to home within several hours of the procedure. Anesthesia risk can be assessed according to the individual patient's American Society of Anesthesiologists (ASA) physical status classification. The surgeon considers the complexity of the surgery, the patient's medical and surgical history, and other factors on a case-by-case basis before surgery to ensure the most appropriate patients are selected for outpatient procedures. Because the majority of thoracic procedures entail entry into the chest, the patient's level of pain, amount of chest tube output, presence or absence of an air leak, and pneumothorax status must be closely monitored before the final determination for discharge that same day.

There are many ambulatory surgical centers in the United States that offer an array of thoracic services. Mediastinoscopies, endoscopic and minimally invasive procedures on the lungs and nerves of the mediastinum, are the most frequently performed thoracic surgeries on an outpatient basis. Through proper patient selection, excellent surgical technique, and exceptional postoperative care the majority of patients treated at these centers can safely be discharged to home the day of surgery. Essential teaching points to cover with the patient and caregiver include pain control, respiratory treatments (to include deep breathing and coughing as ordered by the surgeon), and activity. Because the chest wall has been entered, the nurse must emphasize the importance of seeking emergency care if the patient experiences difficulty breathing, sudden chest pain, palpitations, uncontrollable cough, or bloody sputum.

Though they do not meet the standard definition of outpatient surgery, there is a movement towards programs to fast-track thoracic patients to earlier discharge to reduce inpatient stays. These fast-track programs usually operate, recover, and discharge a patient within a few days of being admitted. The postoperative recovery periods at these centers focus on pain relief and advances in chest tube management. Patients are often able to be discharged home safely with chest tubes in place using either a Heimlich valve or a portable drainage collection system. As more fast-track programs evolve and are able to demonstrate successful outcomes, new indications for outpatient care are likely to evolve.

Modified from Cerolio R, Brant, AS: Does minimally invasive thoracic surgery warrant fast tracking of thoracic surgical patients? *Thorac Surg Clin* 18:301-304, 2008; Molins L et al: Outpatient thoracic surgery, *Thorac Surg Clin* 18:321-327, 2008.

PATIENT AND FAMILY EDUCATION

Patient Education and Home Care Teaching for Oxygen Therapy

GENERAL INFORMATION

- Review the physician's order for the type of delivery system and liter flow or percentage of oxygen to be delivered.
- Give the patient and the caregiver both *oral* and *written* instructions. Provide them with the name and telephone number of the physician to call if questions arise. Use visual aids to assist in instruction.

HOME CARE

- Explain the purpose for oxygen therapy and how it will be delivered to the patient.
- Warning signs (Review the signs and symptoms that should be reported to the physician):
  - Irregular, shallow, or slow breathing; difficulty in breathing
  - Restlessness or anxiety
  - Tiredness, drowsiness, trouble waking up
  - Persistent headache
  - Slurred speech
  - Confusion, difficulty in concentrating
  - Bluish fingernails or lips
- Inform the patient about the symptoms of oxygen toxicity:
  - Sore throat
  - Cough
  - Nausea
  - Anxiety
  - Numbness
  - Muscular twitching
  - Chest pain with deep inspiration

PATIENT AND FAMILY EDUCATION

Patient Education and Home Care Teaching for Oxygen Therapy—cont'd

- Special instructions:
  - Assist the patient to obtain a home healthcare referral for follow-up at home.
  - Explain the importance of maintaining the appropriate flow rate, since high flow rates in patients with chronic obstructive pulmonary disease can suppress the respiratory drive.
  - Teach the patient how to remove and reposition the oxygen equipment to permit wiping and drying the face, blowing the nose, and eating.
  - Instruct the patient on skin care procedures, since prolonged oxygen therapy can cause skin irritation and breakdown, which can provide an additional route for microorganisms. Advise patient to use non–petroleum-based cream on the face, lips, and nostrils to relieve the drying effects of oxygen.
  - Stress the importance of not smoking and not allowing others to smoke near the patient because of the possibility of combustion, fire, or explosion.
  - Ensure that no candles or matches are lit in the immediate area where oxygen is being administered.
  - Explain the necessity of checking all electrical equipment used in the same room as oxygen administration for frayed cords or the potential for sparking to avoid combustion and fire or explosion.
  - Advise the patient to obtain a fire extinguisher and keep it near the oxygen equipment.
- Activity:
  - Encourage walking and other activities as tolerated. Advise the patient to use a portable oxygen source because continuous oxygen therapy can limit mobility.
  - Suggest that the patient use oxygen, as ordered, during meals, showers, or sexual activities.
- Alternative therapy:
  - Discuss the use of relaxation techniques to minimize anxiety associated with shortness of breath.

FOLLOW-UP CARE AND REFERRALS

- Stress the importance of regular follow-up visits. Make sure the patient has the necessary names and telephone numbers.
- Discuss with the patient and caregiver the need to notify the local fire department and electric and gas utility companies of the presence of oxygen in the home.
- Instruct the patient to keep emergency numbers by the telephone.
- Assist the patient to obtain referral services, supplies, and information about support groups.

From Canobbio MM: *Handbook of patient teaching,* ed 3, St Louis, 2006, Mosby.

Standard Bronchoscopy Using Rigid Bronchoscope

Standard bronchoscopy is the direct visualization of the mucosa of the trachea, the main bronchi and their openings, and most of the segmental bronchi. It also includes removal of material for microscopic study if necessary.

Bronchoscopy is an integral part of the examination of patients with pulmonary symptoms such as persistent cough or wheezing, hemoptysis, obstruction, and abnormal roentgenographic changes. Common causes of bleeding (hemoptysis) are bronchiectasis, carcinoma, and tuberculosis. Congenital anomalies and suspected presence of a foreign body, especially in infants and children, are responsible for emergency examination of the respiratory tract.

The surgeon performs bronchoscopy to determine the presence of a lesion in the tracheobronchial passages, to identify and localize that lesion accurately, and to observe periodically the effects of therapy. It can be completed for dilating structures, debriding tumors, or evacuating clots. In suspected carcinoma, the aspirated secretions obtained by bronchoscopy may contain malignant cells.

Procedural Considerations. Flexible bronchoscopy on an adult patient may be completed after induction of local (topical) anesthesia or monitored anesthesia care; a child usually receives a general anesthetic. Patients undergoing rigid bronchoscopy should be paralyzed and ventilation continued to minimize trauma. The adult patient administered a local anesthetic may experience discomfort and anxiety. To reduce anxiety, the perioperative nurse should introduce members of the surgical team, explain intraoperative activities, and provide reassurance to the patient (Patient and Family Education, p. 950). The oral structures, including the teeth and lips, should be assessed for integrity. Loose teeth may require removal before or during the procedure.

The anesthesia provider or nurse providing moderate sedation may administer IV sedatives or analgesics during the procedure. See Chapter 4 for perioperative nursing considerations when the patient is receiving local or monitored anesthesia care. The topical (or local) anesthetic setup should include a headlight for visualization, laryngeal mirrors of various sizes, a lingual spatula, sprays with straight and curved cannulae, and anesthetic drugs, as ordered. Other items include the laryngeal syringe with straight and curved cannulae, Jackson cross-action forceps, and the Schindler pharyngeal anesthetizer, if desired. Luer-Lok 10-ml syringes and 20- and 22-gauge needles are needed for transtracheal injection. The surgical technologist ensures that all requested instrumentation is available to avoid delays and ensure the procedure is performed efficiently for the patient.

Anesthetic drugs frequently used for local or topical anesthesia are lidocaine (Xylocaine), procaine (Novocain), and tetracaine (Pontocaine, Cetacaine) with or without epinephrine. Pauses of 3 to 4 minutes are taken between applications of the anesthetic agent to the tongue, palate, and pharynx and then to the larynx and to the trachea. The surgeon or anesthesia

PATIENT AND FAMILY EDUCATION

Patient Education and Teaching for Bronchoscopy with Patient Administered Local Anesthetic

PREPROCEDURAL TEACHING

- Review the physician's explanation of the procedure and the reason for it; encourage the patient to ask questions and to discuss any fears or anxieties.
- Discuss who will perform the procedure and where it will take place.
- Instruct the patient to have someone available after the procedure to drive the patient home.
- Review the medications that will be used preoperatively (medications to decrease secretions, sedatives) and immediately before the procedure (topical anesthetics). Explain that the topical anesthetic may cause a cold, unpleasant sensation in the throat.
- Explain that the patient will be able to breathe around the bronchoscope.
- Reassure the patient that the nurse will provide emotional support during the procedure.

POSTPROCEDURAL TEACHING

- Explain that after the procedure the patient's vital signs will be monitored frequently; discuss the need to maintain nothing-by-mouth (NPO) status until the gag reflex returns.
- Provide explanations about any temporary hoarseness and sore throat. Lozenges and throat gargles can be provided after the gag reflex returns.
- Review the signs and symptoms that should be reported immediately to a physician or nurse:
  - Difficulty breathing
  - Chest pain
  - Inability to swallow
  - Excessive bloody mucus
- Establish a regular routine of deep breathing and ambulation at least every 2 hours; avoid coughing within the first 24 hours following a biopsy.
- Inform the patient that a soft diet may be needed for the first day or until throat pain disappears.
- Explain that extremely hot foods or liquids should be avoided.
- Encourage fluid intake to thin secretions unless contraindicated.
- Discuss the importance of not smoking.

From Canobbio MM: *Handbook of patient teaching,* ed 3, St Louis, 2006, Mosby.

provider applies the anesthetic agent by means of a spray or laryngeal syringe with a straight or curved cannula.

Some physicians prefer to have the patient sit upright and gargle with the topical anesthetic mixture, rinse it around in the mouth, and then expectorate it, thereby producing a partial anesthesia of the buccal mucosa and pharynx.

For direct bronchoscopy, the surgeon or anesthesia provider uses a long metal cannula attached to a syringe to apply the anesthetic agent to the surface of the vocal cords; then the agent is injected through the anesthetized glottis into the trachea. This act causes the patient to produce a sharp, sudden cough. For intrabronchial anesthesia, a portion of the anesthetic agent is introduced through the bronchoscope.

The patient may be positioned either in the supine position—with the shoulders elevated on a small roll, gel pad, or a sandbag to gently extend the head and neck—or in the sitting position.

The setup includes the bronchoscope, telescopes of desired types, fiberoptic light cords, and the fiberoptic light source. Each standard scope requires a fiberoptic light carrier, cord, and light source. The surgical technologist ensures that duplicates of each, along with the appropriate replacement lightbulbs for the light source, are available for immediate use. The light source should be tested periodically and immediately before use. To test the fiberoptic light carrier and telescope, the instrument should be held vertically by the ocular end. The endoscope should always be tested immediately before passage into the patient. The light-intensity dial should be set at the proper level, as specified by the manufacturer. The light source should be switched on and off to test its function. During a procedure, the perioperative nurse switches the light source to standby mode whenever it is not in active use to conserve the life of the bulb and promote cooling.

Other supplies that will be needed are suction tubing, aspirating tubes, specimen collectors, sponge carriers, and the desired type of forceps. The metal sponge carrier consists of two parts: an inner rod, which has two jaws protruding from its distal end; and an outer band, which is screwed down on the inner rod so that a sponge can be held securely within the jaws. Small gauze sponges are used to keep the field dry, remove secretions, and apply a topical anesthetic agent. Cytologic specimen collectors, such as the Clerf or Lukens, are used to hold secretions as they are obtained. Aspirating tubes of different lengths and designs are used to remove secretions and collect material for microscopic examination and culture(s). The straight aspirating tube with one or two openings at the distal end is used to remove material from the pharynx, larynx, and esophagus. The curved aspirating tube with a flexible tip is used to remove secretions from the upper and dorsal orifices of the bronchi.

The surgeon uses various types of forceps to remove foreign bodies or tissues for histologic study. Biting-tip forceps may be used to secure tissue for pathologic study. Forceps with jaws that veer laterally at about a 45-degree angle from the instrument's axis permit visualization during the biopsy maneuver. Bronchoesophageal forceps consist of a stylet, a cannula with a handle, a screw, a locknut, and a setscrew. Forceps for laryngeal and bronchial regions are designed to remove tissue specimens. The nurse should prepare several specimen containers with the identifying patient information label, along with laboratory

slips for specific requests. If brush specimens are collected, slides and alcohol are required.

The standard bronchoscope is a rigid speculum used for visualizing the tracheobronchial tree. The rigid bronchoscope might be selected for biopsy of a large central mass, for removal of a foreign object, or to control hemorrhage during biopsy of a vascular mass. The rigid bronchoscope remains the instrument of choice for removal of foreign bodies in infants and children. A fiberoptic light carrier is inserted into the bronchoscope to illuminate the distal opening. A side channel is incorporated into the bronchoscope to permit aeration of the lungs with oxygen or anesthetic gases. An additional device, the Sanders Venturi system, which is available to the anesthesia provider, provides adequate patient ventilation during bronchoscopies and laryngoscopies.

The endoscopist risks contamination in the presence of communicable diseases. For this reason, the endoscopist and assistants should wear facemasks and eye protection or wear a transparent shield attached to a headband (see Chapter 3 for specific Transmission-Based Precautions). With increasing numbers of patients with tuberculosis, particulate respirators are recommended as protective devices. Aseptic technique is used to prevent cross-contamination.

Operative Procedure

1. The patient's head is placed in position for visualization of the bronchus—to the left when the right main bronchi are inspected and to the right when the left bronchi are inspected. The head is lowered for inspection of the middle lobe.
2. The endoscopist places a tooth guard to protect the patient's teeth. The bronchoscope is inserted over the surface of the tongue, usually through the right corner of the mouth. The patient's lip is retracted from the upper teeth with a finger of the endoscopist's left hand. The epiglottis is identified and elevated with the tip of the bronchoscope.
3. The endoscopist passes the distal end of the scope through the true vocal cords of the larynx, and views the upper tracheal rings. A small amount of anesthetic solution may be sprayed through the tube on the carina of the trachea and into the bronchus with the bronchial atomizer or spray. The patient's head is moved to the left to obtain a view of the right bronchi. The right-angle telescope is inserted with the light adjusted into the bronchoscope.
4. The segmental bronchial orifices of the upper right lobe bronchi are viewed, and the telescope is removed. The endoscopist uses suction and aspirating tubes to clear the field of vision and remove accumulated secretions.
5. The endoscopist inserts an oblique 45-degree–angle telescope or right-angle telescope and advances it to inspect the middle lobe branches. The patient's head is lowered to view the right middle lobe or turned to the right to view the left main bronchus.
6. Secretions are aspirated by the endoscopist for study. Biopsy forceps are used if indicated; foreign bodies are removed with forceps.
7. The bronchoscope is removed, and the patient's face is cleansed.

The nurse encourages patients who have undergone bronchoscopy after administration of a local anesthetic to sit on the edge of the OR bed before transfer to the stretcher. An emesis basin and sponges should be provided for the patient's use. Assistance and support are provided to the patient to prevent a fall.

Postprocedural Concerns. Patient safety during and after endoscopy using topical anesthetics, local anesthetics, or monitored anesthesia care is a concern attributable to the medications administered. The gag reflex may not return for 2 to 3 hours. The patient may be positioned on his or her side or with the head of the bed elevated to promote drainage of secretions. The patient should be restricted from any oral intake until the gag reflex has returned. During bronchoscopy, particularly with a rigid bronchoscope, teeth could be loosened or oral structures damaged. The lips, teeth, and oral mucosa should be examined to ensure undisturbed integrity. Patients are often anxious to know the results of the procedure, and they benefit from the perioperative nurse's openness and willingness to discuss when results might be available, as well as the patient's feelings and concerns.

Bronchoscopy Using the Flexible Bronchoscope

Flexible bronchoscopy is performed to view structures that cannot be observed with a rigid scope. Flexible bronchoscopy may be performed in addition to a standard rigid bronchoscopy or as an independent procedure. If performed independently, the patient may remain on the transporting stretcher during the procedure. Flexible bronchoscopy is completed for the same reasons as rigid bronchoscopy. Flexible fiberoptic telescopes permit visualization of the upper, middle, and lower lobe bronchi. They can be passed in patients with a jaw deformity or cervical bone rigidity with less difficulty than the rigid scope. Flexible fiberoptic bronchoscopes are more frequently used, as is video endoscopy.

Procedural Considerations. Patient considerations are as described for rigid bronchoscopy. Instruments and equipment used include the flexible bronchoscope, fiberoptic light source, flexible biopsy forceps, flexible brush (optional; if used, slides and alcohol are necessary to collect specimen), labeled specimen collectors, pathology requests, syringe for wash, and suction tubing with collection tube attached to collect the wash specimen.

Operative Procedure

1. The lubricated bronchoscope is passed through the adapter on the endotracheal tube, which is held secure by the anesthesia provider. If local or monitored anesthesia care is used for the procedure, the lubricated bronchoscope may be passed nasally.
2. The suction tube is positioned with the specimen collector attached for collection of bronchial washings. When indicated, the suction tubing is connected to the bronchoscope; the container for collection is held securely in an upright position to prevent loss of the specimen through the suction.
3. The endoscopist or surgical technologist injects approximately 5 ml of saline solution into the channel. Suction is quickly reapplied. This procedure may be repeated as necessary.

After completion of the procedure, the perioperative nurse sends the specimens to the laboratory for analysis.

Mediastinoscopy

Mediastinoscopy is the direct visualization and possible biopsy of lymph nodes or tumors at the tracheobronchial junction, under the carina of the trachea, or on the upper lobe bronchi or subdivisions. Mediastinoscopy may precede an exploratory thoracotomy in known cases of lung carcinoma or may be completed to assist in accurately staging the patient's lymph node status. Patients with positive findings may be treated with radiation or chemotherapy, as indicated. The mediastinoscope is a hollow tube with a fiberoptic light carrier. A fiberoptic light source with a light-intensity dial provides power and control of illumination.

Procedural Considerations. The setup for mediastinoscopy includes a set of instruments for incising, cutting, retracting, and suturing similar to those needed for a minor procedure. In addition, the desired type of mediastinoscope, fiberoptic light cords, fiberoptic light source, suction tubing, aspirating tubes, biopsy forceps, electrosurgical unit (ESU), and an 8-inch, 20-gauge endocardiac needle are required. Depending on institutional policy, a thoracotomy tray may be in the OR on standby in the event of uncontrolled bleeding after biopsy.

The anesthesia provider administers a general anesthetic agent and assists with positioning the patient as described for a tracheostomy (see Chapter 18).

Operative Procedure

1. The surgeon makes a short (approximately 2-cm) transverse incision above the suprasternal notch, and exposes and incises the pretracheal fascia.
2. Using blunt (digital) dissection, the surgeon tunnels alongside the trachea into the mediastinum.
3. The surgeon introduces the mediastinoscope under direct vision deep to the fascial plane and advances it along the side of the trachea toward the mediastinum.
4. The scope is manipulated to visualize the tracheal bifurcation, bronchi, aortic arch, and associated lymph nodes.
5. Lymph node tissue is located for biopsy and aspirated with a small-gauge needle and syringe to verify that it is a nonvascular structure.
6. The surgeon inserts a biopsy forceps through the scope, and obtains a tissue specimen. Pressure can be applied to the excision site with a bronchus sponge on a holder. The mediastinum is reinspected for bleeding.
7. The mediastinoscope is withdrawn.
8. Subcutaneous tissue is sutured with absorbable sutures. The surgeon closes the skin with nonabsorbable material on a small cutting needle.
9. A small dressing is applied.

Video-Assisted Thoracic Surgery

Video-assisted thoracic surgery (VATS) is a minimally invasive operative technique that has evolved over the past decade. It uses an endoscopic approach to visualization of the thoracic cavity for diagnosis of pleural disease or treatment of pleural conditions, such as cysts, blebs, and effusions; for biopsy of mediastinal masses; to perform wedge resections, lobectomy, pericardectomy, lung volume reduction surgery, and cervical sympathectomy; to obtain hemostasis; and to evacuate blood clots or divide adhesions (Khraim, 2007). Pleurodesis with instillation of talc, tetracycline, or other sclerosing treatment can be accomplished through the thoracoscope (Surgical Pharmacology). VATS has many benefits, including the elimination of a thoracotomy incision, decreased pain, shortened hospital stay, and reduced morbidity. VATS may also be used in conjunction with robotically assisted thoracic procedures such as robotic lobectomy.

SURGICAL PHARMACOLOGY

Agents for Chemical Pleurodesis

Pleurodesis is undertaken as a treatment for malignant pleural effusion and for unresolved spontaneous pneumothorax. A variety of chemical agents are used to cause adherence of the pleural layers. Adherence of the pleural layers is thought to prevent the accumulation of pleural fluid in the case of pleural effusion and to prevent subsequent pneumothoraces. Commonly used agents for chemical pleurodesis are listed. Other agents may be used according to the surgeon's preference, surgical region, and agent availability. Perioperative nurses should consult with the surgeon before the procedure to determine the agent used.

Agent	Mechanism of Action	Dosage	Side Effects	Nursing Considerations
Talc	Stimulates mesothelial cells to coordinate an inflammatory response	5-10 g in 250 ml of sodium chloride	Pain, infection, ARDS, pulmonary edema	May be administered as a poudrage, aerosol, or slurry. Facial talc is unsterile, contains asbestos, and requires stringent sterilization technique. Commercially available sterile talc is preferable.
Antineoplastics	Chemical pleural irritation and fibrosis of pleural surfaces	Bleomycin: 60 units mixed with 100-200 mg of lidocaine	Pain, fever, neutropenia	Antineoplastics require special handling to reduce personal exposure. Nurses should follow hospital policies and procedures for safe medication handling procedures.

SURGICAL PHARMACOLOGY

Agents for Chemical Pleurodesis—cont'd

Agent	Mechanism of Action	Dosage	Side Effects	Nursing Considerations
Cyclines	Indirectly stimulate pleural macrophages, activating pleural mesothelial cells; low pH initiates an inflammatory reaction, causing fibrosis	Minocycline: 7 mg/kg Doxycycline: 500 mg in 30-50 ml of sodium chloride	Pain, fever, hemothorax, neutropenia	Determine if patient is allergic to cycline medications before procedure.
Silver nitrate	Coagulates cellular protein to form pleural eschar	20 ml of 0.5% silver nitrate	Pain, fever	Handle with care. Solution stains skin and clothing.
Quinacrine	Causes systemic inflammatory response	500 mg in 200 ml of saline	Pain, fever	Not available in United States or Canada.
Iodopovidone	Mechanism of action unknown	20 ml of 10% iodopovidone in 80 ml of saline	Severe pain, hypotension	Assess patient for allergies to iodine.

ARDS, Acute respiratory distress syndrome.

Modified from Colt HG, Davoudi M: The ideal pleurodesis agent: still searching after all these years, *Lancet Oncol* 9(10):912-913, 2008; Demmy TL, Nwogu C: Malignant pleural and pericardial effusion. In Selke FW et al, editors: *Sabiston & Spencer surgery of the chest,* ed 7, Philadelphia, 2005, Saunders; Dikensoy O, Light RW: Alternative widely available, inexpensive agents for pleurodesis, *Curr Opin Pulmonary Med* 11:340-344, 2005; Khaleeq G, Musani AI: Emerging paradigms in the management of malignant pleural effusions, *Respir Med* 102:939-948, 2008; Kilic D et al: Management of recurrent malignant pleural effusion with chemical pleurodesis, *Surg Today* 35:634-638, 2005.

Procedural Considerations. Endoscopic instrumentation and equipment used for a thoracoscopy include 5- and 10-mm telescopes, light cord, camera, graspers, dissectors, scissors, ligators, and endoscopic soft tissue instruments (scissors, hemostats, suction tips, retractors) and stapling devices. Accessory equipment for video (television monitors, videocassette recorder, printer, light source for camera and scope, slave television monitor) and insufflation is also used. The perioperative nurse will assist in positioning the patient supine, semilaterally or laterally, depending on the anatomic structures involved.

Operative Procedure

1. The surgeon creates a 2- to 3-cm incision between the fifth and seventh intercostal spaces for insertion of the 10- or 12-mm trocar. The zero-degree telescope is inserted to view the site so that the approach can be determined.
2. If the procedure can be completed by thoracoscopy, the surgeon creates additional puncture sites for insertion of additional trocars to allow instrument manipulation. The size of trocars and types of instruments vary for the diagnosis.
3. After the selected procedure, the surgeon inserts a chest tube through one of the surgical puncture sites and secures it to the skin. Trocar sites are closed, and small dressings or adhesive skin tapes are applied.

Endoscopic Thoracic Sympathectomy

Hyperhidrosis is defined as excessive sweating, usually affecting the palms, axillae, and soles of the feet. It may also affect the face, groin, or legs. Patients with severe hyperhidrosis may produce 40 times the normal amount of sweat (Solish et al, 2008). Hyperhidrosis affects approximately 2.8% of the general population, with 1.4% of these individuals projected to have axillary hyperhidrosis and 0.5% to have sweating that is intolerable or interferes with daily activities (Weksler et al, 2008). Familial history of hyperhidrosis is implicated in 30% to 65% of cases (Solish et al, 2008). Endoscopic thoracic sympathectomy (ETS) is a thoracoscopic intervention used to surgically treat hyperhidrosis (Research Highlight). To treat palmar hyperhidrosis, the surgeon interrupts the sympathetic chain at the T2 level. Compensatory sweating, defined as increased sweating in other areas following the procedure, is the most common side effect of this procedure. The incidence of mild compensatory sweating varies from 14% to 90% and the incidence of severe compensatory sweating ranges from 1.2% to 30.9% (Dumont, 2008). Many patients who undergo ETS do so on an ambulatory basis or require only an overnight stay. The procedure produces dramatic and immediate results and is associated with a positive outcome for the patient. ETS may also be used to surgically treat pain syndromes (e.g., complex regional pain syndrome), facial blushing, and Raynaud's syndrome.

Procedural Considerations. The patient is positioned supine, and the anesthesia provider inserts a double-lumen endotracheal tube. Video monitors are placed on each side of the patient to allow the surgeon an unobstructed view from either side, because the procedure is performed bilaterally.

Operative Procedure

1. The anesthesia care provider deflates the patient's lung as directed by the surgeon.
2. The surgeon uses the scalpel to make a small (2 mm or less) incision between the patient's second and third ribs in the axillary plane.
3. A disposable thoracic port is inserted through the incision, and the surgeon inserts a small (2- or 5-mm) telescope through the port.
4. The surgeon identifies the sympathetic chain at the T2 level (Figure 22-9, *A* and *B*), and uses endoscopic scissors to open the pleura.
5. The nerve is grasped with a bipolar forceps and divided with bipolar electrocoagulation (Figure 22-9, *C*). Alternatively, clips may be applied to the nerve.

RESEARCH HIGHLIGHT

Thoracoscopic Sympathectomy versus Medical Management for Severe Hyperhidrosis

Hyperhidrosis can be an extremely disabling condition for which medical management is the first-line treatment. While many patients are able to control their hyperhidrosis through medical management (e.g., topical aluminum chloride, anticoagulants, botulinum toxin A injections, use of iontophoresis [a treatment that uses water to conduct an electrical current through the skin's surface that results in microscopic thickening of the outer layer of the skin, which blocks the flow of sweat to the skin surface]), these treatments are temporary, require a high degree of patient commitment, and are associated with side effects. The researchers in this study sought to compare the outcomes of medical versus surgical management for palmoplantar hyperhidrosis (e.g., excessive sweating of the hands and feet) and evaluate the efficacy and side effects of both treatments.

Researchers conducted a prospective and retrospective study of 192 patients who met the criteria of (1) massive palmar sweating to the point of dripping or near-dripping, (2) plantar sweating approximating the palmar sweating, (3) simultaneous onset either in early childhood or at puberty, and (4) exacerbation with the use of ordinary hand lotion. The vast majority of patients met all four criteria, and no patient had fewer than three of the criteria. A total of 46 patients in the prospective group used the medical treatments for at least 2 weeks, and their responses and side effects were noted. If the medical treatment was unsatisfactory because of intolerable side effects or lack of response, the group was offered endoscopic thoracic sympathectomy (ETS). Only 1 patient from the prospective group and 1 patient from the retrospective group were satisfied enough with the results of medical management to forgo ETS surgery; 89 patients in the retrospective group underwent ETS.

Data analysis revealed that six (3.2%) patients who underwent ETS experienced severe compensatory sweating that resulted in significant discomfort. One patient experienced a pneumothorax, but no other significant complications were reported from ETS. Complications reported from medical management included palmar reactions (from topical solutions), with cracking and continued sweating through the cracks, and mouth dryness/discomfort, blurred vision, mental changes, and headaches. All of the patients who used botulinum toxin A experienced palmar pain, and one third of patients in the iontophoresis group developed pain and irritation from the treatments. Researchers concluded that ETS can "safely and confidently" be recommended as a first-line treatment of severe palmoplantar hyperhidrosis.

Modified from Baumgartner FJ et al: Superiority of thoracoscopic sympathectomy over medical management for the palmoplantar subset of severe hyperhidrosis, *Ann Vasc Surg* 23:1-7, 2009.

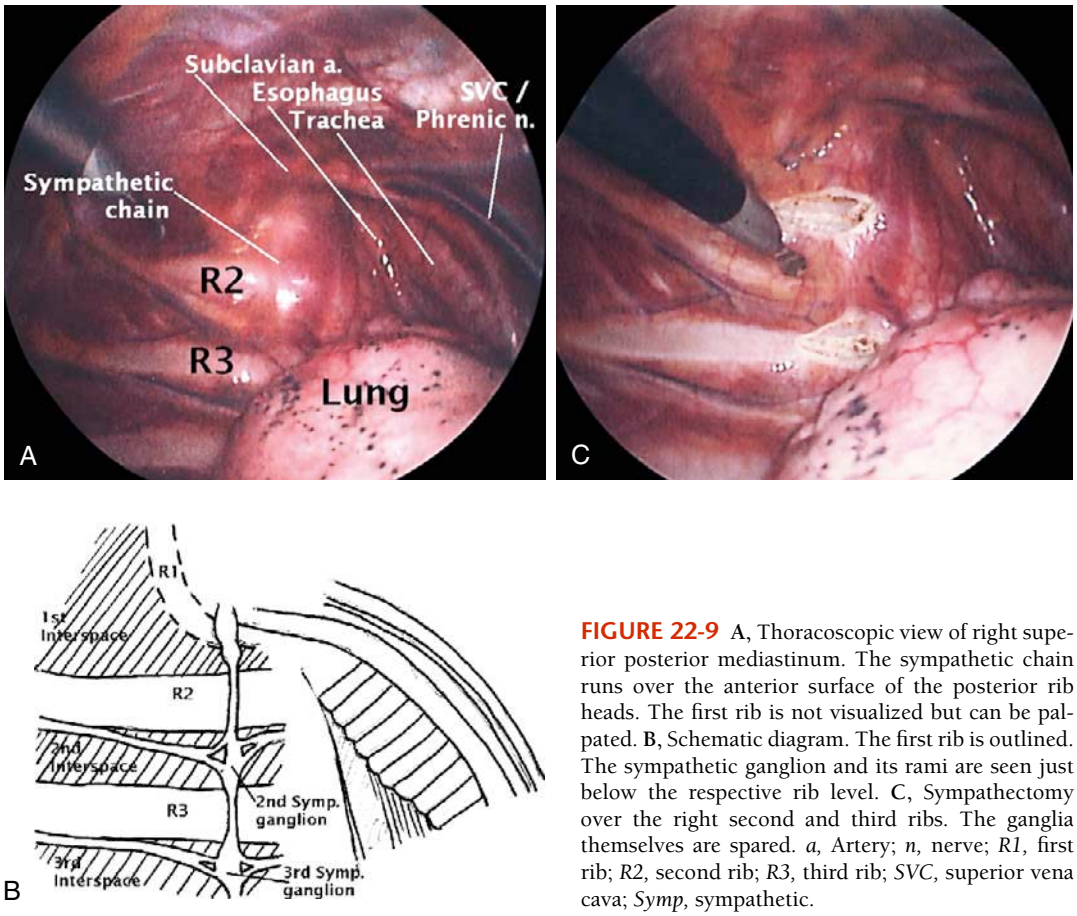


FIGURE 22-9 **A**, Thoracoscopic view of right superior posterior mediastinum. The sympathetic chain runs over the anterior surface of the posterior rib heads. The first rib is not visualized but can be palpated. **B**, Schematic diagram. The first rib is outlined. The sympathetic ganglion and its rami are seen just below the respective rib level. **C**, Sympathectomy over the right second and third ribs. The ganglia themselves are spared. *a*, Artery; *n*, nerve; *R1*, first rib; *R2*, second rib; *R3*, third rib; *SVC*, superior vena cava; *Symp*, sympathetic.

6. The port is removed, and a small thoracic catheter is inserted through the incision.
7. The surgeon closes the incision, and the lung is reexpanded. As the air is forced out of the pleural cavity, the catheter is removed and wound closure is completed.
8. The procedure is repeated for the opposite side.
9. Adhesive skin tapes are placed over the incision sites.
10. A postoperative chest x-ray film is obtained in the PACU to rule out any residual pneumothorax.

Robotic-Assisted Surgery

Robotic-assisted thoracic procedures have evolved since the introduction of robotic technology in the 1990s; they enhance the speed, accuracy, and safety of VATs (Kernstine et al, 2008). During traditional thoracotomy the surgeon's view is hampered by the size of the incision and rigidity of the chest wall. An advantage to the robotic-assisted approach is the superior three-dimensional view of the operative field and thoracic cavity, allowing the surgeon superior visualization, increased magnification, and better maneuverability. Smaller incisions are used for robotic surgery, so patients experience less postoperative pain and morbidity (Figure 22-10). A variety of robotic-assisted procedures are performed by specially trained surgeons, including mediastinal tumor resection, lobectomy, and sympathectomy. Continued advances in technology will allow for the development of additional applications and procedures within the thoracic specialty. The procedure for robotic-assisted lobectomy is described below.

Procedural Considerations. Refer to Chapter 7 for a general discussion of the equipment and instrumentation (e.g., robotic console, chassis) used for the procedure. In addition to preparing for the robotic procedure, the perioperative nurse and surgical technologist ensure that they have also gathered instrumentation and supplies to convert to an open procedure in the event an emergency arises or the surgeon is unable to complete the procedure through the minimally invasive approach. The nurse assists the anesthesia provider with inserting a double-lumen endotracheal tube and helps to position the patient in the lateral position with the operative side up. After the patient is prepped and draped, the anesthesia provider places the patient in reverse Trendelenburg's position. The nurse assists with positioning the robot, video monitors, and three-dimensional vision console equipment.

Operative Procedure

1. The surgeon consults the patient's preoperative CT scans to determine the placement of the thoracoports based on the location of the lesion.
2. The surgeon incises the skin at the seventh to eighth intercostal space along the midposterior axillary line and inserts the 12-mm thoracoport.
3. The robotic system is positioned, and the surgeon inserts a 30-degree scope through the thoracoport and connects the scope to the camera arm.
4. The surgeon incises the skin at the sixth to seventh, fourth to fifth, and fifth to sixth intercostal spaces, inserts the remaining thoracoports, and passes the dissecting instruments through the ports and connects them to the instrument arms.
5. A combination of blunt and sharp dissection is used by the surgeon around the hilar structures to gain exposure to the pulmonary vessels.
6. The surgeon ligates the pulmonary vein and artery using suture and/or robotic clips.
7. The surgeon dissects the lobar bronchus and nodes.
8. A 3.5-mm endostapler is passed through the appropriate thoracoport, clamped, and fired to complete the bronchial transaction.
9. The specimen is placed in a sterile removal bag and removed via the port site.
10. The surgeon tests the bronchial stump for leaks under water.
11. The pleural space is vented and the surgeon places a closed suction drain before closing the incisions.
12. Dressings are applied.

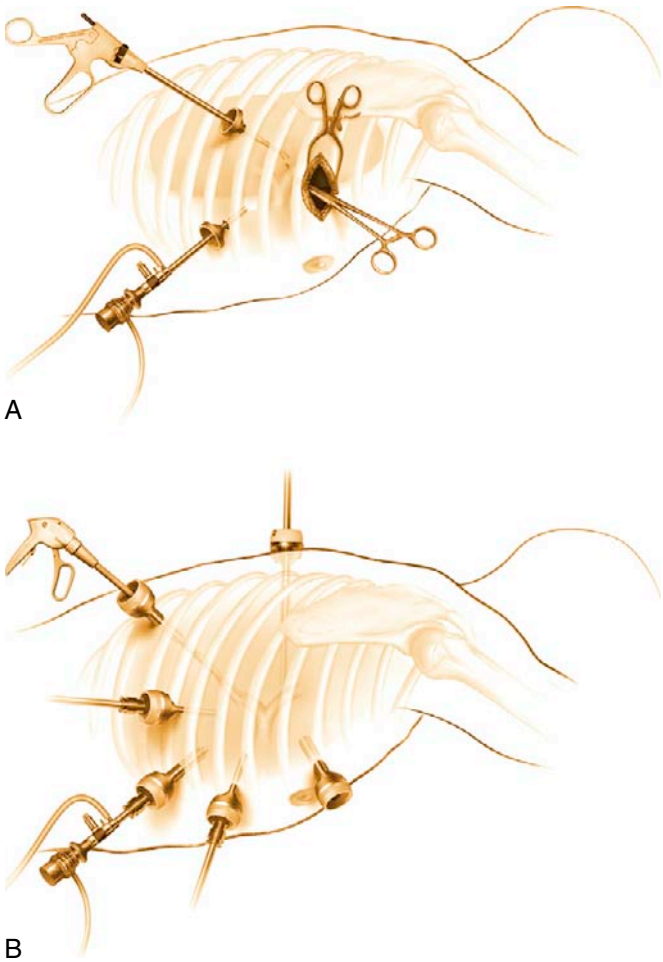


FIGURE 22-10 Comparison of VATS lobectomy to robotic lobectomy: The two patients shown are undergoing hilar dissection. **A**, VATS resection. There are three incisions shown, one for the videoscope and the other two for the right-angle clamp and stapler. The manipulation of the instrumentation and the arcs of rotation occur outside of the chest. The fulcrum of the instrumentation occurs at the chest wall, compressing and distending the intercostal nerves. **B**, Robotic resection. The arcs of rotation and management of the instrumentation for dissection are within the chest, allowing surgical dissection to occur in small spaces.

LUNG SURGERY

Thoracotomy

Thoracotomy involves an incision in the chest wall through a median sternotomy or a lateral or posterolateral incision for the purpose of operating on the lungs (History box). Thoracotomy may be performed for a variety of benign and malignant conditions. Lung cancer (Figure 22-11) is a common diagnosis associated with thoracotomy. Patients with lung cancer may have specific treatment based on their tumor, node, and metastasis (TNM) characteristics. The TNM system defines tumor (T) as the size, location, and spread (pulmonary or extrapulmonary). The designation of nodes (N) refers to spread to a lymph node or group of lymph nodes. Metastasis (M) relates to metastatic tumor activity in distant organs (e.g., brain, liver) (Box 22-1). Staging is based on TNM findings (Figure 22-12). Intraoperative patient care is similar for various thoracotomy procedures, with consideration of the patient's history and disease process, planned procedure, and individualized patient needs. Basic thoracic instrumentation is used and may include a sternal saw and stapling devices. Preparation by the anesthesia care provider with careful monitoring of the patient is a priority. Insertion of a double-lumen endotracheal tube, an arterial line for monitoring ABG samples, and a central venous line to ensure patent access for fluids are procedures performed by the anesthesia provider. An epidural catheter may be inserted for intraoperative and postoperative pain management. Patient preparation by the surgical team includes positioning, placement of devices for prevention of complications (e.g., sequential compression devices, thermal-regulating blanket, electrosurgical dispersive pad), insertion of a urinary catheter, and ongoing evaluation and communication of the patient's status to the family throughout the procedure.

Pneumonectomy

Pneumonectomy is the removal of an entire lung, usually to treat malignant neoplasms. Other reasons for this procedure include removal of an extensive unilateral bronchiectasis (e.g., irreversible dilation of the bronchi) involving the greater part of one lung, drainage of an extensive chronic pulmonary abscess involving portions of one or more lobes, removal of selected benign tumors, and treatment of any extensive unilateral lesion. Other resections are often combined with pneumonectomy, such as resection of mediastinal lymph nodes, resections of portions of the chest wall or diaphragm, and removal of parietal pleura.

HISTORY

Important Events in Thoracic Surgery

As early as 3000 BC, treatments related to the lungs and chest were undertaken as a result of injuries and wounds. It was not until the eighteenth century, however, that physiologic studies and animal experiments included the respiratory system. Several early reports discussed trauma, noting that wound closure helped the patient breathe easier. Thus the relationship between respiration and lung function was first established. During World War I there was increased awareness of the value of immediate closure of chest wounds.

The first thoracic procedure, recorded in 1499, was an unsuccessful excision of a herniation of the lung. From that time, the physiologic effect on the lungs and perceived difficulty entering the chest resulted in hesitancy to perform thoracic procedures. Until the 1880s the only thoracic procedures performed were to drain empyema and lung abscess or to treat traumatic chest injury. In 1823 the first purposeful resection of a part of the lung for accidental injury was reported by Milton Antony, and in 1861 the French surgeon Péan removed part of a lung for tumor.

Treatment of tuberculosis (TB) also provided an impetus for new developments in thoracic procedures. Thoracoplasty became widely used as a means of collapsing the lungs for treatment of TB, followed by other forms of treatment. In 1907 an article was published describing surgical techniques for access to the thoracic cavity. In 1913 Jacobeus is credited with dividing adhesions with an electrosurgical unit (ESU) passed through one cannula while through another he passed a cystoscope-like instrument he called a *thoracoscope.* Student textbooks in the 1920s contained only a short paragraph on cancer of the lung. From that time until the first successful pneumonectomy in 1933, many attempts were made to remove carcinomas, with limited success.

In 1899 the first important article on tumors of the chest wall was written. It summarized case reports of 46 other cases and classified the various tumor types. The first accounts of pulmonary resection were published in 1896, and one of the first cases of cancer of the lung to be reported in the United States was in 1851. Equipment and instrument development also improved the ability to study lung function. Although the bronchoscope was introduced in 1937, it was not used to study chest diseases until later. Using the bronchoscope became more important to remove secretions when Papanicolaou identified the advantages of applying cytologic technique to diagnosis of cancer.

The nursing care of patients with thoracic conditions evolved over time as medical and surgical treatments advanced and technology made new treatments available. Modern-day thoracentesis is generally accomplished using a presterilized disposable kit from a manufacturer. In the 1920s nurses who assisted with thoracentesis were responsible for acquiring a rubber sheet to protect the bed, sterile sheets to create a sterile field, sterile cotton, a hypodermic syringe and needle, sterile gloves and powder for the physician, and the aspirating set. The aspirating set consisted of a graduated 5- to 8-pint glass bottle with a rubber stopper fitted with a bifurcated metal tube and stopcocks. Rubber tubing with metal connectors was attached to the metal tube, and the sterile aspirating needle was connected to one branch of the tubing. The other branch of the tubing was connected to an exhaust pump. The nurse was responsible for testing the apparatus before the physician arrived, because the apparatus was used instead of a syringe for aspiration. Postprocedure treatment for the patient was described as "the patient must remain quietly in bed, in the recumbent position and no exertion or sudden movements should be allowed. The greatest precautions should be taken to prevent the entrance of infection."

Modified from Meade RH: *History of thoracic surgery,* Springfield, Ill, 1961, Charles C Thomas; Scott RJE: *Pocket cyclopedia of nursing,* New York, 1923, The Macmillan Co.

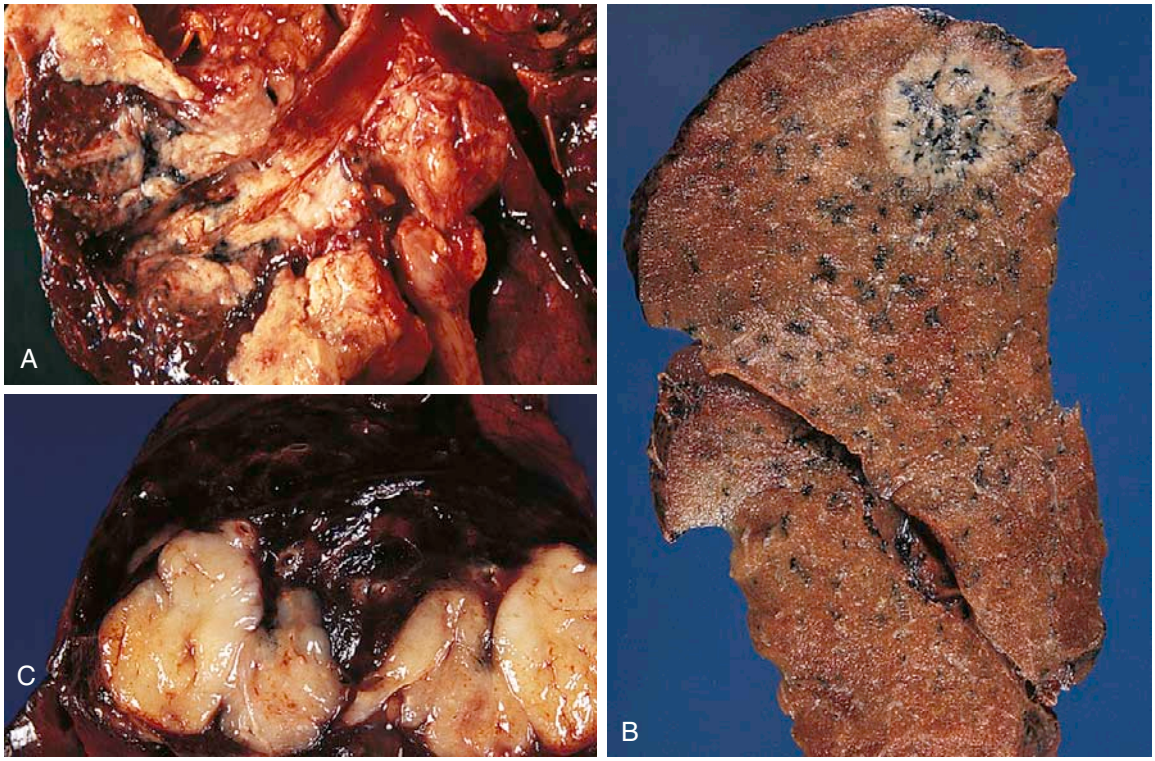


FIGURE 22-11 Lung cancer. **A**, Squamous cell carcinoma originating from the main bronchus. **B**, Peripheral adenoma. **C**, Small cell carcinoma.

BOX 22-1

TNM Definitions and Staging for Lung Cancer

T—PRIMARY TUMOR

T_x	Tumor that cannot be assessed, or malignant cells in sputum or bronchial washings but not visualized by imaging or bronchoscopy.
T_{is}	Carcinoma in situ.
T_0	No evidence of primary tumor.
T_1	A tumor that is 3 cm or less in greatest dimension, surrounded by lung or visceral pleura, and with no evidence of tumor invasion proximal to a lobar bronchus as determined at bronchoscopy.
T_2	A tumor that is either (1) more than 3 cm in greatest dimension or (2) invasive of the visceral pleura or associated with atelectasis or obstructive pneumonitis that extends to the hilar region. At the time of bronchoscopy the proximal extent of the tumor must be within a lobar bronchus or at least 2 cm or more distal to the carina. Any atelectasis or obstructive pneumonitis must not involve the entire lung.
T_3	A tumor of any size that invades the chest wall (including superior sulcus tumors), diaphragm, the mediastinal pleura, or the pericardium, but not involving the heart, great vessels, trachea, esophagus, or vertebral body. A tumor in the main bronchus within 2 cm of the carina without involving it or associated atelectasis or obstructive pneumonitis of entire lung is also a T_3 tumor.
T_4	A tumor of any size that invades the mediastinum, heart, great vessels, trachea, esophagus, vertebral body, or carina; or presence of malignant pleural or pericardial effusion; or with satellite tumor nodules within the ipsilateral, primary tumor lobe of the lung.

N—NODAL INVOLVEMENT

N_x	Regional lymph nodes cannot be assessed.
N_0	No metastasis to regional lymph nodes.
N_1	Metastasis to lymph nodes in the peribronchial or the ipsilateral hilar region or both, including direct extension.
N_2	Metastasis to ipsilateral mediastinal lymph nodes and subcarinal lymph nodes.
N_3	Metastasis to contralateral mediastinal lymph nodes, contralateral hilar lymph nodes, or ipsilateral or contralateral scalene or supraclavicular lymph nodes.

M—DISTANT METASTASIS

M_x	Distant metastasis cannot be assessed.
M_0	No (known) distant metastasis.
M_1	Distant metastasis present.

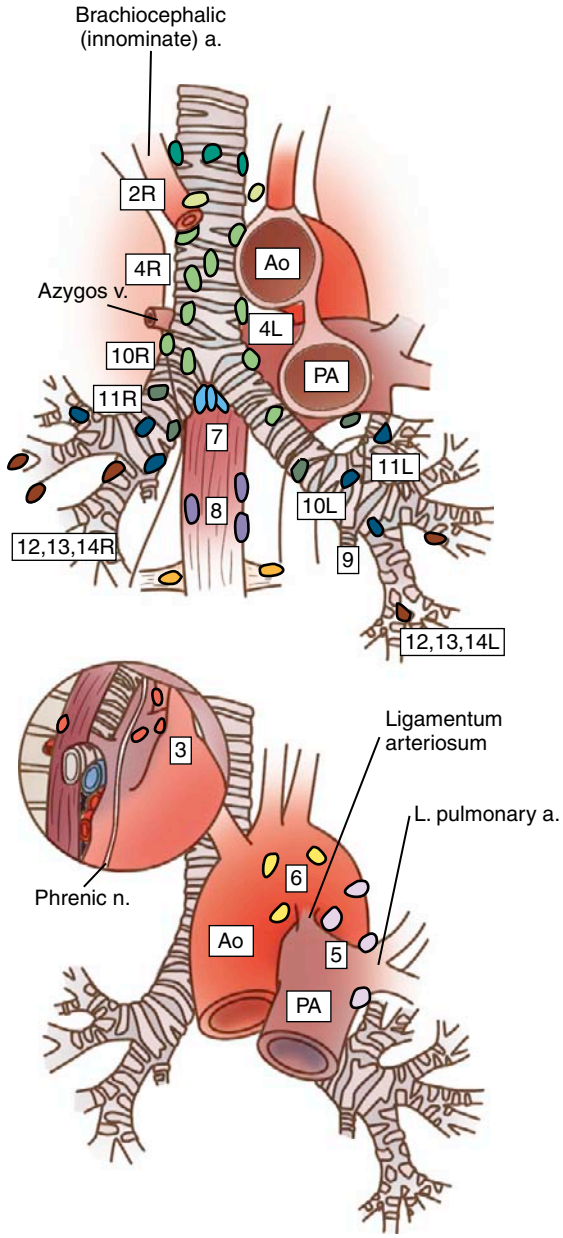
Stage	TNM Subsets
0	T_{is}, N_0, M_0
IA	T_1, N_0, M_0
IB	T_2, N_0, M_0
IIB	T_2, N_1, M_0
	T_3, N_0, M_0
IIIA	T_3, N_1, M_0
	T_{1-3}, N_2, M_0
IIIB	T_4, N_{0-2}, M_0
	Any T, N_3, M_0
IV	Any T, any N, M_1

Modified from Hassan I: *Lung cancer: staging,* eMedicine, 2009, available at http://emedicine.medscape.com/article/362919-overview. Accessed May 6, 2009; Selke FW et al, editors: *Sabiston & Spencer surgery of the chest,* ed 7, Philadelphia, 2005, Saunders.

Continued

BOX 22-1

TNM Definitions and Staging for Lung Cancer—cont'd



Superior Mediastinal Nodes

- 1. Highest mediastinal
- 2. Upper paratracheal
- 3. Prevascular and retrotracheal
- 4. Lower paratracheal (including azygos nodes)

N_2 = single digit, ipsilateral

N_3 = single digit, contralateral supraclavicular

Aortic Nodes

- 5. Subaortic (A-P window)
- 6. Para-aortic (ascending aorta or phrenic)

Inferior Mediastinal Nodes

- 7. Subcarinal
- 8. Paraesophageal (below carina)
- 9. Pulmonary ligament

N_1 Nodes

- 10. Hilar
- 11. Interlobar
- 12. Lobar
- 13. Segmental
- 14. Subsegmental

Regional lymph node stations for the staging of non–small cell lung cancer. Mediastinal nodes (i.e., N_2 nodes) are depicted by single digits, and intrapulmonary nodes (i.e., N_1 nodes) are depicted by two digits.

Procedural Considerations. The basic thoracic instrumentation is used. The perioperative nurse facilitates positioning the patient in the lateral position for a posterolateral incision.

Operative Procedure

1. The surgeon incises the skin, subcutaneous tissue, and muscle with a scalpel and the ESU. Hemostasis is attained. If a rib is to be excised, bone instruments are required.
2. The ribs and tissue are protected with moist sponges; the rib retractor is placed (Figure 22-13) and opened slowly and gently.
3. The surgeon frees any peripheral adhesions to mobilize the lung and divides the pulmonary ligament. Dissection to the hilum of the involved lobe is carried out.
4. The superior pulmonary vein is gently retracted, and the pulmonary artery is dissected.

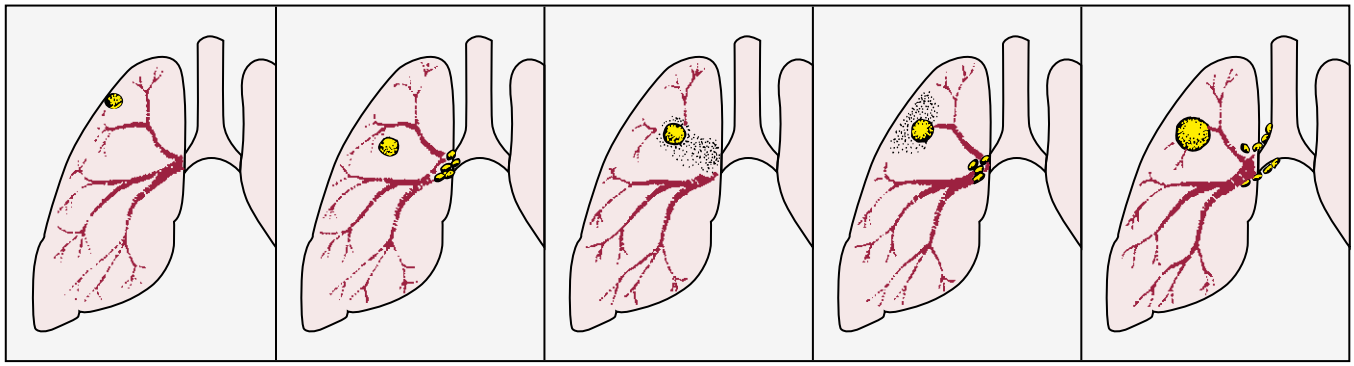


FIGURE 22-12 Staging of lung cancer by TMN system. **A** and **B**, Stage I disease includes tumors classified as T_1 with or without metastasis to the lymph node in the ipsilateral hilar region. **C**, Also included in stage I are tumors classified as T_2 but having no nodal or distant metastases. **D**, Stage II disease includes those tumors classified as T_2, with metastasis only to the ipsilateral hilar lymph nodes. **E**, Stage III includes all tumors more extensive than T_2 or any tumor with metastasis to the lymph nodes in the mediastinum with distant metastasis.

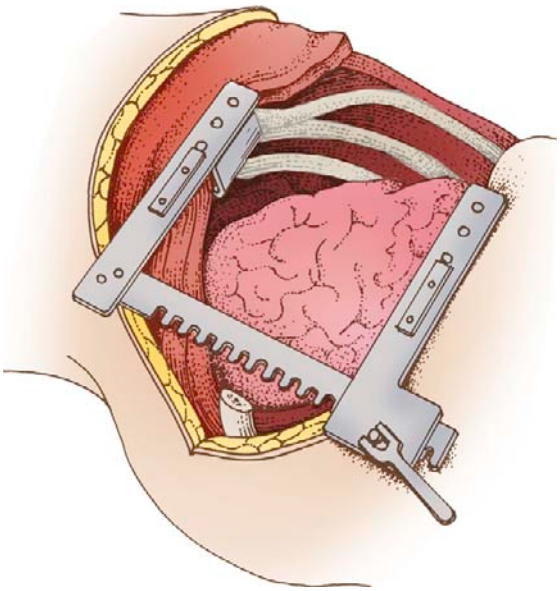


FIGURE 22-13 Rib retractor placed for thoracotomy.

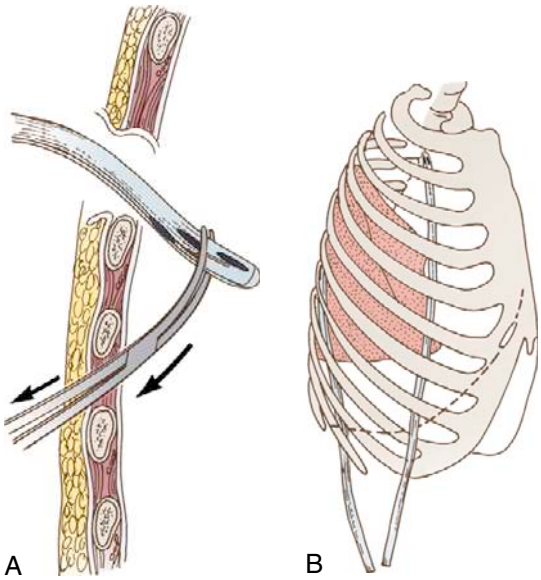


FIGURE 22-14 **A**, Introduction of chest drainage tube through a stab wound. **B**, Placement of apical and basal drainage tubes after upper and middle lobectomy.

5. The surgeon clamps the branches of the pulmonary artery and vein of the involved lobe, places double ligatures, and divides them with fine right-angled vascular clamps, scissors, and nonabsorbable suture.
6. The inferior pulmonary vein is exposed by incising the hilar pleura and retracting the lung anteriorly. The inferior pulmonary vein is clamped, doubly ligated, and divided.
7. The surgeon applies a bronchus clamp and divides the bronchus near the tracheal bifurcation. The stump is closed with atraumatic nonabsorbable mattress sutures or bronchus staples. If staples are applied, the scalpel is used to complete division of the bronchus. The lung is removed from the chest.
8. The surgical technologist supplies normal saline to irrigate the pleural space and check for hemostasis and air leaks during positive-pressure inspiration.
9. A pleural flap is created and sutured over the bronchial stump (other methods of securing the bronchus might be used).
10. Hemostasis is ensured in the pleural space.
11. Chest tubes (28-French to 30-French) are inserted into the pleural space and exteriorized through a stab wound at the eighth or ninth interspace near the anterior axillary line (Figure 22-14). An upper tube is inserted through a second stab wound if indicated to evaluate leaking air. The tubes are secured with heavy sutures and connected to water-seal drainage after closure of the pleural space.
12. The surgeon places the rib approximator (Figure 22-15) and begins closure with interrupted sutures.
13. The muscle, subcutaneous tissue, and skin are closed. Drains are anchored to the chest wall with suture.

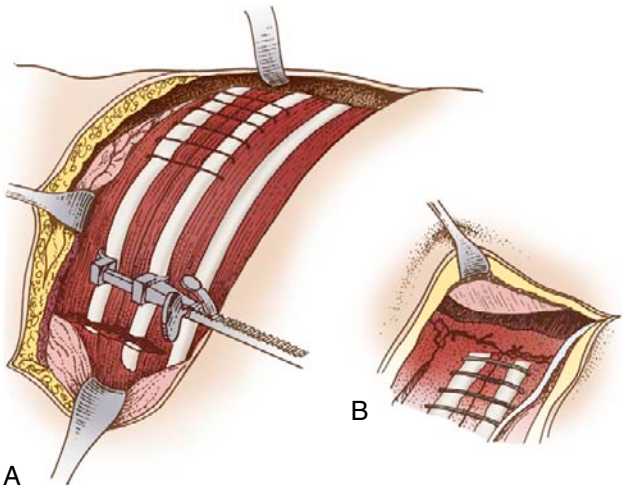


FIGURE 22-15 **A**, Rib approximator placed for closure of incision. **B**, Heavy-gauge suture used for closure of ribs.

14. The dressing is applied.
15. Chest tube connections are secured with Parnham bands or tape and labeled (anterior or posterior).

Lobectomy

Lobectomy is excision of one or more lobes of the lung. It is performed when the primary tumor is located in a particular lobe or to remove metastatic lesions when the tumor is peripherally located and hilar nodes are not involved. Other conditions affecting the lung and treated by lobectomy might be bronchiectasis; giant emphysematous blebs or bullae; large, centrally located benign tumors; fungal infections; and congenital anomalies.

Procedural Considerations. Basic thoracic instrumentation is used. The perioperative nurse assists with placing the patient in a lateral position for a posterolateral approach; the supine position may be used for upper- and middle-lobe resections. The procedure varies with the specific lobe to be removed depending on the anatomic structure.

Operative Procedure

1. The surgeon incises the skin, subcutaneous tissue, and muscle using a blade and the ESU. Hemostasis is attained. If a rib is to be excised, bone instruments are required.
2. The ribs and tissue are protected with sponges. The rib retractor is placed and opened slowly and gently.
3. The surgeon enters the pleura and frees the peripheral adhesions with scissors, blunt dissection, or a sponge on a sponge-holding forceps.
4. The hilar pleura is incised and separated.
5. The branches of the pulmonary arteries and veins are isolated, clamped, doubly ligated, and divided with fine, right-angled vascular clamps, scissors, and nonabsorbable suture.
6. The surgeon identifies the main trunk of the pulmonary artery and the fissure between the lobes.
7. The bronchus clamp is applied. The remaining lung is inflated to identify the line of demarcation. The bronchus is divided with a scalpel or heavy scissors.
8. Bronchial secretions are suctioned.
9. The surgeon closes the bronchus with atraumatic nonabsorbable mattress sutures or bronchus staples. If staples are applied, a blade is used to complete division of the bronchus.
10. Incomplete fissures are divided between hemostats with fine Metzenbaum scissors. Edges may be sutured closed.
11. A pleural flap is created and sutured over the bronchial stump (other methods of securing the bronchus might be used).
12. The pleural cavity is thoroughly irrigated with normal saline, and hemostasis is ensured. The remaining lobes are inflated to check for air leaks, and the degree of expansion of the remaining lobes is assessed.
13. The pleural space is irrigated, and the procedure is completed as described for a pneumonectomy.

Segmental Resection

Segmental resection is removal of one or more anatomic subdivisions of the pulmonary lobe. It conserves healthy, functioning pulmonary tissue by sparing remaining segments. Segmental resection is indicated for any benign lesion with segmental distribution or diseased tissue affecting only one segment of the lung with compromised cardiorespiratory reserve. The most common cause for removal is bronchiectasis. Other conditions requiring removal include chronic, localized inflammation and congenital cysts or blebs.

Procedural Considerations. Basic thoracotomy instrumentation is used. The perioperative nurse assists the surgical team in placing the patient in the lateral position.

Operative Procedure

1. The surgeon incises the skin, subcutaneous tissue, and muscle using a blade and the ESU.
2. The parietal pleura is incised with a scalpel and scissors. Adhesions are divided with sharp or blunt dissection.
3. The segmental artery is identified to provide accurate identification of the bronchus of the diseased segment.
4. The surgeon ligates the segmental pulmonary vein and branches.
5. The surgeon clamps the bronchus with the bronchus clamp, and the remaining lung is inflated. The intersegmental boundary is confirmed, and proper placement of the clamp is ensured.
6. The visceral pleura is incised around the diseased segment, beginning anterior to the hilum and progressing toward the periphery. Exposure is facilitated with a malleable or other type of retractor. The intersegmental vessels are clamped with thoracic hemostats and ligated.
7. The surgeon transects the segmental bronchus and closes the stump with atraumatic nonabsorbable mattress sutures or bronchus staples (Figure 22-16).
8. Dissection is continued to separate segmental surfaces, and vessels are ligated as needed. The segment of the lung is removed.
9. The surgeon creates a pleural flap and sutures it over the bronchial stump (other methods of securing the bronchus may be used).
10. The anesthesia provider reinflates the lung and the surgeon irrigates with normal saline. Bleeding is controlled with ligatures or hemoclips.
11. The procedure is completed as described for pneumonectomy.

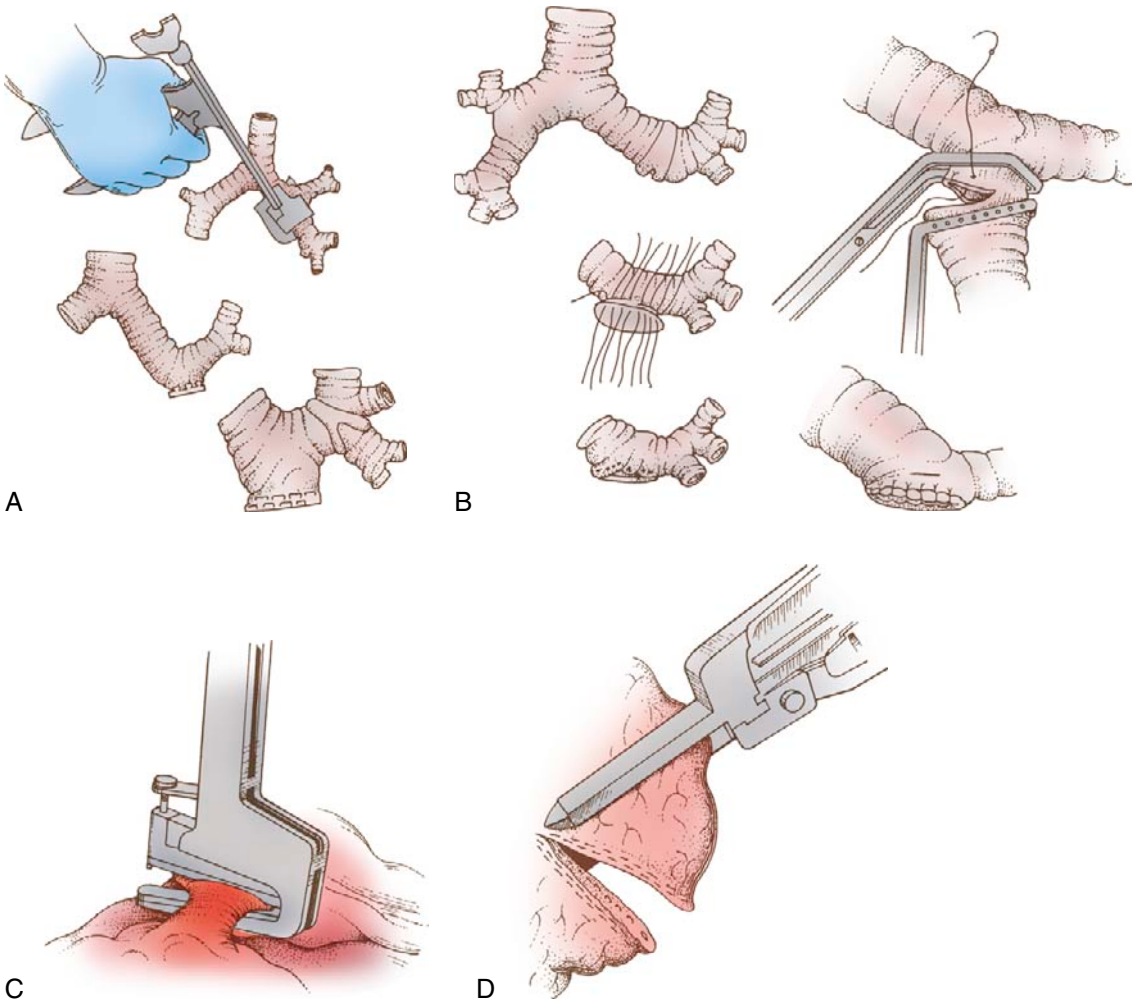


FIGURE 22-16 **A**, Staple suturing of bronchus. **B**, Conventional suturing of bronchus; application of bronchus clamp and incision; closure of stump. **C**, Staple suturing of pulmonary vessels. **D**, Staple suturing of lung tissue (wedge resection or lung biopsy).

Wedge Resection

Wedge resection is removal of a wedge-shaped section of parenchyma that includes the identified lesion, without regard for intersegmental planes. The resection is also used for removal of small, peripherally located benign primary tumors and peripherally located inflammatory disease, as well as for biopsy in patients with chronic, diffuse lung disease.

Procedural Considerations. Thoracic instrumentation is used. The team positions the patient to allow access to the operative site with consideration of the area of lung to be resected.

Operative Procedure

1. The surgeon incises the skin, subcutaneous tissue, and muscle using a blade and the ESU.
2. The rib retractor is placed.
3. The surgeon controls bleeding and secures the small bronchi with clamps and ligature. Large bronchi are ligated or sutured to prevent persistent air leak.
4. The wedge is outlined for excision, with a margin of normal tissue left, using one of the following techniques:
   a. Long hemostatic clamps are applied in three rows to outline the wedge. Excision is accomplished with a scalpel. The tissue is sutured with a running absorbable suture behind the clamps before removal. The edges of the tissue are oversewn with a continuous or interrupted suture (Figure 22-17).
   b. The lobe is grasped with a lung clamp, and the thoracic stapling instrument is applied to the parenchymal portion of the lung. Staples are applied, and the wedge is excised with the scalpel. Staples are reapplied to the opposite side of the lesion adjoining the staple lines.
5. The specimen is removed. The surgeon checks for air leaks by irrigation and inspection. Bleeding is controlled with ligation or hemoclips. The procedure is completed as described for pneumonectomy.

Lung Volume Reduction Surgery

Lung volume reduction surgery (LVRS) is an alternative surgical treatment for patients with chronic pulmonary emphysema (Figure 22-18). The surgery is intended to increase

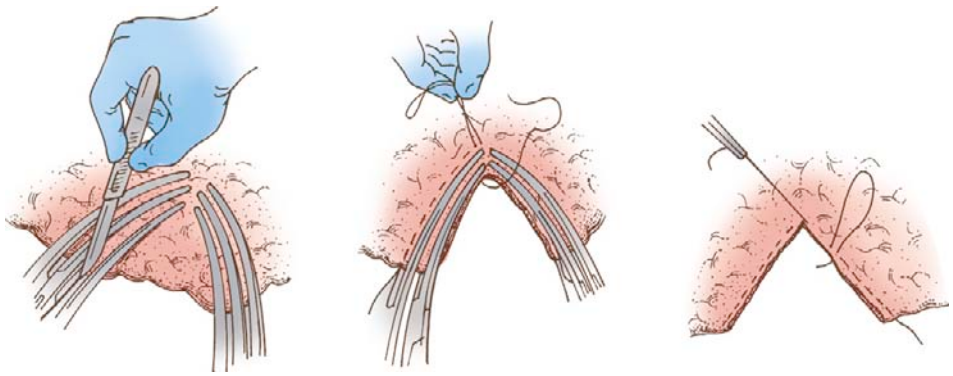


FIGURE 22-17 Wedge resection. Clamps applied to edge of lung tissue to be excised with blade and sutured with a running suture and oversewn.

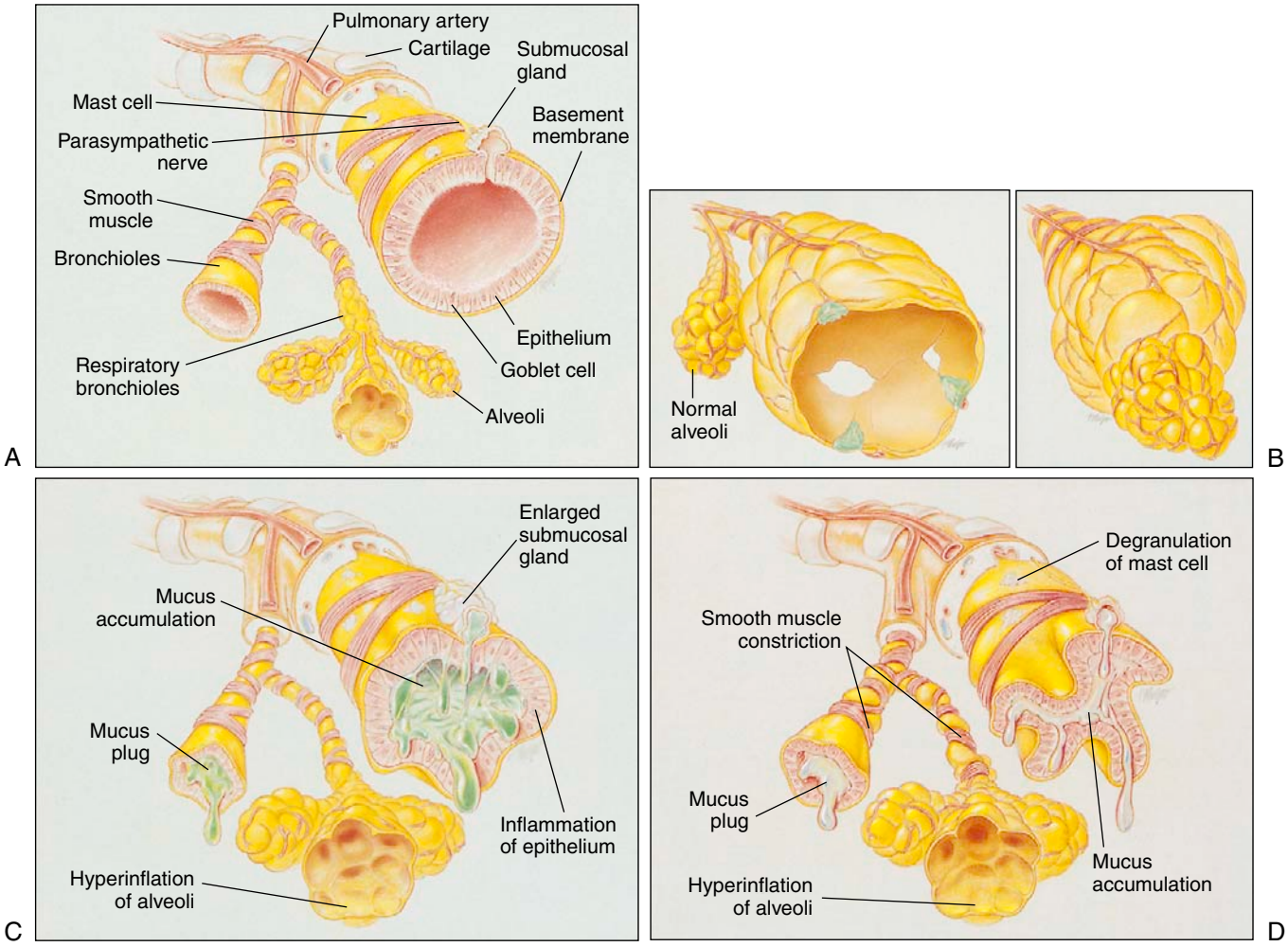


FIGURE 22-18 Airway obstruction caused by emphysema, chronic bronchitis, and asthma. **A**, The normal lung. **B**, Emphysema enlargement and destruction of alveolar walls with loss of elasticity and trapping of air; *(left)* panlobular emphysema showing abnormal weakening and enlargement of all air spaces distal to the terminal bronchioles (normal alveoli shown for comparison only); *(right)* centrilobular emphysema showing abnormal weakening and enlargement of the respiratory bronchioles in the proximal portion of the acinus. **C**, Chronic bronchitis: inflammation and thickening of mucous membrane with accumulation of mucus and pus leading to obstruction; characterized by cough. **D**, Bronchial asthma: thick mucus, mucosal edema, and smooth muscle spasm causing obstruction of small airways; breathing becomes labored, and expiration is difficult.

expiratory airflow, maximal exercise capacity, and respiratory muscle strength, thereby relieving dyspnea. The procedure may also be referred to as *lung volume reduction*, or *pneumoplasty*. Candidates for the procedure are those who have progressive, severe dyspnea secondary to pulmonary dysfunction; those whose medical management is ineffective; and those in whom disease distribution is limited to target areas of severity (Evidence for Practice). The two operative approaches for LVRS are median sternotomy and video-assisted thoracic surgery (VATS). Median sternotomy provides excellent bilateral exposure and flexibility, whereas the VATS approach has the advantage of a shorter hospitalization, fewer days of postoperative air leaks, and fewer days on the ventilator (McKenna, 2007). Patients undergoing LVRS participate in vigorous pulmonary rehabilitation as a standard practice in preparation for surgery. Pulmonary rehabilitation programs not only improve airway clearance and diaphragmatic function but also ensure that optimal conditioning is achieved, which improves surgical outcomes, improves tolerance for surgery, and decreases postoperative complications. An alternative procedure, bronchoscopic lung volume reduction (BLVR), using either an implanted valve system or a distributed sclerosant, is currently being evaluated in clinical trials in the United States (Mamary and Criner, 2008) (Research Highlight).

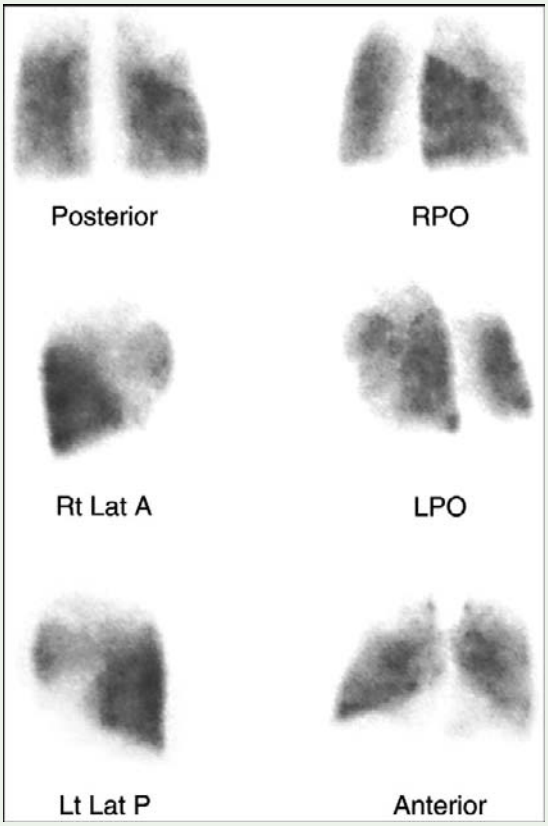
Procedural Considerations. The basic thoracotomy setup and instrumentation are used, along with stapling devices, chest tubes, and a water-seal drainage system. A laser may be required, as may other materials for sealing the resected edges (e.g., bovine pericardium, collagen). Positioning is a particular

EVIDENCE FOR PRACTICE

Determining Candidates for Lung Volume Reduction Surgery

Although lung volume reduction surgery (LVRS) is considered an effective procedure to treat patients with emphysema, successful outcomes depend on factors such as appropriate patient selection, surgical technique, and surgeon experience. After the reintroduction of LVRS to the medical community in 1995, there was a resurgence of interest in the technique. However, surgical interventions were accompanied by significant morbidity and mortality. As a result, the Health Care Financing Administration (HCFA) organized a clinical trial (the National Emphysema Treatment Trial [NETT]) to identify factors that contribute to successful outcomes. The NETT suggests the following criteria as patient eligibility for LVRS:

- High-resolution computed tomography evidence of moderate to severe bilateral heterogeneous emphysema or moderate to severe bilateral homogeneous emphysema; if emphysema is homogeneous, additional physiologic criteria may be required
- Target zones of poorly perfused lung
- Nonsmoker (tobacco products) for a minimum of 4 months before interview for screening, with willingness to sustain nonsmoking status
- Body mass index below 31.1 kg/m^2 (men) or below 32.3 kg/m^2 (women)
- No previous laser surgery or LVRS
- No giant bulla (one third or more of the volume of the lung in which the bulla is located)
- No previous coronary artery bypass surgery
- Oxygen requirement of 6 L/min or less to keep saturation at 90% or higher during an oxygen titration assessment
- No cardiac dysrhythmia that, in the judgment of the supervising physician, might pose a risk to the patient during exercise testing or training
- Postbronchodilator total lung capacity (TLC) at 110% or more of predicted
- Postbronchodilator residual volume (RV) at 220% or more of predicted
- Postbronchodilator forced expiratory volume in 1 second (FEV_1) at 45% or less of predicted and, if age 70 years or older, postbronchodilator FEV_1 at 15% or more of predicted
- FEV_1 postbronchodilator increase of 30% or less, or 300 ml or less
- DL_{co} (lung diffusing capacity for carbon monoxide) at 70% or less of predicted
- Consent for screening and patient registry
- Consent for pulmonary rehabilitation



Pulmonary perfusion scintigraphy demonstrating typical upper lobe predominant emphysema that is viewed as the most suitable morphology for lung reduction surgery. (From Selke FW et al, editors: *Sabiston & Spencer surgery of the chest*, ed 7, Philadelphia, 2005, Saunders.)

Modified from Benditt JO: Surgical options for patients with COPD: sorting out the choices, *Respir Care* 51(2):173-182, 2006; Meyers BF, Cooper JD: Surgery for emphysema. In Selke FW et al, editors: *Sabiston & Spencer surgery of the chest,* ed 7, Philadelphia, 2005, Saunders.

RESEARCH HIGHLIGHT

Bronchoscopic Lung Volume Reduction Surgery

Although LVRS is a viable treatment for emphysema, the surgical trauma associated even with the VATS approach is considerable and many patients who could benefit from LVRS do not meet eligibility requirements because of their existing morbidity and overall condition. Bronchoscopic lung volume reduction (BLVR) procedures may provide a new option for some patients.

There are currently three BLVR systems undergoing clinical trials in the United States. Two of the systems use one-way endobronchial valves that the surgeon deploys into the patient's bronchi through a flexible or rigid bronchoscope using a catheter or guidewire system. Although structured differently (e.g., one employs a duckbill valve, the other an umbrella frame), the two valve systems are both designed to prevent inspiratory airflow and facilitate expiratory air and secretion drainage. The intent is to produce volume reduction through progressive deflation and absorption atelectasis. The other system involves the use of a bronchoscope with a dual-lumen catheter to apply a liquid hydrogel to targeted areas of lung; the hydrogel contains biocompatible and biodegradable substances composed of fibroblast growth factor, chondroitin sulfate, thrombin, and tetracycline. The solution collapses the areas where it is applied and instigates an inflammatory reaction that leads to the formation of scar tissue. The scar tissue shrinks the lung and reduces its volume over a period of weeks.

Wan reported the results of a study involving 98 patients at nine centers in seven countries who were treated with an endobronchial valve configured with the duckbill valve system. Patients ranged in age from 50 to 80 years with a distribution of 20 females and 78 males. All patients had symptomatic emphysema with shortness of breath during activities of daily living that was unresponsive to maximal medical management. Valves were placed either unilaterally or bilaterally using a guidewire system via a flexible bronchoscope. The most frequent serious complication was prolonged air leak beyond the seventh postoperative day. Other complications included exacerbation of COPD, pneumothorax, and pneumonia. The researchers were able to demonstrate improvements in the study participants' spirometry results, diffusing capacity for CO_2, and exercise tolerance. Ongoing studies are underway to confirm the efficacy of the devices and refine the criteria for patient selection.

Reilly's study evaluated six men with COPD who underwent a chemically induced lung volume reduction via the unilateral instillation of a sclerosant composed of a fibrinogen suspension combined with thrombin. The mean age of the men in the study was 66 years, and all tolerated the procedure with minimal side effects (which were attributed to bronchoscopy) and were discharged within 24 hours of the procedure. The researchers noted that while the primary purpose of the study was to examine safety, all patients reported improvements in pulmonary function and exercise tolerance at their 3-month follow-up appointment.

Additional studies for both methods are ongoing and needed before FDA approval is granted.

Modified from Mamary AJ, Criner GJ: Lung volume reduction surgery and bronchoscopic lung volume reduction in severe emphysema, *Respir Med* 4:44-59, 2008; Reilly J et al: Biological lung volume reduction: a new bronchoscopic therapy for advanced emphysema, *Chest* 131:1108-1113, 2007; Wan IYP et al: Bronchoscopic lung volume reduction for end-stage emphysema: report on the first 98 patients, *Chest* 129:518-526, 2006.

concern for this patient population, who are often malnourished and are at increased risk for positioning injury. The perioperative nurse must collaborate with the surgeon and anesthesia provider to ensure that the best possible positioning practices are implemented.

Operative Procedure

1. The surgeon exposes the patient's lungs through a transverse anterior thoracotomy incision using the sternal saw to separate the sternum. Adhesiotomies are performed, and the inferior pulmonary ligaments are incised.
2. The anesthesia provider deflates the patient's lungs to allow for visualization of the portions of the lung where air is trapped in emphysematous lung tissue.
3. A lung-grasping forceps is used to hold the portion of the lung to be excised. A surgical stapling device is lined with bovine pericardium and positioned on either side of the lung. The stapling of emphysematous lung tissue continues, and staple lines are overlapped to prevent air leaks. Alternative means of sealing the resection line include the use of a pleural flap or the application of collagen.
4. The anesthesia provider reinflates the lung to identify air leaks. If air leaks are found, the lung is deflated and the stapling procedure continues.
5. One or two chest tubes are placed into each pleural space. The chest tubes are connected to water-seal drainage systems without suction.
6. The surgeon reapproximates the ribs and sternum using stainless-steel surgical wire. The muscle layer, subcutaneous tissue, and skin are closed, and dressings are applied.

Lung Biopsy

Lung biopsy is the resection of a small portion of the lung for diagnosis. The biopsy allows removal of relatively large specimens for microscopic examination of the lung tissue. Indications include (1) failure of closed methods (needle biopsy) for diagnosis and (2) the presence of small, localized lesions that can be removed by biopsy.

Procedural Considerations. In addition to the basic instrument setup, a rib retractor, a lung-grasping forceps, dissecting scissors, a chest tube and water-seal system, and an endostapling device are required. More than one specimen container may be needed. The patient is positioned in a semilateral position for an anterolateral incision.

Operative Procedure

1. A short incision (approximately 5 cm) is made at the fifth intercostal space. The surgeon incises the pleura and retracts the ribs.
2. The lung is secured and exteriorized using a Duval lung clamp.
3. Using a Satinsky clamp or a stapling device, the surgeon segments the tissue to be biopsied. The tissue to be removed is

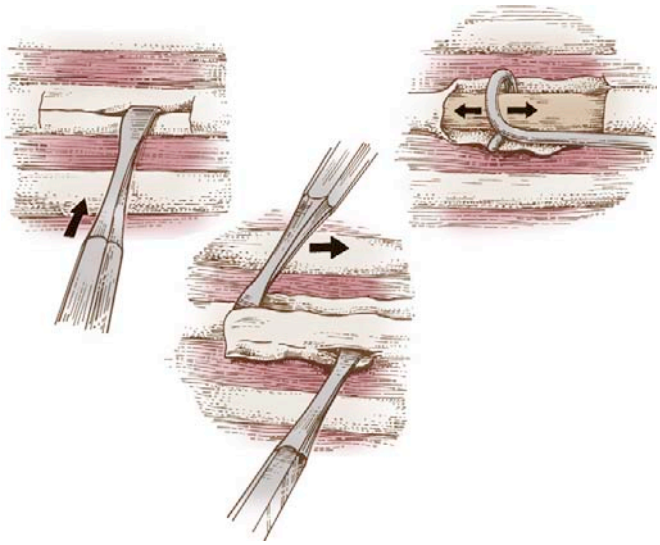


FIGURE 22-19 Separation of muscles of rib with a periosteal elevator and rib stripper.

excised with a scalpel. After application of the clamp, tissue edges are approximated with absorbable suture.

4. Bleeding is controlled by the application of a moist sponge at the incision site. The area is irrigated and inspected for air leaks.
5. The chest tube (28F to 30F) is inserted and connected to suction.
6. The incision is closed, the chest tube is anchored to the chest wall, and a dressing is applied.

Decortication

Decortication of the lung is removal of any fibrinous deposit, cancer, or restrictive membrane on the visceral and parietal pleura that interferes with pulmonary ventilatory function. It may also be done in conjunction with a pleurectomy for patients with pleural-based tumors, such as mesothelioma. The procedure results in blood loss and trauma and should be used only if the underlying lung is healthy. The objective is to return the lung to near-normal function.

Procedural Considerations. The basic thoracic instrumentation is used. The perioperative nurse assists with positioning the patient in a lateral position for a posterolateral incision.

Operative Procedure

1. The surgeon incises the skin, subcutaneous tissue, and muscle using a blade and the ESU.
2. A rib, usually the fifth or sixth, is stripped (Figure 22-19) and resected.
3. The surgical technologist provides moist sponges to protect the ribs and tissue. The rib retractor is placed and slowly and gently opened.
4. Parietal adhesions are divided to the margins of the lung, mediastinal surface, and pericardium with thoracic scissors, forceps, and a moist sponge on sponge-holding forceps.
5. The fibrous membrane is incised and separated from the visceral pleura using blunt and sharp dissection, handling the tissues gently (Figure 22-20). The procedure is completed as described for pneumonectomy.

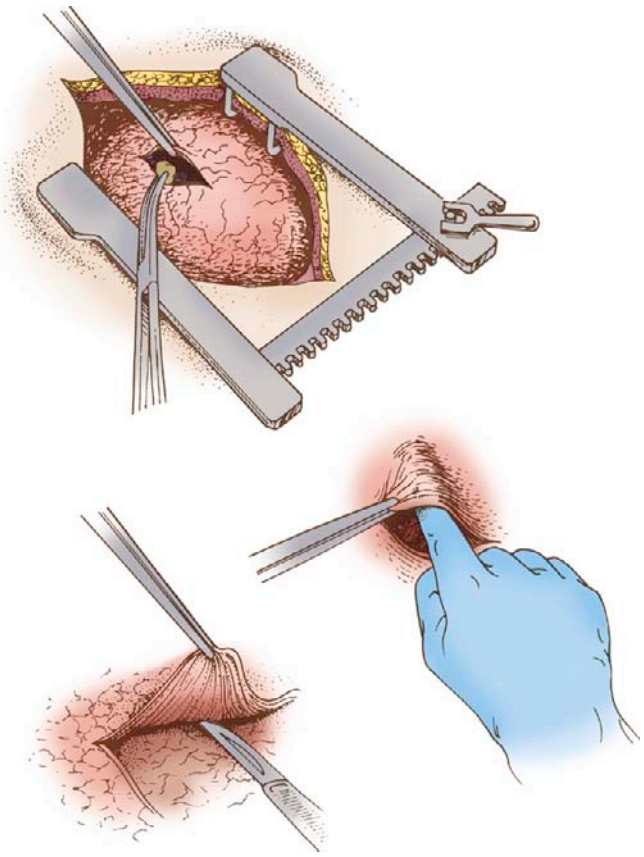


FIGURE 22-20 Decortication. Methods of separating fibrous membrane from visceral pleura.

Drainage of Empyema

The accumulation of pus in the pleural space might be associated with acute or chronic infection. Acute empyema may result from a lung abscess, pneumonia, or infection after thoracotomy. Parapneumonic effusions occur in 20% to 60% of patients hospitalized for bacterial pneumonia; 5% to 10% of these parapneumonic effusions progress to empyema. The mortality of empyema in the elderly and debilitated is 25% to 75% (Lee, 2005). Empyema (other than a pure tuberculous type) must be drained to prevent fibrothorax, and patients with empyema may require further treatment with decortication. When the infection is not extensive the procedure can be performed with the patient administered a local anesthetic. Prolonged intrapleural infection results in chronic empyema, which can create additional complications such as mediastinal shift, swallowing difficulties, respiratory limitations, bronchus erosion, and chest deformity. Talc poudrage may be the treatment of choice for patients able to tolerate additional procedures and who experience relief of pleural effusion by thoracentesis. Postoperative empyema or empyema occurring in immunosuppressed patients is effectively treated with a rib resection and drainage.

Procedural Considerations. If the patient is administered a general anesthetic, the basic thoracic instrumentation is

used. The team positions the patient in a lateral position for an anterolateral incision. A catheter for instillation of the sclerosing agent is required. The chest cavity is irrigated profusely during and on completion of the procedure.

Operative Procedure

1. The surgeon incises the skin and tissues with a scalpel to expose the affected area of the lung. Suction is used to prevent spillage of drainage from the chest.
2. The adjacent rib is resected, and the intercostal neurovascular bundle is divided.
3. The underlying thickened pleura is incised, and gross pus is evacuated. An inflammatory response might be created by stripping the parietal pleura from the visceral pleura by sharp or blunt dissection.
4. A large-bore catheter (46F) is inserted, and the sclerosing agent is instilled when indicated.
5. The surgeon closes the incision site as described for other thoracotomy procedures.
6. A dressing is applied.

Open Thoracostomy—Partial Rib Resection

Partial rib resection is removal of a portion of selected rib or ribs through an open thoracostomy incision to allow healing and reinflation of an infected lung. The procedure is performed for treatment of chronic empyemic lesions to establish a mechanism for continuous drainage.

Procedural Considerations. The basic thoracic instrument set and bone-cutting instruments are used. An ESU, chest tube, and water-seal drainage system are required, as are culture tubes for aerobic and anaerobic laboratory analysis. The patient is placed in a lateral position for a posterolateral incision. The surgical procedure can be completed with the patient administered a local anesthetic.

Operative Procedure

1. The surgeon incises the skin, subcutaneous tissue, and muscle using a blade and the ESU.
2. The rib is resected, and the pleura is incised. Suction is used to control anticipated drainage.
3. Aerobic and anaerobic swabs for culture and sensitivity are obtained. The chest cavity is irrigated.
4. A large chest tube is inserted through the pleural opening. The incision is closed or packed open (depending on the extent of the disease process).
5. The chest tube is secured with a suture of heavy-gauge material on a cutting needle.
6. The chest tube is connected to a water-seal drainage system, and connections are secured.
7. A dressing is applied. A number of layers of dressing may be necessary to absorb drainage.

Closed Thoracostomy—Intercostal Drainage

Closed thoracostomy is insertion of a chest catheter through an intercostal space for establishment of closed drainage. The procedure provides continuous aspiration of air, blood, or infectious fluid from the pleural cavity. It is indicated for treatment of spontaneous pneumothorax, traumatic hemothorax, pleural effusion, and acute empyema. Malignant pleural effusions (Figure 22-21) may be managed by drainage and chemical pleurodesis by way of the thoracostomy tube.

Procedural Considerations. The thoracostomy may not take place in an OR setting. The procedure is usually done with monitored anesthesia care and local anesthesia. A local anesthesia set, including syringes, needles, and an anesthetic agent of choice for local injection, will be needed. The minor instrument set is used, in addition to disposable chest catheters, water-seal drainage system, two aspirating needles, and culture tubes. The patient is placed in a lateral or sitting position. Despite the administration of local anesthetic, thoracostomy can be uncomfortable for the patient. The perioperative nurse should provide explanations and emotional support to the patient during the procedure.

Operative Procedure

1. The surgeon estimates the correct depth of insertion and marks the catheter. The operative site is anesthetized.
2. An aspirating needle attached to a syringe is introduced into the chest cavity to verify the presence of purulent drainage, air, or blood.
3. The surgeon incises the skin and introduces a clamp through the incision into the intercostal space and pleural cavity.
4. Next, the surgeon inserts a catheter through the incision site and clamps it to prevent egress of air as it is inserted into the cavity.
5. The incision site is sutured, and the catheter is secured.
6. The catheter is attached to water-seal drainage, and the tubing is secured. The clamp is removed, and a dressing is applied.

Decompression for Thoracic Outlet Syndrome

Thoracic outlet syndrome is a compression of the subclavian vessels and brachial plexus at the superior aperture of the thorax (Figure 22-22). The first rib is the usual cause of the compression, because of either a congenital deformity or a traumatic injury that results in anatomic changes. Fibromuscular bands

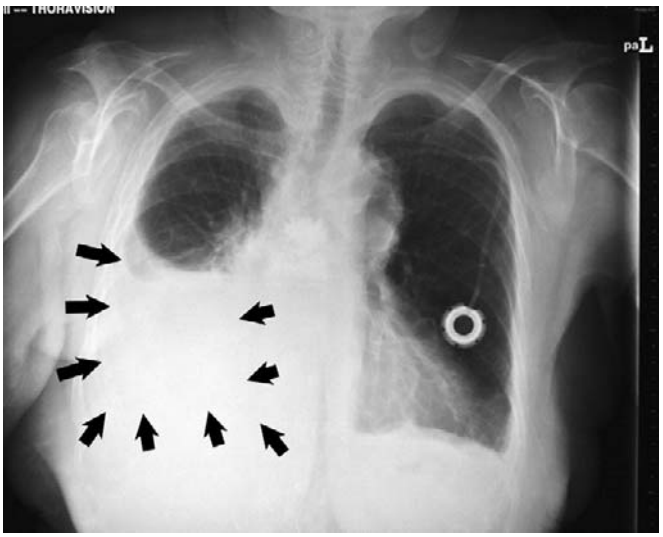


FIGURE 22-21 Chest x-ray showing large right pleural effusion outlined by arrows.

may also form between the cervical rib and other structures (i.e., scalenus tubercle) and cause compression. Symptoms depend on whether nerves, blood vessels, or both are compressed at the thoracic outlet. Decompression is accomplished through partial or entire removal of the rib using an open technique or video-assisted endoscopic techniques.

Procedural Considerations. Soft tissue and bone instrumentation is used. An ESU is required. The patient is positioned in a lateral decubitus position.

Operative Procedure—Open Technique

1. The surgeon incises the skin, subcutaneous tissue, and muscle using a blade and the ESU. Soft tissue dissection continues to identify the neurovascular bundle.
2. The first rib is meticulously dissected subperiosteally using the periosteal elevator. The rib elevator, stripper, and rib raspatories may be required. Undue traction on the brachial plexus and damage to the subclavian artery or vein are avoided during the dissection.
3. A wedge is taken from the midportion, or the rib is removed in its entirety using rib shears.
4. A drain is placed, and the incision is closed. A dressing is applied.

Excision of Mediastinal Lesion

Excision of a mediastinal lesion involves removal of a lesion from the anterior, middle, and posterior sections of the mediastinum. Identifying the compartment is important for planning a surgical approach to the resection, for optimal exposure and access. A mediastinoscopy should be performed to determine the diagnosis of an anterior mediastinal lesion. Indications for excision of a mediastinal lesion include miscellaneous cysts and tumors, thymoma, lymphoma, and neurogenic tumor.

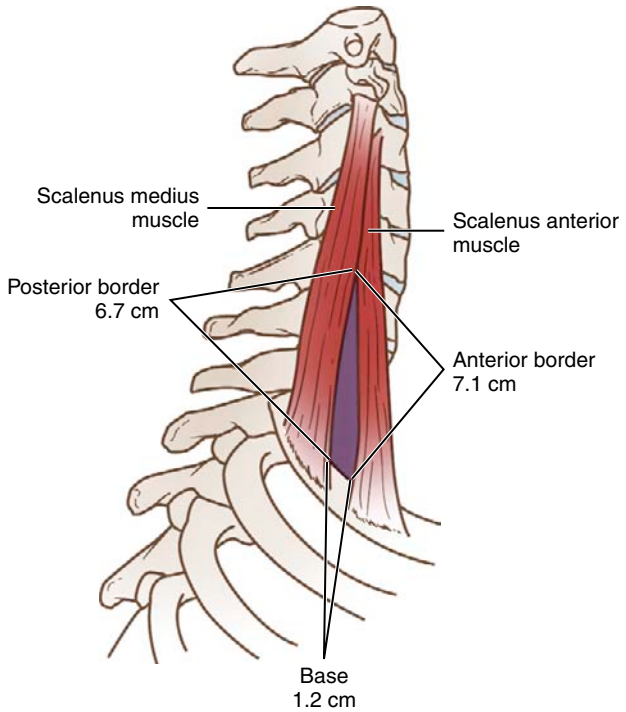


FIGURE 22-22 The scalene (anterior) triangle showing its measurements and the narrow space through which the neurovascular bundle passes.

Procedural Considerations. The thoracic instrumentation set is used. A procedure on the superior mediastinum might require use of thyroid instruments (see Chapter 15). The ESU and bone wax are needed. The perioperative nurse assists with placing the patient in a supine position for a median sternotomy incision (alternatively, lateral position may be used).

Operative Procedure—Thymectomy

1. The surgeon incises the skin, subcutaneous tissue, and muscle using a blade and the ESU.
2. The sternum is transected with a power saw or sternal knife. Bleeding is controlled at the bone edges with bone wax.
3. The thymus gland is dissected; vessels are clamped, ligated, and divided. The gland is removed.
4. The incision is closed. The sternum is reapproximated and closed with heavy wire. The skin is sutured closed. A dressing is applied.

Lung Transplantation

Since 1988 more than 17,000 lung transplants have been performed (Organ Procurement & Transplantation Network, 2009). Indications for single-lung transplantation (SLT) include restrictive lung disease, emphysema, pulmonary hypertension, and other nonseptic end-stage pulmonary diseases. Double-lung transplantation (DLT) is indicated for patients with cystic fibrosis or patients with a chronic infection in end-stage pulmonary failure. The procedure involves the allografting of one or both lungs from a cadaver or donor who has met clinical criteria for brain death. Developments in SLT include donor contribution from living relatives for patients who have chronic disease and a high risk for death while waiting on the donor transplantation list. Contraindications for transplantation include multisystem disease other than the lung, history of carcinoma or sarcoma, current infection, significant renal or hepatic dysfunction, cigarette smoking within 3 or 4 months, drug or alcohol abuse, psychologic instability, or poor medication compliance. Although the surgical technique is increasingly successful, it is anticipated that future application of lung transplantation techniques may be limited by donor supply. As the field of lung transplantation continues to evolve, questions will need to be answered regarding quality of life after transplantation and whether the single or double procedure is ultimately best for patients with chronic obstructive lung disease and primary pulmonary hypertension. Issues include the shortage of suitable donors, improved methods for early detection of chronic rejection, and improved immunosuppressive agents and regimens.

Procedural Considerations. Selection of the donor and recipients, preservation of the lung, and administration of anesthetic agents are considerations in this procedure. The nursing plan of care is modified considerably for each patient, since nursing personnel are caring for two patients with different needs. Recipient patients will have been started preoperatively on immunosuppressive therapy and infection prophylaxis. The patient's positioning will vary for the techniques being employed. The instrumentation is similar to that used for

a thoracotomy. Cardiopulmonary bypass (CPB) may be required, as described in Chapter 24, along with the ESU, cold perfusion solution, and surgical stapling devices. The perioperative nurse will need to collaborate with the anesthesia provider, since continuous hemodynamic monitoring, oximetry, and ventricular function assessment by transesophageal echocardiography (TEE) are all performed intraoperatively.

Operative Procedure—Single-Lung Transplantation

DONOR HARVESTING

1. The patient's skin is prepped from chin to knees and laterally to the midaxillary line. A median sternotomy incision or thoracotomy incision may be used.
2. The surgeon opens the pleura longitudinally posterior to the sternum, and divides the pericardium back to the hilum on both sides. The inferior pulmonary ligament is dissected, pleural adhesions are incised, and the proximal pulmonary arteries are dissected at their origin.
3. After heparinization and hypotensive anesthesia, the superior vena cava is ligated and divided and heavy silk ties are placed around each vessel.
4. The surgeon dissects the aortic arch free, and divides the ligamentum arteriosum. The anterior and inferior margins of the pulmonary artery are separated from the main artery and ascending aorta. Umbilical tapes are placed around the pulmonary artery and aorta. A purse-string suture is placed for infusion of the cardioplegia solution in the heart.
5. Once cardioplegia and pulmoplegia are accomplished, the heart is prepared for removal; veins and arteries are separated, and the heart is removed and placed in cold Collins solution.
6. Using blunt and sharp dissection the surgeon dissects the pulmonary arteries free from the mediastinum to the hilum anteriorly and then posteriorly to the anterior aorta and hilum. The trachea is dissected free. The lungs are inflated before stapling and dissection. The lungs are removed and immersed in cold Collins solution.

RECIPIENT PREPARATION AND TRANSPLANTATION

1. The perioperative nurse assists with positioning the patient laterally, and performs a wide skin prep for exposure of the chest and abdomen (nipple line to knees).
2. An incision is made for a thoracotomy. The procedure depends on which lung is to be removed. If the right lung is being removed, the pulmonary vein is isolated extrapericardially; the pulmonary artery is isolated as close to the lung as possible. The surgeon ligates and divides the azygos vein; the pulmonary artery is dissected.
3. If the left lung is being removed, the ligamentum arteriosum is divided.
4. The anesthesia provider collapses the lung to be removed, and the proximal pulmonary artery is occluded. If instability occurs after occlusion, partial femoral arteriovenous bypass is initiated. If the patient remains stable, the pneumonectomy is performed.
5. Pulmonary veins are divided extrapericardially. The first branch of the pulmonary artery and descending branch are separated. The blood supply to the bronchus is preserved by not dissecting tissue around the bronchus.
6. The surgeon divides the bronchus and removes the lung. The pericardium is opened around the pulmonary veins to allow room for the atrial clamp.
7. Inferior and superior pulmonary veins are incised and joined.
8. Three anastomoses are completed for a single-lung transplant: bronchus to bronchus, pulmonary artery to pulmonary artery, and recipient pulmonary veins to donor atrial cuff. Techniques used to minimize bronchial anastomotic complications include shortening the donor bronchial stump, reinforcing the anastomosis with a vascularized tissue pedicle such as omentum or intercostal muscle pedicle flap, or using an intussuscepting bronchial anastomosis technique.
9. After anastomoses and restoration of circulation, the lung is fully inflated and observed.
10. After closure of the chest, the surgeon performs a bronchoscopy to remove secretions and to ensure that the anastomosis is intact.

REFERENCES

Amdo T: Imaging bronchoscopic correlations for interventional pulmonology, *Radiol Clin North Am* 47:271–287, 2009.

Coughlin AM, Parchinsky C: Go with the flow of chest tube therapy, *Nursing* 36(3):36–41, 2006.

Denholm B: Tucking patient's arms and general positioning, *AORN J* 89(4):755–757, 2009.

Dumont P: Side effects and complications of surgery for hyperhidrosis, *Thorac Surg Clin* 18:193–207, 2008.

Fox J et al: Bloodless surgery and patient safety issues, *Perioperative Nursing Clinics* 3:345–354, 2008.

Kernstine KH et al: Robotic lobectomy, *Operative Techniques in Thoracic and Cardiovascular Surgery* 13(3):204.e1–204.e23, 2008.

Khraim FM: The wider scope of video-assisted thoracoscopic surgery,, *AORN J* 85:1199–1208, 2007.

Lee RB: Benign pleural disease: empyema thoracis. In Selke FW et al: *Sabiston & Spencer surgery of the chest*, ed 7, Philadelphia, 2005, Saunders.

Mamary AJ, Criner GJ: Lung volume reduction surgery and bronchoscopic lung volume reduction in severe emphysema, *Respir Med* 4:44–59, 2008.

McKenna RJ: Thoracoscopic lung volume reduction surgery, *Operative Techniques in Thoracic and Cardiovascular Surgery* 12(2):141–149, 2007.

Organ Procurement & Transplantation Network (OPTN): Transplants by donor type 1988-2009, available at: http://optn.transplant.hrsa.gov/latestData/rptData.asp. Accessed May 6, 2009.

Rees HC: Assessment of the respiratory system. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care*, ed 6, St Louis, 2010, Saunders.

Solish N et al: Evaluating the patient presenting with hyperhidrosis, *Thorac Surg Clin* 18:133–140, 2008.

Weksler B et al: Thoracic sympathectomy: at what level should you perform surgery? *Thorac Surg Clin* 18:183–191, 2008.

CHAPTER 23

Vascular Surgery

PATRICIA WIECZOREK

Atherosclerosis continues to be one of the leading causes of death and disability in the Western world. It is estimated that peripheral atherosclerosis, including carotid, mesenteric, renal, and peripheral arterial disease (PAD) (also referred to as peripheral arterial occlusive disease [PAOD]), affects about 5% of Americans older than 60 years and up to 15% who are older than 70 years (Linsky et al, 2008). This is particularly striking, given that by the year 2030 the percentage of the U.S. population older than 65 years will increase to 20% (Federal Interagency Forum on Aging-Related Statistics, 2008). Many of these people will require interventions for the syndromes of peripheral ischemia, aneurysm, and venous disease.

Interventional therapy for peripheral atherosclerosis has become common. Aortic procedures are now routinely performed with minimal mortality. Carotid endarterectomy has also proven to be safe and effective. Peripheral angioplasty and bypass have a high initial success rate, but restenosis, graft failure, and progression of distal disease still lead to limb loss in certain patients after several years. Thus emphasis has been placed on decreasing morbidity and hospital stay associated with revascularization. Minimally invasive methods and strategies, including endovascular aortic aneurysm repair (Pearce, 2005), carotid artery stenting (Liu et al, 2009) (Research Highlight), stenting for lower-limb ischemia (Rosen and Karmy-Jones, 2009), and percutaneous transluminal angioplasty (Zeller et al, 2009), have been developed, and their application and popularity continue to increase. New technologies, such as miniature shavers and laser arthrectomy devices for arterial plaque, continue to be developed (Nguyen and Garcia, 2008). Perioperative nurses must be prepared for the demands of patient care in vascular surgery. This chapter reviews surgical anatomy, perioperative nursing considerations, and surgical interventions for a variety of vascular procedures.

RESEARCH HIGHLIGHT

Long-Term Results of Carotid Stenting versus Endarterectomy in High-Risk Patients

With the continued evolution of endovascular techniques, carotid stenting has become an option in high-risk patients. The authors previously reported that carotid stenting did not produce inferior results to carotid endarterectomy for the treatment of carotid artery disease at 30-days and at 1-year postprocedure. This study now reports the results of those same patients at 3 years. The prespecified major endpoint at 3 years was a composite of death, stroke, or myocardial infarction within 30 days after the procedure or death or ipsilateral stoke between 31 days and 1080 days. Data were available for 260 patients (77.8% of the initial group). The prespecified endpoint occurred in 41 patients in the stenting group (cumulative incidence, 24.6%) and 45 patients in the endarterectomy group (cumulative incidence, 26.9%); 15 patients in each group had a stroke. The authors concluded that in their trial of patients with severe carotid artery stenosis and increased surgical risk, no significant difference was seen in the long-term outcomes between the two groups. Further studies focusing on preprocedural variables are recommended as well as longer-term outcome results.

Modified from Gurm H et al: Long-term results of carotid stenting versus endarterectomy in high risk patients, *N Engl J Med* 358(15):1572-1581, 2008.

Surgical Anatomy

Basic knowledge of anatomy is essential when caring for perioperative patients with a vascular disorder. Figure 23-1 depicts the principal arteries and veins of the body. Arteries and veins have three layers:

- Tunica intima (innermost layer)
- Tunica media (muscular middle layer)
- Tunica adventitia (fibrous outer layer)

Arteries differ from veins in function and slightly in structure (Figure 23-2). Structurally, arteries have a thicker muscle layer and more elastic fibers than veins. The properties of elasticity and distensibility enable arteries to compensate for changes in blood pressure and volume. Because of the thicker muscle layer, severed arteries are capable of contracting and constricting enough to stop hemorrhage. In contrast, veins are more fragile than arteries, and whether its cause is traumatic or iatrogenic, venous bleeding may be difficult to control. Another difference is the presence of semilunar intimal folds, or valves, in veins that prevent backflow. Veins and arteries are nourished by a tiny network of vessels (the vasa vasorum), as well as from the intraluminal blood flow. Both are regulated by the autonomic nervous system, with veins having fewer nerve fibers than arteries. The two systems are connected (except for the pulmonary artery and pulmonary venous system): major arteries carry oxygenated blood, they branch into smaller arteries and arterioles, and then blood moves into capillaries to venules and to veins. The work of exchanging nutrients and metabolic waste is done at the capillary level.

Blood flow is a complex process that depends on many factors. Blood flows through arteries such that the blood in the center of the vessel moves faster than the blood at the

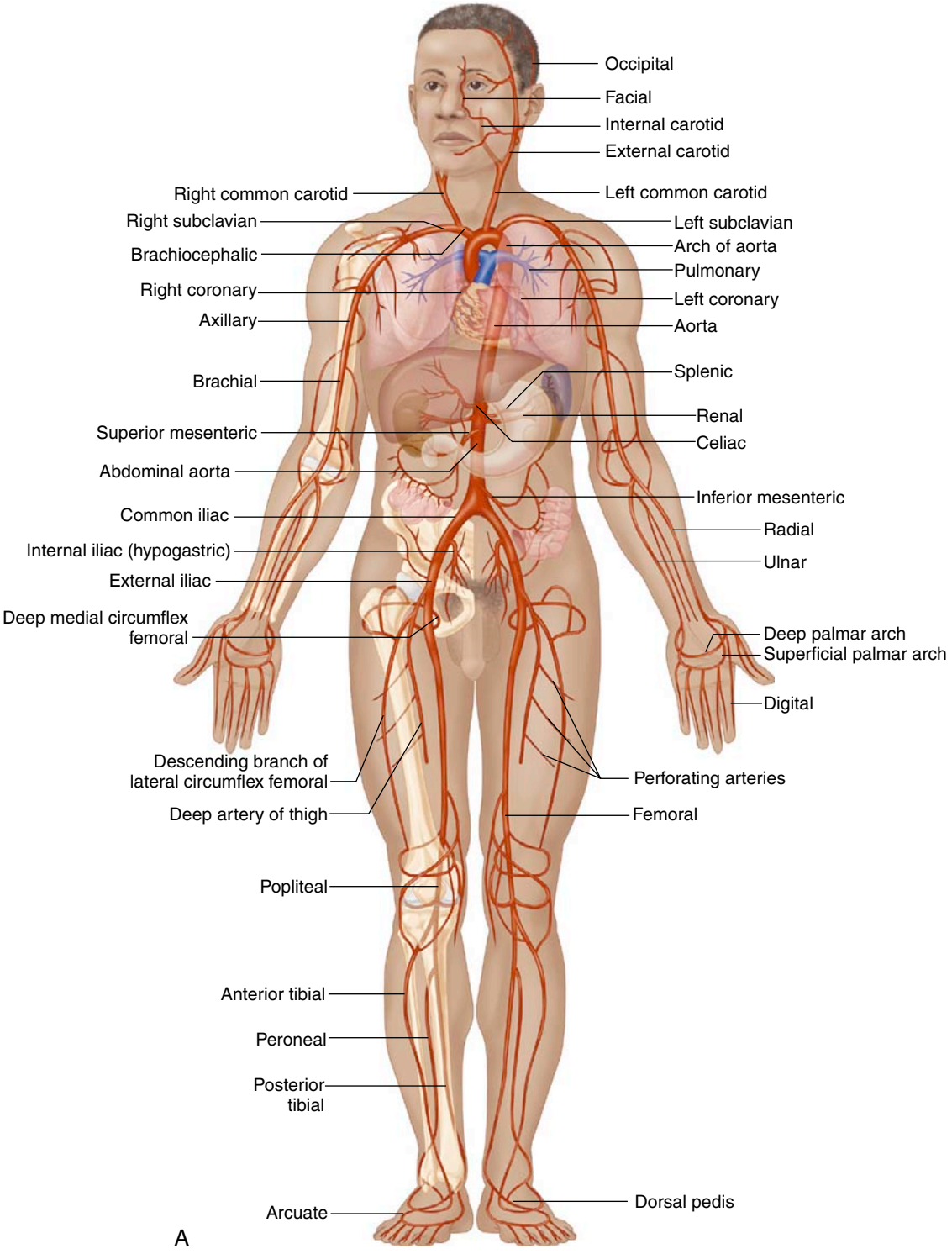


FIGURE 23-1 A, Principal arteries of the body.

periphery. Because the movement of the blood is in parallel lines, it is referred to as *laminar*. When flow is disrupted by an obstruction, stenosis, curve, or bifurcation, the particle motion is referred to as *turbulent*. Turbulence may be evidenced by the presence of a bruit (e.g., turbulent noise), detected by auscultation, or detected by a characteristic Doppler signal. Flow depends on blood viscosity, vessel wall resistance, and the peripheral resistance of the arterioles. There must be a difference in pressures, or a pressure gradient, to allow blood to flow. The gradient is provided by the contraction of the left ventricle. The negative pressure created by the relaxed right ventricle assists in venous return by creating a suctioning effect and the skeletal and visceral muscles help propel venous return toward the heart.

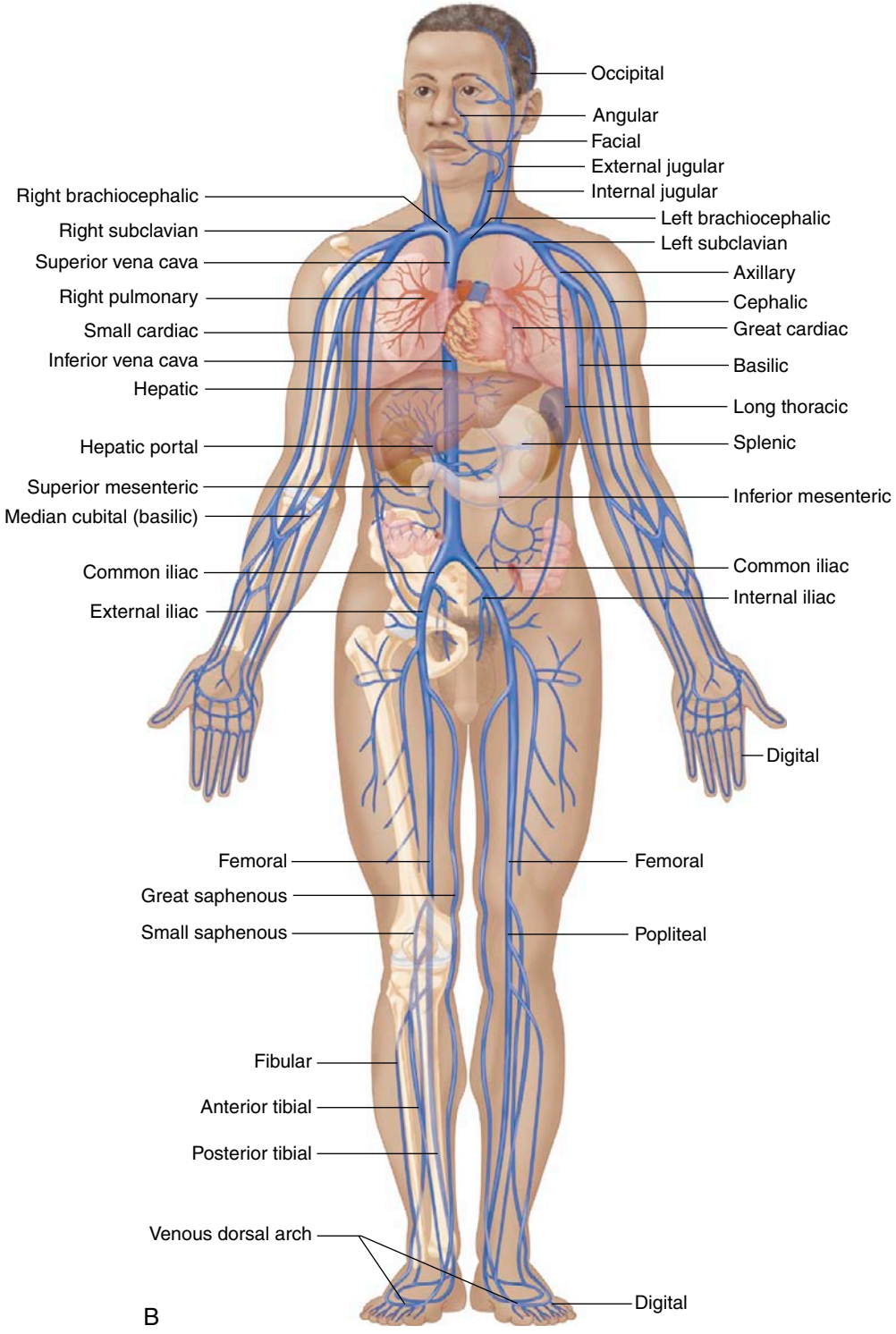


FIGURE 23-1 cont'd B, Principal veins of the body.

ARTERIAL DISEASE

Aneurysmal Disease

The most common cause of an arterial aneurysm is atherosclerotic degeneration of the arterial wall (Gloviczki and Ricotta, 2008). The pathogenesis is a multifactorial process, involving atherosclerosis along with genetic predisposition, aging, inflammation, and localized activation of proteolytic enzymes (Gloviczki and Ricotta, 2008). A true aneurysm is a dilation of all layers of the artery wall. A dissecting aneurysm results from a tear in the artery wall, allowing blood to dissect between the layers of the vessel wall. A false aneurysm, or pseudoaneurysm, is not an aneurysm but a disruption through all the layers of a vessel wall with the escaping blood being contained by the

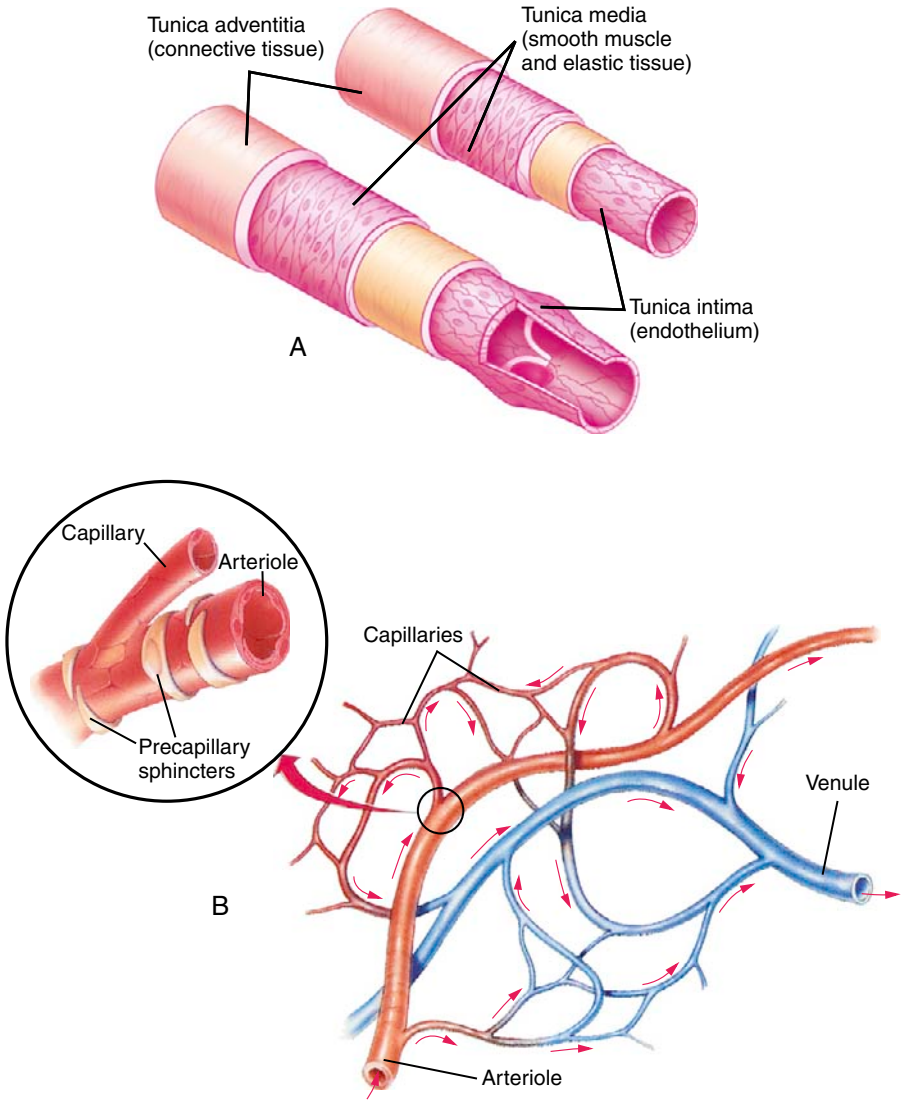


FIGURE 23-2 **A**, Layers of artery and vein. Drawings of a sectioned artery and vein show the three layers of large vessel walls. **B**, Microcirculation. The smaller blood vessels—arterioles, capillaries, and venules—cannot be observed without magnification. Note that the control of blood flow through any particular region of a capillary network can be regulated by the relative contraction of precapillary sphincters in the walls of the arterioles (*inset*). Note also that capillaries have a wall composed of only a single layer of flattened cells, whereas the walls of the larger vessels also have a smooth layer.

perivascular tissues. False aneurysms may result from trauma, infection, or disruption of an arterial suture line after surgery. True aneurysms are most frequently found in the abdominal aorta but are also found in the thoracic aorta and iliac, femoral, and popliteal arteries. More men than women are affected, and aneurysmal disease tends to be a disease of older persons. As early as 1977, a familial tendency was observed that subsequent research verified; as many as 18% of patients with abdominal aortic aneurysms have a first-degree relative with a similar diagnosis (Gloviczki and Ricotta, 2008).

Abdominal aortic aneurysms (AAAs), which account for most aneurysms, occur primarily between the renal arteries and the aortic bifurcation (Ignatavicius and Walicek, 2010). An aneurysm involves intimal damage of the aorta and weakening of the tunica media (Alberto et al, 2008) or elastic portion (collagen and elastin defects) of the arterial wall. Gradually the vessel wall in the damaged area expands and atheroma develops within the aneurysm sac (Figure 23-3). An AAA has minimal symptoms and is generally discovered on routine history and physical examination. In men, the diameter of the infrarenal aorta normally measures between 14 and 24 mm and in women it measures between 12 and 21 mm. An AAA is diagnosed if the diameter is 3 cm or larger for men or 2.6 cm or larger for females (Gloviczki and Ricotta, 2008). Mortality is low with elective resection of the aneurysm. Dissection and rupture of the aneurysm (aortic dissection) dramatically increase operative mortality because of the abrupt and massive hemorrhagic shock that accompanies the rupture. Aortic dissection is believed to arise from a sudden tear in the aortic intima, opening the way for blood to enter the aortic wall.

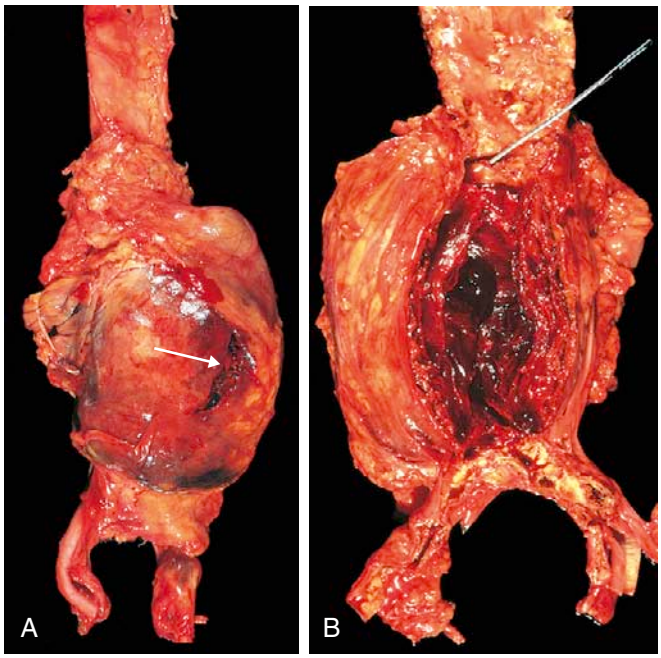


FIGURE 23-3 Abdominal aortic aneurysm. **A**, External view, gross photograph of a large aortic aneurysm that ruptured (*arrow*). **B**, Opened view. The wall of the aneurysm is thin and the lumen is filled with a large quantity of thrombus. The probe indicates the track of the rupture.

BOX 23-1

Risk Factors for Atherosclerosis

FIRMLY ESTABLISHED FACTORS
- Hypercholesterolemia
- Cigarette smoking
- Hypertension
- Diabetes mellitus

RELATIVE FACTORS
- Advanced age
- Male gender
- Hypertriglyceridemia
- Hyperhomocystinemia
- Sedentary lifestyle
- Family history

From Hirsch A et al: ACC/AHA 2005 practice guidelines for the management of patients with peripheral arterial disease: a collaborative report, *Circulation* 113(11):e463-e654, 2006.

Acute Arterial Insufficiency

Arterial insufficiency may result from an acute occlusion, as in embolic disease, or from the rupture of an unstable atherosclerotic plaque, causing acute thrombosis of the vessel. Emboli usually arise from the heart as a result of atrial fibrillation but may occasionally result from a myocardial infarction (MI), where a clot forms on the endocardium (the lining of the heart) in an area of muscle damage. Atherosclerotic plaque can also break loose from other areas and result in an acute arterial blockage. Patients with acute arterial occlusion usually present with the onset of the six *P*'s: sudden severe *p*ain, *p*ulselessness, *p*aresthesia, *p*aralysis, *p*allor, and *p*oikilothermia (coolness) of an extremity (Ignatavicius and Walicek, 2010). Heparin is the mainstay to prevent the enlargement of emboli while allowing time for collateral blood flow to develop. However, in the threatened limb there are basically two options: surgical removal of the clot (embolectomy) or chemical removal of the clot with the use of a thrombolytic medication. If the limb reaches the point where the muscle is rigid, the limb is not salvageable and amputation is a lifesaving procedure.

Chronic Arterial Insufficiency

Chronic arterial insufficiency occurs because of the deposition of calcium and cholesterol within the wall of the artery. Arteriosclerosis is a natural part of the aging process and occurs when the walls of the arterial vasculature undergo changes such as increased thickness and hardening, reducing the elasticity of the arteries. The decrease in elasticity should not be confused with atherosclerosis obliterans, which is a pathologic process that affects the intimal layer of the artery with the buildup of a fibrous plaque of lipids that can calcify and necrose. Atherosclerosis is the most common cause of PAOD, the probable mechanism being initial damage to the intima and subsequent activation and aggregation of the body's platelets. Inflammation follows, with the deposition of lipoproteins forming an atheroma. Calcification of this lesion leads to the development of an atherosclerotic plaque, resulting in inadequate muscle perfusion and ischemia (Rosen and Karmy-Jones, 2009). The process is a gradual one, and a localized lesion usually indicates systemic disease. The body develops a network of collateral vessels as an adaptive mechanism to supply the tissues with oxygenated blood. Many theories have been postulated to explain the process of atherogenesis. The inflammatory process of intimal injury, as just described, seems to be the current and most widely accepted hypothesis. Box 23-1 presents risk factors for atherosclerosis. A large number of vascular surgical procedures revolve around the results of chronic arterial insufficiency.

Arterial Insufficiency: Cerebrovascular Disease and Stroke

Cerebrovascular accident (CVA or stroke) is a leading cause of death in the United States and most industrialized countries. In the United States, approximately 795,000 persons experience a stroke each year (Lloyd-Jones et al, 2009). Cerebrovascular disease may manifest itself as a transient ischemic attack (TIA) or as a major or minor stroke. A TIA is an episode of neurologic dysfunction that resolves in 24 hours. It may be caused by atheromatous debris or a thromboembolism from a carotid artery or the vertebral basilar system. Vascular lesions in the carotid artery occur primarily at the bifurcation of the common carotid artery into the internal and the external carotid arteries. The internal carotid artery supplies the brain with needed oxygenated blood. Obstruction in this arterial vessel leads to cerebrovascular insufficiency.

The right and the left carotid and vertebral arteries supply the brain (Figure 23-4). The first major branch of the internal carotid artery is the ophthalmic artery. Thromboembolic events that affect this artery may result in visual disturbances, ocular

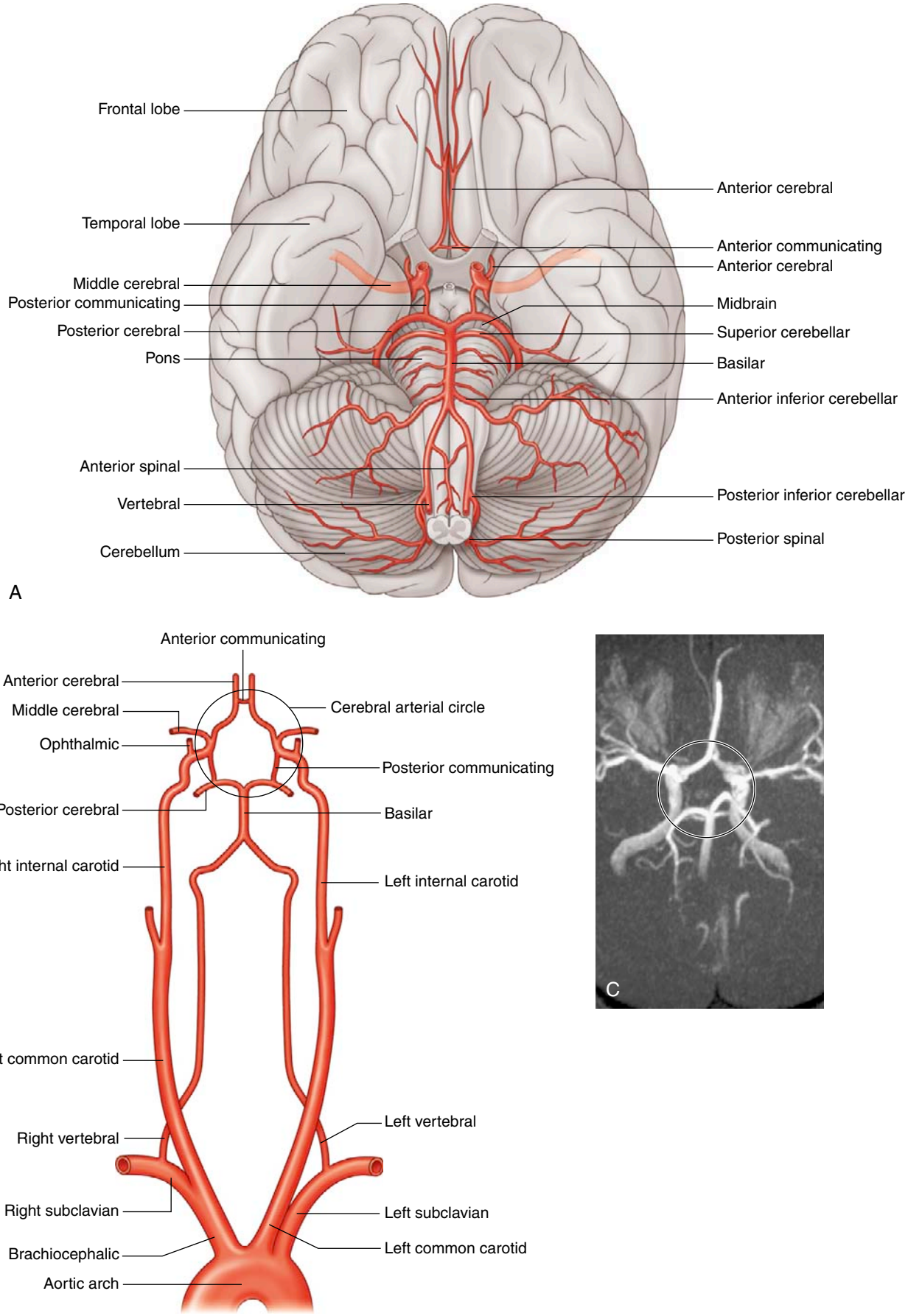


FIGURE 23-4 Arteries at the base of the brain. **A**, Diagram shows the cerebral arterial circle (of Willis) and related structures on the base of the brain. Note the arterial anastomoses. **B**, Origins of blood vessels that form the cerebral arterial circle. **C**, Magnetic resonance image of the cerebral arterial circle.

TIAs, or "amaurosis fugax" (complete or partial loss of vision). Patients will often describe amaurosis fugax as a curtain over a partial field of vision, usually the top. Clinical conditions that generally indicate the need for a carotid endarterectomy (CEA) are transient cerebral ischemia, asymptomatic severe stenosis, and stable strokes. Carotid disease may recur after a CEA. Redo surgery for restenosis poses the same complication risks as the original procedure.

Arterial Insufficiency: Peripheral Vascular Disease

The initial and most important symptom of vascular disease in the aortoiliac vessels and distal arteries is intermittent claudication. The term *claudication* is derived from the Latin word "claudicare," which means "to limp" (History box). This is the most common symptom of lower-extremity PAD and occurs distal to the arterial obstruction while the patient is exercising. Many patients are asymptomatic and do not experience pain. When this symptom does occur, it is typically located in the working muscle, occurs with the same amount of exercise each time, and is relieved with rest. This is referred to as functional ischemia; blood flow is adequate at rest but inadequate to sustain exercise. The increased muscle demand for oxygen with exercise cannot be met distal to the arterial obstruction. Anaerobic metabolism occurs, and muscle cramping develops. Surgery is not usually performed for claudication unless it is unusually disabling.

The second symptom—rest pain, which is located in the foot—develops as the vascular disease progresses (Faisal and Cooper, 2008). At this stage the ischemia is termed *critical*. Rest pain occurs without exercise and is a constant discomfort, often aggravated at night. The body is now unable to meet the oxygen needs of distal tissues even at rest. Rest pain may be somewhat relieved by analgesics or by lowering the legs off the bed. Gravity assists in increasing the tissue perfusion and oxygen supply to decrease the pain. Unless the vascular disease is corrected, nonhealing ulcers and gangrene can develop. Gangrene occurs when the arterial vessels are unable to meet the oxygen needs of distal tissues even at complete rest.

HISTORY

Osler's Recognition of Intermittent Claudication

Surgery on the vascular system has been performed since antiquity. In 1902 Osler described a theory of intermittent claudication. He noted that this phenomenon had been earlier described by a French veterinarian's studies of a horse. Later, the analogy was made between a male patient and a condition that corresponded to the intermittent claudication described in the horse. The patient was unable to walk more than one quarter of a mile without experiencing cramps in the legs. After a period of rest, he would improve and be able to resume walking. This patient died, and on autopsy a ball was found encysted in the vicinity of the iliac artery; a traumatic aneurysm was found as well that had obliterated the artery in its lower part. Osler further noted that the circulation was carried by the collateral channels, which were ample to maintain nutrition while the patient was at rest and for short periods of exertion.

Since the early writings of Osler, significant advancements have occurred in vascular surgery. Contributing to this rapid forward progress have been the development of effective anticoagulants, availability of arterial allografts, expansion of surgical techniques, improvements in suture materials, refinements in angiography, and the advent of noninvasive diagnostic methods. Current endovascular surgical devices continue to be modified, expanding the possibilities for their use and broadening the vascular surgery frontier.

Modified from Fye WB, editor: *William Osler's collected papers on the cardiovascular system,* Birmingham, AL, 1985, The Classics of Cardiology Library.

VENOUS DISEASE

Acute Venous Insufficiency

Acute venous insufficiency is caused by a clot in the deep venous system, or deep vein thrombosis (DVT). Such venous insufficiency can be a diagnosis of DVT, phlebitis, thrombophlebitis, or phlebothrombosis, which merely indicates that there is a clot, usually in the lower extremity. Virchow, a pathologist, identified the three elements that trigger venous thrombosis. Referred to as Virchow's triad, these elements, or risk factors, are endothelial injury, venostasis, and hypercoagulability (Ignatavicius and Walicek, 2010). The cause of hypercoagulability is sometimes unknown but is seen in patients with tissue trauma (e.g., surgery, burns, or stroke), malignancy, sepsis, pregnancy or estrogen use, and diabetes mellitus. The patient may be asymptomatic or present with limb swelling, pain, and a skin color change. The danger lies in the potential emboli migrating to the right ventricle and proceeding to the lungs. Pulmonary emboli (PEs) can be fatal. The majority of pulmonary emboli cases are caused by DVT. The majority of these originate in the lower extremities. The use of heparin and bed rest is the usual medical treatment. In cases that preclude the use of systemic heparin or in which heparin is ineffective, surgical insertion of a vena cava filter may be indicated.

Chronic Venous Insufficiency

Patients with chronic venous insufficiency (CVI) have not been treated surgically as often as patients with arterial disease for several reasons. CVI is generally not life-threatening or limb-threatening. Improved imaging techniques (e.g., duplex ultrasonography) allow better diagnoses of the precise problem. The treatment of the majority of venous disorders is nonsurgical and aimed at increasing venous return and decreasing edema. CVI, which presents with stasis ulcers from postphlebitic syndrome, usually occurs in one leg. The leg is usually very swollen with a cyclic edema, which does not change visibly after overnight leg elevation. Stasis ulcers and hyperpigmentation usually are found in the "gaiter" area and above the medial malleolus on the leg. The condition is caused by incompetent perforator valves. The perforating veins connect the superficial and deep venous systems. The usual management is to apply 20 to 30 mm Hg of external pressure by means of special pressure stockings. Surgical interventions such as valvuloplasty (direct repair of the valve), valve transposition or transplantation (moving a valve from the arm to the leg), or perforator interruptions are occasionally performed but have had limited success. Patient selection is critical, and long-term results are mixed.

Perioperative Nursing Considerations

Assessment

Nursing Responsibilities. A preoperative assessment is necessary for an adequate understanding of the patient's disease, the patient's response, and the proposed surgical procedure. Knowledge of vascular disease and its progression assists the perioperative nurse in performing a critical review of the comprehensive assessment and developing a plan of care for patients undergoing vascular surgical procedures.

The perioperative nurse should assess the patient, reviewing an already completed, current nursing assessment for the development and extent of vascular symptoms. The nurse must assess medical conditions—including cardiac, renal, and pulmonary disease; coagulation status; and allergies (Box 23-2)—to ensure that the patient can tolerate a possible angiogram, because the contrast medium is toxic and increased fluid volumes are needed if angioscopy is planned. This is a shared responsibility of the nursing, surgical, and anesthesia providers. The patient's nutritional status, the patient's use of alcohol and tobacco, and the existence of any skin lesions should also be noted. Preoperative location, grading, and marking of distal peripheral pulses assist the perioperative nurse with intraoperative and postoperative assessment of tissue perfusion. The nurse shares pertinent information gathered during the assessment phase with the rest of the surgical team, including the surgical technologist, as appropriate.

The nurse greets the patient by name and verifies identification using two unique identifiers. When possible, the patient should confirm such identification. Identification must also be confirmed by the name band, medical record, surgical consent, OR schedule, and marked surgical site. Safety is always the first priority. The surgical procedure must be confirmed and the patient's understanding of the procedure and associated risks assessed; inaccuracies or misconceptions must be clarified before proceeding with surgery. Written consent is designed to protect the patient by providing written clarification of the proposed procedure. The National Quality Forum (NQF) has identified Safe Practice 10 for informed consent, recommending that each patient (or legal surrogate) be asked to "teach back" what he or she has been told during the informed consent discussion (Wu et al, 2005). Consents that are valid and obtained freely from a competent person remain in effect for as long as the person still agrees to the surgery or procedure. This may vary by institutional modification.

The nurse assesses patient comfort before continuing the interview and assessment. This reflects caring and will promote nurse-patient rapport and facilitate obtaining accurate and complete information. The acuity of the patient's condition will also affect the order of priority of the assessments and interactions. After reviewing the results of the patient's physical examination, the perioperative nurse should verify signs and symptoms of vascular disease that need to be considered during intraoperative care. Muscle and skin atrophy, the presence of tissue ulceration or necrosis, pain, neurovascular status, skin color and temperature, and other integumentary changes should be noted. Elderly, cachectic, or obese patients are at increased risk for pressure injuries.

The perioperative nurse should assess the patient's mental status and determine the level of understanding and emotional response to the surgery. Patients with vascular disorders usually have systemic disease, and the fear of a stroke (if the patient is having a carotid procedure), amputation (if the patient has an ischemic limb), or other complications may be a realistic concern. A skin assessment should include notation of color, integrity, pain, and pulses. Any musculoskeletal problems that preclude patients moving themselves to the OR bed and any weaknesses that may have resulted from a stroke or that would modify the positioning for surgery should be noted. Correction of misunderstandings is possible only if the perioperative nurse identifies the patient's current level of knowledge. Identification of the patient's fears and concerns helps with planning supportive nursing interventions.

Vascular surgery can be lengthy. The nurse must consider the effects of hypothermia during long procedures. The patient's extremities should be assessed for color, temperature, and strength of pedal pulses before the surgical procedure so that baseline data will be available for comparison with perioperative assessment data. This assessment evaluates tissue perfusion distal to the arterial obstruction.

Preoperative Tests. A variety of tests may be required to plan for surgical interventions. Segmental pressure measurements give partial anatomic information in that they assist in locating lesions. Hemodynamic tests provide information on the flow of blood, such as that to the brain or an extremity, and the effects on flow caused by a vascular lesion.

ANGIOGRAPHY. Invasive diagnostic tests may be performed preoperatively to identify the extent and location of the patient's peripheral vascular disease (Faisal and Cooper, 2008). The introduction of a contrast medium through a catheter into the arterial or venous system of the patient facilitates this visualization. Angiography also involves injecting a contrast medium into the patient's arterial system and taking serial radiographs of the movement of the dye through the arteries.

BOX 23-2

Review of Patient's Medical Record

The perioperative nurse should review the patient's medical record, confirming or obtaining information for the following items:

- Correct and current medical record/chart
- Surgical consent
- History and physical examination
- Baseline vital signs (including height and weight)
- Mental status
- Medications
- Allergies or adverse reactions to drugs, topical agents, or other substances (e.g., latex)
- Skin tone and integrity
- Physical limitations
- Laboratory data (e.g., prescribed blood work, electrocardiogram [ECG] report, urinalysis, ultrasound or x-ray studies, other pertinent tests)
- Religious, cultural, ethnic preferences
- Nursing plan of care or other notations from transferring nurse
- Presence or disposition of prosthetic devices (e.g., hearing aids, dentures, glasses)

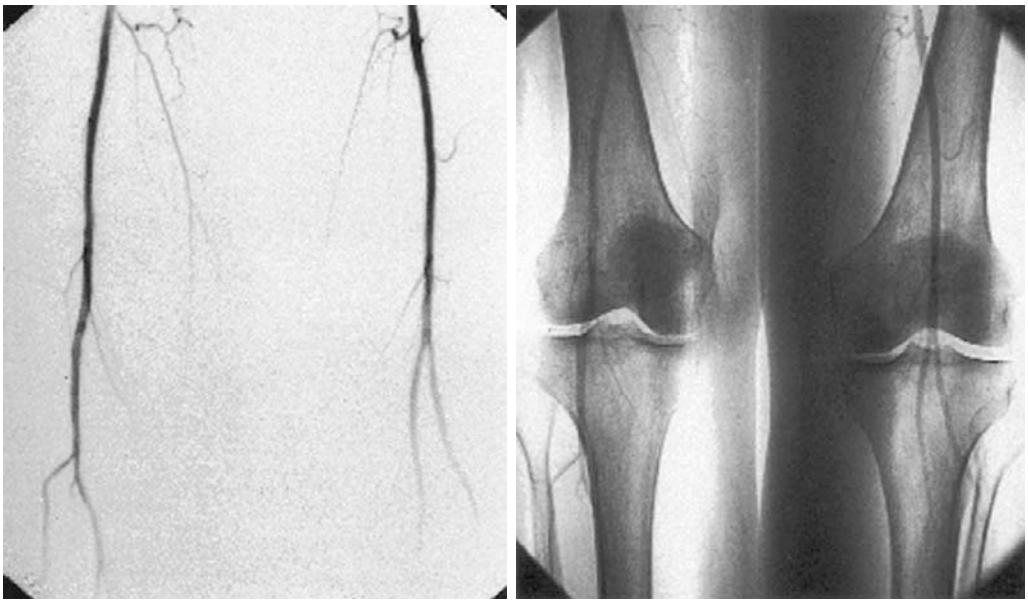


FIGURE 23-5 Digital subtraction angiography.

Digital subtraction angiography (DSA) is one such technique that uses a computer along with contrast medium injection to make the image (Figure 23-5). Usually one side of the film shows the bone for orientation, and the other side subtracts the density of the bone and soft tissue to allow a clearer view of the vessels. Arteriography provides information on arterial anatomy and the location of stenotic or occluded vessels and assists the surgeon in planning bypass procedures. A venogram (contrast venography) is performed to show venous abnormalities in extremities, the vena cava, and the hepatic and renal systems. Ascending venography can differentiate between acute and chronic thrombosis and can define anatomy. Descending venography assesses valve competence of the lower extremities.

DOPPLER SCANNING. The Doppler effect is the change in the frequency of echo signals that occurs whenever there is a change in the distance between the sources of a sound and the receiving object. The probe, or transducer, is aimed toward the blood vessel at an angle of 45 to 60 degrees. This directs an ultrasound beam that is reflected back to the probe by moving red blood cells (RBCs). The velocity of the flow of cells is converted into an audible signal heard through a speaker. The signal is described as a swishing sound. The sound is called a signal, not a pulse. The tip of the probe is made of an element called a ceramic piezoelectric crystal, which can send, receive, and convert signals when an electric current is applied. The element becomes thicker and thinner, thus resulting in a pressure wave converted to an audible signal. The simplest form is the continuous wave (CW) Doppler probe. It has two elements: one sends a high-frequency wave, and the other receives it. In a pulsed Doppler probe, the same element sends and receives signals. The pulsed Doppler probe has the advantage of being able to differentiate among vessels of different depths. A normal arterial Doppler signal is either biphasic or triphasic. The first sound corresponds to systolic flow and is forward-moving and of high velocity. The second sound is related to early diastole and has a lesser reversal of flow. The third sound is later diastole and is smaller, forward-flowing, and of a lower velocity. The pitch is described as rising quickly in systole and dropping quickly in early diastole. An abnormal signal, indicating stenosis or occlusion, is heard as low-pitched and monophasic. These abnormal arterial signals may sound like venous signals.

The Doppler probe can provide information in three forms: the audible signal, a visible graph printout similar to an electrocardiogram (ECG) tracing, and a spectral analysis that appears on a screen and may be recorded on paper as well. The Doppler transducer is the most widely used instrument for vascular study. It has the advantages of being readily available, inexpensive, and easy to use. A small, portable battery unit is durable and can be transported and stored easily. When the probe is used on intact skin, a water-soluble gel is needed to conduct a signal. Probes can be used directly on a vessel intraoperatively. The probes are heat-sensitive and must either be sterilized according to manufacturer's instructions or be inserted into a sterile sleeve or probe cover. If they are handled gently, the probes have a reasonable life span. Care must be taken to protect the sensitive tip from being dropped or crushed. The biggest drawback of the Doppler probe is a negative finding in the presence of a stenotic lesion pronounced enough to produce a flow disturbance that results in an altered signal.

A bruit is a sound disturbance that is sometimes described as a low-pitched, blowing sound. It can be heard through a stethoscope over an area of blood flow turbulence that occurs at points of vessel stenoses. Bruits do not provide information on the extent of a lesion—only that an abnormal flow may exist. They occur at points of significant stenosis and are not heard when severe flow restriction or total flow occlusion occurs. The Doppler probe is noninvasive and painless for patients.

ULTRASONOGRAPHY. Ultrasonography is done to obtain information about structures through the emission of high-frequency sound waves. These sound waves are reflected, or

bounced back, to the probe or transducer that emits them and are electronically transformed into an image.

B-Mode Ultrasonography. B-mode is brightness modulation, a technique in ultrasound imaging that projects a two-dimensional image on an oscilloscope screen. The image appears as dots from the echoes of the signal. The strength of the echo is shown by the intensity and brightness of the dots on the screen.

Duplex Ultrasonography. A duplex ultrasound machine is a combination of the pulsed Doppler image and the so-called real-time B-mode image ultrasonogram. "Real time" simply refers to the image projecting current, undelayed information. B-mode image is best when the probe is perpendicular to the vessel, but the Doppler probe does not pick up signals at a perpendicular angle. Some manipulation of the probe angle is required to obtain the best results. Color duplex imaging converts the detected signals caused by blood flow into a color, depending on the direction of flow. Flow toward the probe may be displayed as red, away from the probe as blue, and turbulence as multiple colors. This imaging provides both hemodynamic and anatomic information. The technology is also used in transesophageal echocardiography (TEE) and is the diagnostic method of choice for venous insufficiency.

Pulse Volume Recording (PVR), or Sequential Volume Plethysmography. A plethysmograph measures and records the changes in the sizes and volumes in extremities by measuring the blood volumes at blood pressure cuffs placed at intervals along the extremity. The methods include electrical impedance, mercury in Silastic strain gauges, and air or fluid displacement. This test, which is used to determine the location of an arterial lesion and estimate the severity of the disease, requires careful limb positioning and a cooperative patient. A negative study is a good predictor of low risk for pulmonary embolus (PE).

This test is inexpensive, has good predictive value, and is accurate in detecting thrombosis. It has the disadvantage of a high rate of false-positive results in the presence of old DVT, congestive heart failure (CHF), and external compression.

Magnetic Resonance Imaging. Magnetic resonance imaging (MRI) measures the behavior of atoms in a strong magnetic field. This test provides detailed and three-dimensional images of anatomy for evaluation of carotid, aortic, and lower-extremity disease (Faisal and Cooper, 2008). An MRI provides more detail than ultrasonography or computed tomography (CT) scan and avoids the complications of contrast medium injection and exposure to x-rays. MRI is contraindicated for patients with pre-existing implantable devices.

Nursing Diagnosis

Nursing diagnoses related to the care of patients undergoing vascular surgery might include the following:

- Anxiety related to the surgical intervention and its outcomes
- Hypothermia related to surgical exposure and anesthesia
- Risk for Deficient Fluid Volume related to loss of body fluids
- Risk for Impaired Skin Integrity and Ineffective Tissue Perfusion related to surgical positioning, presence of vascular disease, and vascular clamping

Based on the perioperative nurse's assessment, identification and prioritization of nursing diagnoses aid in the development of an individualized plan of care.

Outcome Identification

Outcomes identified for the selected nursing diagnoses could be stated as follows:

- The patient will have all questions answered, will verbalize decreased anxiety and understanding of surgical procedure and perioperative routines, and will exhibit increased relaxation as shown by facial expression or other body language.
- The patient's body temperature will remain within normal limits as evidenced by postoperative temperature equivalent to preoperative level and absence of postoperative shivering.
- Fluid balance will be maintained as evidenced by postoperative pulses equivalent to preoperative level, hourly urine output of at least 30 ml, and good skin turgor.
- Skin integrity will be maintained. Skin temperature and color will be within normal limits. No skin injury lesions will be evident, and the electrosurgical unit (ESU) dispersive pad site will be intact.

Planning

Before the patient is transported to the OR, the perioperative nurse should procure the necessary supplies and equipment for the intended surgical intervention. Because the need for intraoperative arteriography or fluoroscopy for endovascular procedures is a possibility, the patient with a vascular disorder should be positioned on an appropriate OR bed with x-ray capabilities. The perioperative nurse needs to coordinate the availability of x-ray department personnel. Appropriate contrast media, catheters, and impermeable sterile x-ray covers must be available. Radiation-protection devices, such as lead aprons and shields, should be used for the patient, when possible, and for surgical team members. A typical plan of care for a patient undergoing vascular surgery, using the suggested nursing diagnoses, is seen in the Sample Plan of Care on p. 979.

Arterial procedures, especially those that involve the aorta, may place the patient at risk for significant blood loss. The perioperative nurse should confirm the availability of ordered blood-replacement products. The use of rapid infusion systems or blood salvage equipment should be determined and planned.

Implementation

Site Verification: "Time Out." Patient safety is of utmost importance. It is the entire surgical team's responsibility to verify that the correct patient is receiving the correct procedure on the correct site immediately before the start of any surgical procedure. The surgical site needs to be marked and visible after draping if laterality is involved. The "time out" is a requirement of The Joint Commission. During the time-out, the patient's name, procedure, site verification, and laterality are reviewed. Other items that may be discussed include the consent, anesthesia plan/concerns, the patient's allergies, antibiotics ordered, the patient's position, required instruments and special equipment, availability of blood, and anticipated length of the procedure. Such briefings improve team communication and intraoperative patient care (Makary et al, 2007).

Intraoperative Monitoring. Intraoperative monitoring for patients with vascular disorders includes the use of the basic ECG, pulse oximeter, and blood pressure cuff. For patients undergoing saphenous vein stripping or amputation, these

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Anxiety related to the surgical intervention and its outcomes

OUTCOME
The patient will have all questions answered. The patient will verbalize decreased anxiety and understanding of surgical procedure and perioperative routines. The patient will exhibit increased relaxation as shown by facial expression or other body language.

INTERVENTIONS
- Include the family, significant others, or both in explanations of perioperative routines.
- Allow time for patient's questions; provide explanations, or make appropriate referral.
- Observe verbal and nonverbal indications of anxiety; assist the patient with anxiety-reducing/coping techniques that have proven personally effective in the past, such as meditation, prayer, rhythmic breathing, music, self-guided imagery, massage, and relaxation.
- Encourage expression of concerns and fears; clarify any misperceptions, and reinforce information provided by other members of the healthcare team.
- Provide emotional support and comforting nursing measures (e.g., touch, a warm blanket).
- Demonstrate warmth, calmness, and acceptance of the patient's anxiety.
- Maintain a quiet environment; minimize distractions.
- Document patient's reactions.

NURSING DIAGNOSIS
Hypothermia related to surgical exposure and anesthesia

OUTCOME
The patient's body temperature will remain within normal limits as evidenced by postoperative temperature equivalent to preoperative level and absence of postoperative shivering.

INTERVENTIONS
- Limit the patient's physical exposure; expose only those body surfaces required for skin preparation.
- Cover the patient's head with a blanket or cap.
- Use a warming device (e.g., a forced-air warming unit).
- Provide the anesthesia provider with a fluid warmer.
- Consult with the anesthesia provider regarding the patient's temperature.
- Use warm saline for irrigation.
- Provide warm blankets at the end of the surgical procedure.

NURSING DIAGNOSIS
Risk for Deficient Fluid Volume related to loss of body fluids

OUTCOME
The patient's fluid balance will be maintained as evidenced by postoperative pulses equivalent to preoperative level, hourly urine output of at least 30 ml, and good skin turgor.

INTERVENTIONS
- Determine the availability of replacement blood or blood products.
- Assist with the insertion of intravenous (IV) lines and fluid replacement therapy. Keep IV lines patent.
- Estimate blood loss on sponges and drapes; communicate to the anesthesia care provider and surgeon.
- Initiate autotransfusion or use of an autologous blood salvage unit as required.
- Record the amount of irrigation used.
- Document the contents of the suction canisters.
- Monitor and document hourly urine output (as applicable); communicate results of measurements.
- Collaborate with the collection and interpretation of intraoperative blood analyses.

NURSING DIAGNOSIS
Risk for Impaired Skin Integrity and **Ineffective Tissue Perfusion** related to surgical positioning, presence of vascular disease, and vascular clamping

OUTCOME
The patient's skin integrity will be maintained. Skin temperature and color will be within normal limits. No skin injury lesions will be evident, and the electrosurgical unit (ESU) dispersive pad site will be intact.

INTERVENTIONS
- Assess and document the patient's preoperative skin condition and tissue perfusion.
- Position the patient on a pressure-reducing mattress on the OR bed.
- Collaborate with the anesthesia care provider in modifications of surgical position required for access to airway and monitoring devices.
- Keep OR bed sheets dry and wrinkle-free.
- Pad all bony prominences.
- Maintain body alignment.
- Place restraining straps snugly but not tightly.
- Protect vulnerable neurovascular bundles from compression.
- Monitor and record tissue perfusion (e.g., color, temperature, pulses) as required.
- Elevate drapes off the patient's toes; use appropriate positioning accessories.
- Implement safety precautions for proper use of ESU.
- Reassess and document the patient's postoperative skin condition and tissue perfusion.

are usually adequate. For lengthy procedures, such as arterial bypass or reconstruction, an arterial line is usually placed percutaneously into the radial artery. This is kept open by a pressurized heparin drip line attached to a transducer, and a waveform monitor reads the systolic and diastolic pressures. The monitor calculates the mean arterial pressure (MAP), which aids in the evaluation of the perfusion of systemic and cardiac circulation. This arterial line also allows easy access for collecting specimens for arterial blood gas (ABG) analysis. Continuous assessment of the patient's arterial pressure is a critical part of the surgical procedure. Pulmonary capillary wedge pressure, as an index of left atrial pressure (LAP), may be monitored depending on the patient's physiologic status. A general anesthetic may be administered and the patient intubated; local or regional anesthesia may also be used, depending on the surgical intervention. Epidural catheters may be placed to provide intraoperative anesthesia that can be augmented to accommodate increased surgical time, as opposed to a spinal anesthetic, which provides a finite period of anesthesia. Epidural catheters may be left in place postoperatively for pain

management as well. Because many patients undergoing vascular surgery have generalized atherosclerotic disease, the perioperative nurse should be constantly alert for cardiac dysrhythmias and blood pressure changes. Acid-base balance and pulmonary gas exchange are assessed from the ABG analysis.

A central venous pressure (CVP) catheter or pulmonary artery (PA) catheter may be inserted, usually by way of the right internal jugular vein. The CVP line allows assessment of blood volume and vascular tone. The PA catheter monitors cardiac output, fluid balance, and the cardiac response to medications. PA catheters are commonly used for patients undergoing aortic surgery or for patients with cardiac disease.

TEE may be used to monitor the heart noninvasively during aortic surgery. The device looks similar to a bronchoscope and can be passed down the esophagus to provide an ultrasonic image. The cardiac structures, blood flow, wall motion, and great vessels can be observed. Use of TEE requires highly skilled personnel and may not be available in all surgical settings.

Electroencephalographic (EEG) monitoring is used for patients undergoing a carotid endarterectomy and allows for immediate observation of the slowing of brain waves caused by cerebral ischemia or reduced perfusion. The surgeon may elect to place a temporary shunt in the artery if this occurs during clamping, potentially reducing the chances of perioperative stroke.

The perioperative nurse inserts a urinary catheter for many procedures, including the following: if the proposed procedure involves the renal arteries or clamping of the aorta above the renal arteries; if considerable blood loss is anticipated; if the planned procedure time is lengthy; or whenever spinal or epidural anesthesia is used, because they delay the patient's ability to void voluntarily. Urinary catheterization facilitates accurate hourly measurements of urine during and after the surgical procedure and assists in the assessment of renal perfusion and fluid status.

Positioning. Positioning of the patient undergoing vascular surgery is of particular importance because of restricted circulation distal to the area of arterial obstruction and a generalized state of poor circulation. Particular care must be exercised in positioning elderly patients (see Chapter 26). Awareness of joint range-of-motion limitations attributable to immobility or joint surgery is critical even for a procedure as routine as urinary catheter insertion. Again, preoperative assessment can prevent injury and decrease OR time. Whenever possible, the perioperative nurse should have the awake patient demonstrate the ability to assume the position for the proposed procedure and provide feedback. A footboard may be applied to the OR bed to prevent the weight of drapes resting on the patient's lower extremities. A head support may be used to position the head. A roll may be placed between the scapulae. For surgical procedures involving a lower extremity, the patient's thigh may be externally rotated and abducted with the knee flexed. A small bolster may be used under the knee to support the patient's leg. Proper skeletal alignment during surgery prevents injury to the neuromuscular system. The nurse pays close attention to the skin overlying bony prominences, especially the heels, sacrum, and elbows, and uses the proper supports and pads to prevent pressure and potential positioning injury to the patient. If the procedure will be lengthy, a pressure-reducing mattress or pad can be placed on the OR bed to help prevent patient injury. Arms are placed on padded armboards with the palms up and fingers extended. Armboards are maintained at less than a 90-degree angle to prevent brachial plexus stretch. If there are surgical reasons to tuck the arms at the side, the elbows are padded to protect the ulnar nerve, the palms face inward, and the wrist is maintained in a neutral position (Denholm, 2009). A drape secures the arms. It should be tucked snuggly under the patient, not under the mattress. This prevents the arm from shifting downward intraoperatively and resting against the OR bed rail. During the procedure the perioperative nurse and surgical technologist continually monitor the sterile field to ensure heavy instruments and drapes do not rest on the patient's body and cause pressure injuries.

Skin Preparation and Draping. Skin preparation for vascular surgery may be extensive. Hair should be removed preoperatively only if it interferes with the procedure; if hair removal is necessary, it should be done immediately before the surgical procedure using clippers (Evidence for Practice), not a razor (Association of periOperative Registered Nurses [AORN], 2009). For abdominal aortic surgery, the patient's skin is prepped from the nipple line to the midthigh area. For peripheral vascular surgery on the lower extremities, the patient is prepped from the umbilicus to the feet. The patient's legs are prepped circumferentially. For carotid surgery, the patient is prepped from the ear and chin on the affected side to below the clavicle. It is important that alcohol-based prep solutions are allowed to dry completely before applying the surgical drapes and starting the surgical procedure.

Draping should permit the surgeon free access to involved areas. For example, abdominal surgery may also require exposure of the groin region for possible exploration of the femoral arteries. A femoral-popliteal bypass on one leg may require access to the other leg for saphenous vein harvesting. Impervious drapes should be used to prevent contamination of the surgical field from blood and irrigation fluids.

EVIDENCE FOR PRACTICE

Reducing the Risks of Surgical Site Infections: Preoperative Hair Removal

Surgical site infections (SSIs) can be devastating to patients. An infection may mean a prolonged hospital stay, additional surgical procedures, or even death in an extreme case. A systematic literature review by Tanner (2007) showed that clinical studies done 20 years ago indicated that shaving with a razor increased the frequency of SSIs and that using clippers is the preferred method for hair removal when hair removal is deemed necessary. The increased SSI risk associated with shaving versus clipping is attributed to microscopic cuts in the skin that later serve as foci for bacterial multiplication. The Centers for Disease Control and Prevention (CDC) developed guidelines to reduce the risks of surgical site infections using this evidence of best practice from the literature. Following the CDC's recommended guidelines for hair removal to reduce the risks of SSIs equates to providing optimal patient care.

Modified from Tanner J: Preoperative hair removal: a systemic review, *J Periop Pract* 17(3):118-121, 2007; Mangram A et al: Guidelines for prevention of surgical site infection, *Infect Control Hosp Epidemiol* 20(4): 247-278, 1999, available at www.cdc.gov/ncidod/dhqp/pdf/guidelines/SSI.pdf. Accessed April 28, 2009.

Medications and Solutions. In vascular surgery, several medications may be present on the sterile field at any given time. These may include heparin, heparinized saline, and papaverine, as well as local anesthetic medications and contrast dye. All medications and solutions on and off the sterile field must be labeled (Crum, 2006) (Risk Reduction Strategies). Heparin is the most common medication used in vascular surgery (Surgical Pharmacology) and may be given as an intravenous (IV) bolus by the anesthesia provider for systemic anticoagulation. When administered parenterally, heparin has a rapid onset of action, peaks in minutes, and has a 2- to 6-hour duration. Because it is metabolized in the liver and excreted by the kidneys, the effects of heparin may be prolonged in patients with liver and renal disease. The anticoagulant effects may be monitored by measurement of the activated partial thromboplastin time (APTT) or partial thromboplastin time (PTT). Patients are given anticoagulants just before the placement of a vascular clamp to prevent a thromboembolic event. The effects of systemic heparin may or may not need to be reversed at the end of the surgical procedure. Monitoring the activated clotting time (ACT) intraoperatively provides useful data for judging the need for reversal or additional medication. The effects of heparin can be reversed by the administration of protamine sulfate.

Since protamine sulfate is derived from fish sperm and testes, caution is advised when administering it to patients who are allergic to fish or who have received protamine-containing insulin. One milligram of protamine neutralizes 100 mg of heparin. The dose should be calculated to offset half of the last dose of heparin. Protamine must be given slowly, at a maximum rate of 50 mg in 10 minutes, or dyspnea, flushing, bradycardia, and severe hypotension may occur. Another reason for monitoring heparin dose is that protamine, given in the absence of circulating heparin, acts as an anticoagulant and could delay hemostasis intraoperatively.

Heparinized saline solution is often used during vascular surgery for irrigation. It may be used to irrigate a blood vessel lumen during surgery, usually after the patient has been systemically heparinized. It is also commonly used to flush the lumen of tubes used to shunt blood. The strength of the heparin solution

RISK REDUCTION STRATEGIES

Medication Safety During Surgical Procedures

In vascular surgery, at any given time several medications may be present on the sterile field in basins or syringes. These may include heparin, heparinized saline, and papaverine as well as local anesthetics and contrast dye. Confusion that occurs during procedures as a result of unlabeled medications and solutions may result in serious medication errors. All medications and solutions on and off the sterile field must be labeled to help prevent an untoward event. The Association of periOperative Registered Nurses has helpful guidance statements and a medication safety toolkit to assist in the development of policies and protocols. The following risk reduction strategies are included: ensure concurrent verification, both verbally and visually, between the perioperative nurse and scrub person of all medications introduced to the sterile field, including medication name, strength, dose, and expiration date; use preprinted medication labels or have blank labels and a sterile marking pen available to label all solutions and medications as they are introduced to the sterile field; remove any unlabeled medication or solution from the field; for reference, keep all containers from medications used during any procedure in the OR until the conclusion of the procedure; verify all medications concurrently with the entering and exiting personnel at shift change or break relief.

Modified from Sheridan DJ et al: Labeling solutions and medications in sterile procedural settings, *Jt Comm J Qual Patient Saf* 32(5):276-282, 2006; AORN guidance statement: safe medication practices in perioperative practice settings. In *Perioperative standards and recommended practices,* Denver, 2009, The Association.

SURGICAL PHARMACOLOGY

Heparin—A High-Alert Medication

Heparin sodium is an anticoagulant that interferes with blood coagulation by blocking conversion of prothrombin to thrombin and fibrinogen to fibrin. It has no effect on a blood clot that has already formed or on ischemic tissue injured as a result of inadequate blood supply caused by a clot.

It is considered a high-alert drug, so designated by The Joint Commission and the Institute for Safe Medication Practices (ISMP) because it may cause life-threatening or permanent harm to the patient if administered incorrectly.

It is used for prophylaxis and/or treatment of vascular thromboembolic disorders, such as venous thrombosis and peripheral arterial embolism, and for prevention of thromboembolus during vascular surgical procedures. The number of units per milliliter varies in available dosage forms (supplied in vials). The most often used form is 5000 units/ml. One milligram of heparin is the equivalent of 100 units. Heparin may be administered by the anesthesia provider as an intravenous medication, administered by the surgeon as a full-strength injection during certain vascular procedures, or prepared as an irrigating solution for the scrub person. Standardized practices in the OR should be used to reduce the risk of an adverse drug event from the administration of anticoagulants such as heparin.

Sound-alike caution: Hespan. Institutions should identify and at a minimum annually review look-alike/sound-alike drugs to prevent errors involving the interchange of such drugs.

Labeling requirements: Any medication container, such as a syringe, medicine cup, or basin, containing heparin or a heparin solution must be labeled whether it is on or off the sterile field in perioperative or other procedural settings. Labels should be verified by two qualified individuals if the person preparing the medication is not the person administering it; this may be the case during relief of OR personnel (Crum, 2006).

Modified from *Drug information handbook for perioperative nursing,* Hudson, Ohio, 2006, Lexi-Comp; The Joint Commission: Preventing errors relating to commonly used anticoagulants, *Sentinel Event Alert,* September 24, 2008, available at www.jointcommission.org/SentinelEvents/SentinelEventAlert/sea_41.htm. Accessed April 15, 2009; ISMP Medication Safety Alert! ISMP Quarterly Action Agenda—January-March 2008, *The Institute for Safe Medication Practices,* available at www.ismp.org/Newsletters/acutecare/articles/A2Q08Action.asp. Accessed April 15, 2009; Crum BG: Revised national patient safety goal on medication handling, *AORN J* 83(4):955-957, 2006.

will vary according to the manufacturer's recommendations for certain implant devices or by the surgeon's preference. A reasonable range is 250 to 1000 units in 250 ml of normal saline.

Surgeon preferences differ regarding solutions with which to distend, irrigate, or store vein grafts. Some surgeons prefer a cold solution to decrease the metabolic demands of the vessel, whereas others believe this may lead to spasm. Spasm may be of particular concern when working with the small vessels of the distal leg or foot. Papaverine hydrochloride (HCl) may be added to a heparinized saline solution for its direct antispasmodic effect on the smooth muscle of the vessel wall and for its vasodilating properties. A reasonable dose is 120 mg in 250 ml of saline. The pressure of a handheld syringe to distend vein grafts has been viewed as a potential cause of graft failure or graft stenosis because this causes endothelial damage. Papaverine HCl, as a smooth muscle relaxant, allows distention at a lower pressure and may decrease the risk of injury. Concentrations for infiltration range from 0.05 to 0.6 mg/ml, or 12.5 to 150 mg per 250 ml of solution.

Topical hemostatic agents may be needed. Absorbable hemostatics are effective by creating an environment that promotes the adhesion of platelets. For example, an absorbable gelatin sponge may be applied to a bleeding surface to provide a matrix into which clots form. It may be applied dry, moistened with saline, or soaked in a topical thrombin-saline solution; 100 to 2000 NIH units of thrombin per 1 ml of saline or blood may be applied to control bleeding.

Infections of prosthetic vascular grafts are rare but are extremely serious. Infection may be life-threatening for patients with aortic grafts or may be limb-threatening in lower-extremity procedures. Protecting the prosthetic graft from contact with the skin is essential to prevent bacterial contamination. Prophylactic IV antibiotics that provide coverage for any likely organisms to be encountered in the procedure should be administered within 1 hour before the surgical incision (Hawn et al, 2006). In some institutions, medical staff–approved protocols are available for selection of the appropriate antibiotic.

Vascular Prostheses. Vascular grafting materials and techniques are of major importance to the field of vascular surgery for bypass procedures and reconstruction. The understanding, study, and comparison of new prosthetic grafts; utilization and preparation of autogenous grafts; and knowledge of long-term patency rates are critical to improving patient outcomes. Grafts are made in various sizes and configurations; they may be straight, tapered, or Y-shaped (i.e., bifurcated); or they may be pieces of material cut for use as a patch. The arteriotomy from a carotid endarterectomy may be closed primarily or with a patch of either vein or synthetic fabric. In aortic surgery, a straight tube or a bifurcated synthetic graft is used. Dacron (polyester) grafts are the usual choice and have been used successfully for many years. Large vessels, such as the aorta, have high flow rates and thus have a low incidence of thrombus formation and excellent graft-patency rate. Desirable characteristics for vascular grafts are that they are reasonably priced, readily available in a variety of sizes, suitable for use anywhere in the body, biocompatible and hypoallergenic, and able to survive repeated sterilizations. Grafts should be easy to handle and last a lifetime while permitting blood passage without clotting or infection.

Prosthetic grafts are nonantigenic; tissue incorporates well, which helps prevent infection, and such grafts generally resist thrombosis. For years, knitted polyester grafts were preferred over woven polyester because they were easier to handle, although they had to be preclotted because of their high porosity. Woven grafts are somewhat stronger and bleed less through the fabric interstices but can be less flexible. Newer grafts have been developed to incorporate the best of both by using velour polyester. They are often impregnated with albumin, collagen, or gelatin to provide ease in handling without the need to preclot. The surgical technologist ensures the graft is preclotted by submerging it into a basin containing a small quantity of the patient's own blood collected before systemic heparinization. This makes the graft impervious by allowing fibrin to fill in the fabric spaces.

The other popular prosthetic material is polytetrafluoroethylene (PTFE), which is available in straight, tapered, and bifurcated styles of varying lengths and may have external support rings to prevent compression. These grafts do not stretch, and needle-hole bleeding may be troublesome.

Cryo-preserved saphenous vein grafts are commercially available for patients who have no veins available because of previous bypass procedures, saphenous vein stripping, or poor quality or size of available veins. The nurse and surgical technologist must follow the manufacturers' instructions for rinsing these grafts to remove all traces of preservative.

Volumes have been written about vascular grafts, and the reader should consider this chapter an introduction only. The American National Standards Institute (ANSI), the U.S. Food and Drug Administration (FDA), and the Association for the Advancement of Medical Instrumentation (AAMI) are a few of the organizations active in setting standards and regulating usage and development of grafts.

Autogenous vein grafting for infrainguinal bypass is considered the criterion standard. Undamaged endothelial cells inhibit the clotting mechanism by the natural release of fibrinolytic substances and plasminogen factors. Two methods of grafting veins have been extensively studied, and the results are not totally conclusive that one method is better than the other. These are the in situ graft and the reversed vein graft. The in situ method leaves the vein in its place, side branches are ligated to prevent arteriovenous fistulas, and the valves that would impede arterial flow are disrupted with instruments specifically designed to cut valves, called *valvulotomes* (Figure 23-6). Reoperation is more frequent with the in situ method because of missed valves and residual arteriovenous fistulas. Reversal of a vein graft is performed per the surgeon's preference or when it must be harvested from the contralateral limb. Vein grafts are used in below-knee (BK) bypass procedures. Above-knee (AK) bypasses may use PTFE or other synthetic grafts for vein sparing, or they may be used in high-risk patients who may not tolerate the longer vein harvesting or have a life expectancy of less than 3 years. *Atraumatic* clamps with rubber, plastic, or hydrostatic jaw clamps are used to protect vein grafts from injury. Distal bypasses, particularly those in persons with diabetes, are more successful today as a result of improved tissue handling. The surgeon may also use the pneumatic tourniquet as an alternative to clamping the vessels.

Sutures. Most vascular sutures are made of synthetic nonabsorbable materials, such as Dacron, polyester, PTFE, and polypropylene. Vascular sutures have swaged-on needles of various sizes and are available in sizes 0 to 10-0. The suture may be

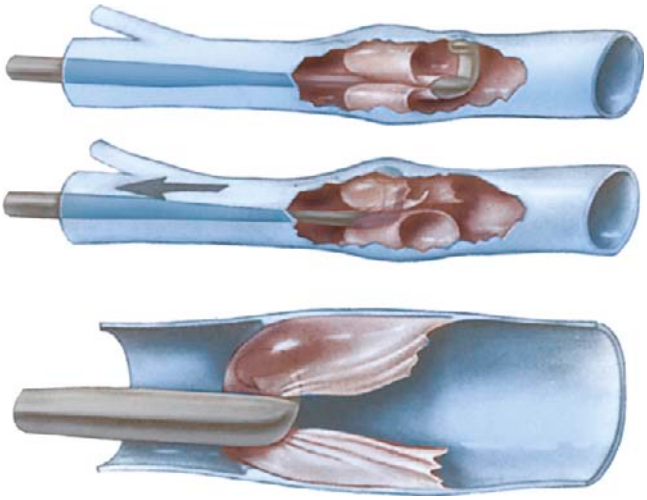


FIGURE 23-6 Valve incision with valvulotome.

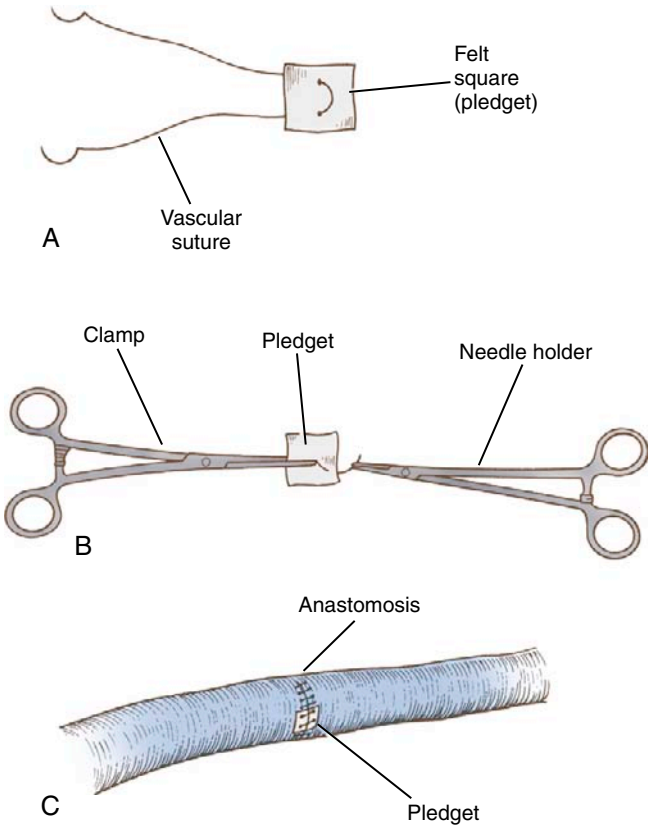


FIGURE 23-7 Pledgetted suture. **A**, Double-armed vascular suture prepared with pledget. **B**, Technique for surgeon to add pledget to suture already in use. **C**, Appearance of suture line with pledget in place.

single-armed or double-armed (i.e., a needle on one or both ends). The size and curve of the needle depend on the vessel and its location. Teflon felt or leftover pieces of graft material (synthetic or vein) may be used as pledgets or buttresses under a suture. They are used when tissue is friable to keep the suture from tearing through or when an anastomosis leaks and needs a better seal. The pledget may be loaded onto the vascular suture or added by the surgeon to a suture already in use. The pledget remains on the suture line (Figure 23-7).

Vascular Monitoring Equipment. Assessing blood flow through diseased vessels by palpation is often difficult. Physical assessment of the patient's hemodynamic status during surgery can be further complicated by spasm of the vessel walls, the cool environment of the OR, and alterations in blood pressure caused by hemorrhage. Therefore the surgeon often uses vascular monitoring equipment to evaluate tissue perfusion and flow. The Doppler device is critical when pulses cannot be palpated. With a coupling gel, the unsterile Doppler probe can be placed on the patient's skin distal to the surgical site. Some probes can be sterilized and used within the sterile field to assess the flow in an arterial graft or determine whether the blood supply to the intestines or other structures is intact after aortic surgery. Besides providing an audible signal, the Doppler probe can provide a permanent record of the sound if a recorder is attached.

An EEG accurately determines reduced cerebral perfusion during a CEA. This enables the surgeon to decide whether to use a temporary shunt in the carotid artery or if the patient can tolerate clamping. Sterile IV tubing connected to an arterial transducer can also be used to check pressure gradients intraoperatively. The stump pressure of unclamped carotid arteries before thromboendarterectomy can also determine the need for intraoperative shunting. Trained personnel are necessary to operate this equipment.

Instrumentation. Most vascular procedures begin with a basic laparotomy set (for scissors, clamps, and retractors) and a vascular set. Items specific to each surgical procedure are then added. For abdominal surgery, a large self-retaining retractor should be added. Additional individually wrapped, sterile aortic clamps; some long clamps (cystic duct and right angle); and long forceps for larger patients should be available in the OR. Smaller vascular clamps and vascular bulldog clamps should also be kept sterile in the OR. For peripheral procedures, a variety of Weitlaner self-retaining retractors should be available. Carotid surgery requires carotid shunt clamps, shunts, microforceps, and dissectors for peeling plaque from the artery. The surgeon may use the saphenous vein as a graft conduit by removing and reversing it or by using it in situ. A variety of instruments are available for disrupting the valves to permit arterial flow in the in situ procedure. Amputations do not require vascular instrumentation. A minor basic set and appropriately sized bone instruments are needed.

Documentation. During the implementation of perioperative nursing care, documentation of patient problems and nursing actions addressing these identified problems is important. Every patient is identified and assessed for allergies; the surgical procedure is verified; and any other interventions performed by the nurse for patient safety and mandated by institution policy are documented. A brief mental status and neurologic assessment is especially important for vascular patients who are at risk for stroke. For a patient undergoing vascular surgery, documentation may include the preoperative and postoperative assessment of the integrity of the patient's

skin, the presence or absence of peripheral pulses, the surgical position and positioning devices used, fluid intake and output measurements, and the achievement of patient goals. During surgery, various local anesthetic medications and irrigating solutions, such as thrombin, antibiotic, and heparin solutions, may be used. The surgical technologist ensures that each medication or solution container on the sterile field is labeled with the medication name, strength, and amount. Labels should be verified by two qualified individuals if the person preparing the medication is not the person administering it (Crum, 2006). The perioperative nurse maintains an accurate record of the solutions used and the amounts administered. The recording of ischemic times is captured when vascular clamps are applied and removed from arteries. The type, size, and serial and lot numbers of vascular implants should be documented according to institutional policy and procedure.

Evaluation

Evaluation is an ongoing process during which the perioperative nurse determines the extent to which the patient goals are met. Patient evaluation is continuous as the perioperative nurse assesses, observes, and appraises the results of nursing interventions. The conclusion of the intraoperative phase is the transfer of the care of the vascular surgical patient to colleagues in the postanesthesia care unit (PACU) or the intensive care unit (ICU). A nursing hand-off report should be given, which includes identification of the patient, the surgical procedure performed, any allergies or special needs, and the achievement of patient outcomes.

Some of the desired patient outcomes are achieved at the end of the intraoperative phase of surgical patient care. Others require ongoing evaluation during the postoperative phase. Because perioperative nursing practice is collaborative, the perioperative nurse develops a plan of care that extends from the admission to the surgical suite through safe recovery from surgery. Some goals can be measured immediately upon discharge from the OR; others require the collaboration of the PACU or unit nurse for final evaluation. The perioperative nurse thus develops and contributes to a comprehensive, holistic plan of patient care. Such planning and measurement of outcomes provide evidence of quality patient care and provide a mechanism of communication and continuity of care with other healthcare professionals.

Outcomes identified for the stated nursing diagnoses could be stated as follows:

- The patient verbalized an understanding of the surgical procedure and routines. All questions were answered to the patient's satisfaction. The patient appeared calmer as evidenced by facial expression and other body language.
- The patient's temperature remained within normal limits.
- The patient's fluid balance was maintained. Intake and output measurements were documented.
- The patient's skin remained intact, with no lesions or reddened areas; skin color, temperature, and turgor were adequate.

Patient and Family Education and Discharge Planning

All surgical patients need basic instruction on care of their wounds, identification of the signs and symptoms of infection, review of medications (Patient Safety), schedule of follow-up appointments, and procedure for contacting healthcare providers. Proper handwashing should be reviewed and emphasized to prevent wound infection. Patients who have undergone a lower-extremity arterial bypass are most interested in information that will assist them in recognizing, preventing, and managing complications. They need instruction on incision care and bathing to optimize incision healing. Many have had experience with slow healing of wounds because of their arterial disease. Pain, sleep disturbances, and fatigue have been identified as important areas for instruction. Patients are often capable of identifying their discharge learning needs in the preoperative period. Patients should be taught to manage the discomfort of incisions and leg swelling to prevent sleep disturbances. The need to balance activity and rest should be emphasized. Patients in the immediate postoperative period are often

PATIENT SAFETY

Teaching the Patient Discharged Home and Prescribed Anticoagulant Therapy

Anticoagulant therapy is prescribed to prevent the formation of blood clots. The length of time a patient is prescribed anticoagulant therapy depends on the underlying condition for which it is prescribed. It can be of short duration or lifelong. The patient and family or other caregiver should be provided with both verbal and written instructions. These should include the condition requiring anticoagulation therapy; reasons and benefits of therapy; name of the anticoagulant prescribed along with dosage, time of administration, and side effects; importance of follow-up monitoring; compliance issues; potential for any drug interactions; and safety precautions. After the patient and family member or other caregiver are instructed, they should "teach back" information in their own words. In this way, the nurse can verify their understanding. Additional helpful information to provide includes the following:

- Use only an electric razor or hair removal cream; do not use a straight razor.
- Take precautions to avoid injury. For example, do not use tools such as saws or hammers, which could lead to an accident. Avoid contact sports and other hazardous activities that can increase the risk of tissue injury.
- Report any signs and symptoms of bleeding, such as excessive bleeding from cuts; blood in urine, stool, or vomit; nosebleeds; bleeding from the gums; excessive menstrual bleeding; unusual bruising for unknown reasons; a change in mental status; dizziness; severe headache; or blurred vision.
- Take the prescribed dose of medication at the precise time it is prescribed to be taken.
- Do not stop taking the medication abruptly; the surgeon usually tapers this medication gradually.
- Carry or wear a Medic-Alert bracelet or tag, and carry information in your wallet naming the specific medication.
- Avoid eating foods high in vitamin K, such as tomatoes, dark leafy vegetables, bananas, and fish.
- In the event of a missed dose, do not make up for any missed dose or double-up on doses. Call your physician if you are unsure about what to do in the event of a missed dose.

Modified from Ignatavicius DD, Walicek SH: Interventions for clients with vascular problems. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, St Louis, 2010, Saunders; Canobbio MM: *Mosby's handbook of patient teaching,* ed 3, St Louis, 2006, Mosby.

receptive to counseling on risk-factor modification, such as cessation of smoking and control of hypertension, diabetes, and stress (Faisal and Cooper, 2008). Assisting the patient in setting realistic goals without overwhelming demands is usually most productive. Patients must believe that their efforts will make a difference in improving their quality of life for lifestyle changes to be sustained.

Patient and family education related to postoperative activities and discharge planning for vascular procedures varies. Following an integrated care pathway improves efficiency and length of stay. Major vascular procedures, such as the resection of an AAA, have different educational concerns than peripheral vascular surgery. Patient and family education and discharge teaching for various procedures are presented in the Patient and Family Education box.

Surgical Interventions

ABDOMINAL AORTIC ANEURYSM RESECTION

Abdominal aortic aneurysmectomy is surgical obliteration of the aneurysm, which may or may not include the iliac arteries, with insertion of a synthetic prosthesis to reestablish functional continuity. The majority of AAAs begin below the renal arteries (infrarenal), and many extend to involve the bifurcation and common iliac arteries. Severe back pain, along with symptoms of hypotension, shock, and distal vascular insufficiency, usually indicates rupture and represents a true emergency condition. The prime surgical consideration when a rupture occurs is the control of hemorrhage by occlusion of the aorta proximal to the point of rupture. AAAs are usually asymptomatic and are

PATIENT AND FAMILY EDUCATION

Education for Various Vascular Procedures

ABDOMINAL AORTIC ANEURYSM RESECTION

Postoperative care procedures include the following:

- Maintain intubation and ventilation for 12 hours (varies with setting and surgeon preference).
- Monitor cardiac, respiratory, and renal function.
- Maintain nothing-by-mouth (NPO) status and nasogastric tube placement until bowel signs and flatus return; diet is advanced as tolerated.
- Perform hourly assessment of lower-extremity perfusion.
- Assessment of pain: Provide pain relief via epidural and/or patient-controlled analgesia (PCA); provide periods of rest.
- Prescribe bed rest, with the patient out of bed on postoperative day 1 and ambulating on postoperative day 2.

Discharge planning education includes the following instructions to the patient:

- Feelings of fatigue are normal and take weeks to resolve.
- Incision care: Showering is permitted; use soap and water only, and pat dry. Protect incision from oils, lotions, and powder. If wound closure strips are in place, showering is permitted. The strips will peel away in about 5 to 7 days.
- Activity is allowed with specific restrictions per surgeon:
  - Avoid lifting more than 5 to 10 pounds for 6 weeks to allow abdominal healing.
  - Walk to increase strength and improve circulation; progress gradually.
  - Climb stairs and walk outside as desired.
  - Avoid sitting for more than 1 or 2 hours.
  - Avoid crossing legs.
  - Driving requires permission from surgeon, usually after first office visit and when pain medication is discontinued.
- Smoking should be stopped because it has a profound effect on vascular disease and wound healing.
- Follow surgeon's instructions regarding dietary recommendations and medication use.
- Antibiotics may be prescribed before any endoscopy procedures, surgery, or dental procedures.
- Notify surgeon of the following: changes in wound (e.g., redness, swelling, increased tenderness, bleeding, drainage), fever, change in bowel habits.

ENDOVASCULAR ABDOMINAL AORTIC ANEURYSM REPAIR

Postoperative care procedures include the following:

- Transfer patient from OR to PACU.
- Monitor cardiac, respiratory, and renal function.
- Assess peripheral pulses every 15 minutes for 1 hour, every hour ×4, every 2 hours ×4, and then every 4 hours (in general).
- Assess presence of abdominal or back pain, sensation, and movement in lower extremities.
- Provide pain management as ordered (encourage patient to request pain medication).
- Transfer to a general nursing unit within 2 hours.
- Advance patient from clear liquid to regular diet the first evening after surgery. Patient is NPO after midnight for ultrasound examination on day 2, with regular diet resumed after the examination.
- Perform gradual ambulation three times on day 1 (within 4 to 6 hours after surgery) and ambulation at will on day 2.
- Discharge to home generally on day 2.

Discharge planning education includes the following instructions to the patient:

- Showers are permitted; tub soaks are not.
- Intercourse is permitted as comfortable, with no restrictions.
- No driving is permitted until cleared by surgeon.
- No lifting more than 5 pounds is allowed for 6 weeks.
- Soap and water on sterile wound closure strips is permitted; strips will gradually fall off.
- Stair climbing is permitted.

Continued

PATIENT AND FAMILY EDUCATION

Education for Various Vascular Procedures—cont'd

ARTERIAL RECONSTRUCTIVE PROCEDURES OF THE LOWER EXTREMITY

Patient and family education and discharge planning include the following instructions to the patient:

- Diabetes and hypertension control is very important.
- Smoking should be stopped because it has a profound effect on vascular disease and wound healing.
- Observe for signs and symptoms of graft failure; assess pulses.
- Implement a foot care program as noted below:
  - Inspect daily (use mirror-assistive methods, or have family member help).
  - Observe for cracks, ulcers, blisters, rashes, or discoloration.
  - Trim nails properly for prevention of ingrown toenails.
  - Shoes must fit properly (avoid walking barefoot).
  - Avoid tight socks or hose.
- Incision care is essential for avoiding infection and promoting wound healing.
- Ace wraps for leg swelling (normal after surgery) should be applied per surgeon's instructions.
- Sleep disruption and fatigue are normal after surgery. Ongoing pain management is important; pain levels should decrease gradually.
- Driving with surgeon's approval is allowed after follow-up office visit (approximately 2 weeks postoperatively).
- No heavy lifting, vigorous exercise, or prolonged upright sitting is allowed; walking, stair climbing, and going outside are permissible as able.
- Gentle range-of-motion exercise of leg prevents flexion contractures.
- Showering is permitted.
- Diet: Resume previous diet; follow special diets (e.g., diabetic, low salt, low fat) per surgeon's instructions.
- Notify surgeon of the following: return of preoperative symptoms; wound changes (e.g., redness, swelling, drainage, pain); fever; change in color, temperature, sensation, or use of leg, foot, or toes.
- Antibiotics may be recommended before any dental or endoscopic procedures if a synthetic graft was implanted.

CAROTID ENDARTERECTOMY

- Teach patient about possibility of reperfusion headaches (patients may fear that they are having recurrent symptoms unless they know about this possibility).
- Explain that if there are no postoperative complications, discharge to home will occur within 24 to 48 hours after surgery.
- Explain that activity may return to normal as tolerated and driving may be resumed when neck discomfort no longer restricts range of motion and the surgeon has examined patient 2 weeks postoperatively.
- Explain that fatigue for 4 to 6 weeks after surgery is normal.
- Explain incision care: Keep incision clean and dry; may shower with transparent dressing in place. Remove transparent dressing in 3 or 4 days. Wash incision with soap and water; pat gently to dry. Avoid the use of powder and lotion. Do not shave over incision until it is well healed.
- Explain that numbness around the incision and extending to the ear is normal, as well as mild swelling.
- Teach the patient about any cranial nerve deficits that may be the result of manipulation of nerves during surgery. Assist the patient in understanding the difference between an intraoperative stroke and cranial nerve deficits; that is, nerve injury or trauma from surgical manipulation occurs on the same side as surgery except for eye symptoms. Use diagrams and pictures to review pertinent anatomy.
- Encourage relevant lifestyle changes as indicated (e.g., low-cholesterol diet, review of diabetic diet, smoking cessation).
- Teach the patient and family to observe for and report any new symptoms, transient ischemic attacks (TIAs), mental status changes, personality changes, or speech difficulties.
- If a synthetic patch is in place, explain that the patient will need antibiotics before dental procedures or scope procedures. Instruct the patient to notify dentists and other healthcare providers of this need.
- Explain that if a vein was used for a patch, occasional swelling in the leg may occur. If this occurs, elevate leg above the level of the heart. Swelling may take 4 to 6 weeks to completely resolve.

VENA CAVA FILTER INSERTION (INFERIOR VENA CAVAL INTERRUPTION)

Postoperative patient teaching for vena cava filter insertion includes the following:

- For a femoral vein insertion site, do not bend leg for about 8 hours.
- Avoid strenuous activity or lifting more than 5 pounds.
- Expect that bruising of the insertion site may occur because this is common in patients who are or have been receiving anticoagulant therapy.
- Inspect the incision site for bleeding; apply pressure using appropriate method if bleeding at insertion site occurs.
- Report signs of local infection or significant bleeding.
- Elevate affected leg and wear elastic stockings to relieve lower-extremity swelling, which may be temporary side effect of the underlying deep vein thrombosis (DVT).
- Understand the purpose of and proper way to wear support stockings.
- Report sudden or severe leg swelling.
- Follow instructions for DVT prophylaxis.

VARICOSE VEIN SURGERY

- Provide instruction on the proper way to wrap an Ace bandage, the timing of rest and leg elevation, and how to apply manual pressure if bleeding occurs.
- Remind patient that walking is permitted, but sitting should be limited as should standing in one place. Legs should be elevated when sitting.

found on routine physical examination. They occur more frequently in men than in women. Aneurysmal disease is caused by a disruption of the tunica media, which structurally weakens the aortic wall. Aneurysmal aortas are found to have a significantly decreased amount of collagen and elastin in the vessel wall. Rupture carries less than a 50% death rate for patients in stable condition with a contained rupture. Risks from AAA surgery include massive hemorrhage and hypotension, injury to the ureters, renal failure, spinal cord ischemia, and death. Because peripheral vascular disease is a manifestation of a systemic disorder, it is not surprising that patients with aneurysms often have concomitant coronary artery disease. Patients are at risk of myocardial ischemia, myocardial infarction, hypotension, and hypertension. Myocardial infarction is the leading cause of death after AAA repair; therefore it is imperative that a patient with cardiac symptoms or ECG abnormalities have a thorough preoperative cardiac assessment.

The perioperative nurse must be alert to the fact that at the time the aortic clamp is released to permit distal flow, "declamping shock" or severe hypotension may occur. This may be attributable to the presence of inadequate volume replacement, the sudden reestablishment of flow to dilated distal vessels, or the release of acidic metabolites. Declamping shock and hemorrhage have been proposed as causes of renal failure from acute tubular necrosis.

Procedural Considerations

The patient is placed in the supine position. General endotracheal anesthesia is used. The anesthesia provider inserts a central venous catheter and arterial line. After inserting the urinary catheter, the perioperative nurse preps the fields for a midline abdominal incision, and the surgical technologist assists with draping to permit access to the groin region for possible exploration of femoral arteries. The nurse ensures the patient's pedal pulses are marked before the beginning of the procedure so that they may be located easily when the surgeon requests a check of the pulses. This assessment of pulses can be done manually or with a Doppler probe.

Operative Procedure—Transperitoneal Approach

1. The surgeon opens the patient's abdomen through a long midline incision (Figure 23-8, *A*) from the xiphoid process to the symphysis pubis and achieves hemostasis.
2. An abdominal self-retaining retractor is inserted into the wound. The surgeon and assistant retract the patient's small bowel, including the duodenum, to the right; they may place it outside the abdomen and cover it with moist laparotomy packs for better exposure.
3. The retroperitoneum overlying the aneurysm is incised and extended superiorly to expose the aneurysm and also inferiorly over the bifurcation and beyond the iliac arteries. Metzenbaum scissors, smooth forceps, and hemostats are used.
4. Careful blunt and sharp dissection is used to expose the aorta above the aneurysm to permit placement of an aortic clamp while avoiding the renal artery and ureters. The surgeon inspects the iliac vessels and bifurcation for evidence of small aneurysms, thrombosis, and calcification.
5. The anesthesia provider administers a dose of heparin intravenously, and the surgeon applies and closes an aortic clamp such as a DeBakey, Fogarty, or Satinsky around the aorta. Distal runoff vessels are also clamped. Opening of the aneurysm is undertaken with a scalpel or electrosurgical blade and heavy scissors (Figure 23-8, *B*).
6. The aneurysm is completely opened, and all atheromatous and thrombotic material is removed. The aneurysm walls may be excised but usually are left in place for eventual coverage of the prosthesis. In either case, the posterior aspect of the aorta is left intact (Figure 23-8, *C*). The surgeon controls bleeding, especially from the lumbar vessels, which enter posteriorly, by oversewing their orifices with vascular suture.
7. At the direction of the surgeon, the surgical technologist prepares the prosthetic graft of appropriate size for insertion. If the aneurysm does not involve the aortic bifurcation, a straight tubular graft is used; otherwise, a bifurcated or Y-shaped graft is necessary. Preclotting of a knitted graft may be accomplished by immersing the graft into a small quantity of the patient's own blood before systemic heparinization, or a manufactured graft impregnated with collagen, albumin, or gelatin may be used.
8. The aortic cuff is prepared for anastomosis by irrigating it with heparinized saline solution and by removing all fibrotic plaques. One or two vascular sutures (double-armed) are used to accomplish the anastomosis by a through-and-through continuous suture (Figure 23-8, *D*). Additional interrupted sutures may be needed if the anastomosis leaks on completion. A strip of Teflon felt may be used along the suture line for reinforcement.
9. The surgeon opens and inspects the distal vessels for backbleeding, and may inject heparinized saline solution to prevent clotting.
10. Each limb of the graft is anastomosed to the iliac artery, using a smaller vascular suture and similar technique (Figure 23-8, *E*). After the first side of the anastomosis has been completed, blood is permitted to circulate and the remaining limb of the graft is clamped to prevent leaking during the last part of the anastomosis.
11. The aneurysm may be closed over the graft.
12. The peritoneum is closed to exclude contact of the intestine with the graft, and the abdominal wound is closed.

ENDOVASCULAR ABDOMINAL AORTIC ANEURYSM REPAIR

Endovascular aneurysm repair (EVAR) differs from open surgical repair in that the surgeon introduces the prosthetic endograft or stent-graft into the aneurysm through a surgically exposed femoral artery and fixes it in place to the nonaneurysmal infrarenal neck and iliac arteries with self-expanding or balloon-expandable stents rather than sutures (Figure 23-9). A major abdominal incision is thus avoided, and patient morbidity related to the procedure is much reduced. The benefits of this procedure are a hospital stay of 1 to 2 days, a rapid return to normal physical activity, and a reduction in the mortality and complication rates compared with those of the conventional surgical procedure (Egorova et al, 2008). The procedure may also be applicable to high-risk patients.

A number of commercially manufactured stent-grafts have been developed since the first endovascular aneurysm repair was carried out in 1991, using a Dacron graft sutured onto

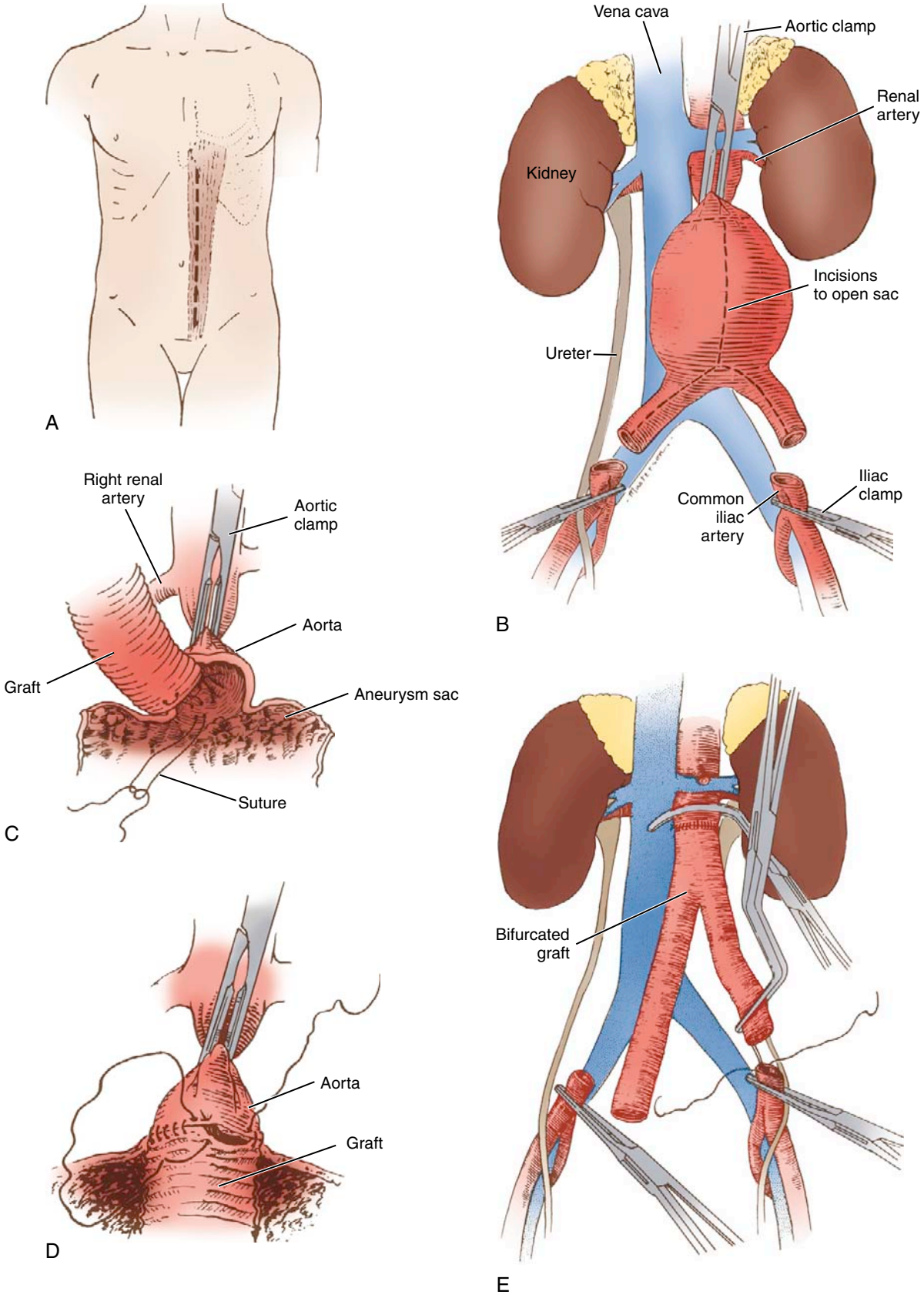


FIGURE 23-8 Resection of abdominal aortic aneurysm. **A**, Midline abdominal incision. **B**, Aneurysm sac is opened. **C**, Prosthetic graft is sewn to back wall of aorta, creating a cuff. **D**, Completion of aortic graft anastomosis. **E**, Iliac artery anastomosis.

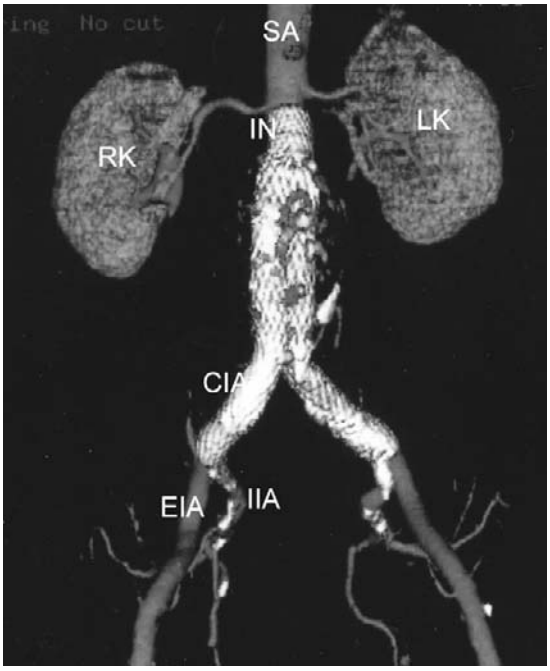


FIGURE 23-9 Endovascular abdominal aortic aneurysm repair involves aneurysm exclusion with an endoluminal aortic stent-graft introduced remotely, usually through the femoral artery. An endovascular graft extends from the infrarenal aorta to both common iliac arteries, preserving the flow to the internal iliac arteries. *SA,* Suprarenal aorta; *IN,* infrarenal aortic neck; *CIA,* common iliac artery; *EIA,* external iliac artery; *IIA,* internal iliac artery; *RK,* right kidney; *LK,* left kidney.

balloon-expandable Palmaz stents. Early tubular grafts have largely been replaced by modular bifurcated grafts that have expanded the applicability of this therapy. Different graft configurations, depending on the anatomic problem, are available. For patients with an AAA that is limited to the aorta and in whom there is both a neck between the renal arteries and the aneurysm and a neck between the lower portion of the aneurysm and the iliac bifurcation, a graft of tubular configuration is available. For those patients in whom the abdominal aneurysm extends to the iliac bifurcation, a bifurcated or Y-shaped graft is available. For those patients who have both an AAA and an aneurysm of one or both iliac arteries, a tapered tube graft that excludes both the aortic aneurysm and one iliac aneurysm is usually selected. The technical details of endovascular repair vary with each specific device, but the general principles are similar. Candidates for this procedure include patients with a proximal infrarenal neck at least 1 to 2 cm in length and common iliac arteries for proximal and distal fixation of an endograft, without excessive tortuosity and with appropriate iliofemoral access. Long-term follow-up data are ongoing, and patients undergoing this procedure should understand that prolonged follow-up with periodic imaging will be required and that reintervention may become necessary. Nonetheless, the future of endoluminal grafting continues to evolve and has the potential of significant rewards (Schermerhorn et al, 2008).

Procedural Considerations

The team positions the patient supine on a radiolucent OR bed with a special marker board. The board has remotely controlled radiopaque cursors that are used to fluoroscopically detect proximal and distal positions for graft deployment. An ample supply of lead gowns needs to be available. The anesthesia provider may administer a general anesthetic or an epidural anesthetic. If an epidural anesthetic is used, mechanical ventilation is available in case conversion to the traditional surgical procedure is required. The anesthesia provider inserts a central venous catheter and an arterial catheter for hemodynamic monitoring. The perioperative nurse inserts a urinary catheter, and ensures that the patient's abdomen and groin areas are prepped and draped to allow conversion to the traditional surgical technique if necessary.

Operative Procedure

1. The surgeon performs bilateral groin cutdowns and dissects both common femoral arteries.
2. After the anesthesia provider administers IV heparin, the surgeon clamps the right common femoral artery, performs an arteriotomy, and introduces an 8-French (8F) sheath into the right external iliac artery.
3. The left femoral artery is punctured, and the surgeon places a 12F sheath into the left external iliac artery. An angiocath is inserted, and an arteriogram is obtained to clearly mark the renal arteries and aortic bifurcation. The final length of the device to cover the aorta from the renal arteries to a suitable section of the common iliac arteries is chosen.
4. A snare is introduced into the aorta through the left femoral artery, and a pull wire is introduced into the aorta by way of the right femoral artery. The pull wire is snared above the aortic bifurcation and retracted into the left iliac artery. This step is done to help position the limbs of the graft into the iliac arteries.
5. The surgeon inserts the grafting device into the right femoral artery, advances it into the proximal part of the aorta, and positions it above the aortic bifurcation. Fluoroscopy is used to determine proper position of the stent.
6. The device is exposed by retracting a covering jacket, and the graft limbs are positioned in the iliac arteries. The hooks of the graft become attached to the walls of the aorta and the iliac arteries as the attachment systems are deployed.
7. The balloon on the device is inflated to secure the proximal attachment system to the aorta and the contralateral and ipsilateral systems to the iliac arteries.
8. An arteriogram is obtained to confirm proper positioning and complete exclusion of the AAA. Ideally, the graft is positioned to occlude the inferior mesenteric artery to prevent persistent blood flow within the aneurysmal sac.
9. After all the sheaths are removed, the surgeon closes the wounds with subcuticular sutures.

PERCUTANEOUS TRANSLUMINAL ANGIOPLASTY

Percutaneous transluminal angioplasty (PTA) is performed with a local anesthetic and minimal sedation, as a same-day surgery admission. Although initially performed only in the common iliac artery for stenosis, PTA is routinely used to treat short-segment occlusions as well as external iliac lesions. Iliac artery PTA may be particularly useful to help improve inflow before a more distal surgical reconstruction.

The use of iliac artery stents has also begun to play an increasing role in the management of patients with aortoiliac

occlusive disease. Iliac artery stents are most useful after initial suboptimal results from PTA. However, they are used primarily in the treatment of complex lesions. When PTA is not an option, a number of surgical alternatives are available. Depending on the condition of the patient and the patient's pathologic anatomy, the options include aortobifemoral bypass, aortoiliac thromboendarterectomy, axillofemoral bypass, iliofemoral bypass, and femorofemoral bypass.

FEMORAL-POPLITEAL AND FEMORAL-TIBIAL BYPASS

Femoral-popliteal bypass is the restoration of blood flow to the leg with a graft bypassing the occluded section of the femoral artery (Research Highlight). The bypass may be a saphenous vein or straight synthetic graft. The patient must have a patent outflow artery for a successful bypass procedure. If popliteal patency is doubtful, artery exploration is necessary as the first procedure. Involvement of the popliteal artery may necessitate the exposure and use of the tibial vessels for the lower anastomosis. If this occurs, the procedure could require the use of microvascular instruments and technique.

Procedural Considerations

The patient is placed in a supine position. The hip is externally rotated and abducted with the knee flexed. Prepping and draping include the entire groin and leg. The instrument setup includes the basic minor and vascular sets, plus the following: Gelpi retractors, Garrett or Weitlaner retractors, a device to tunnel, and supplies and equipment for operative arteriograms.

RESEARCH HIGHLIGHT

Below-Knee Revascularization in Patients with Critical Limb Ischemia: Long-Term Comparison of Redo versus Primary Interventions

The purpose of this study was to evaluate the authors' experience in below-knee revascularization for patients with critical limb ischemia by comparing the long-term outcomes of primary and secondary interventions. The study examined 140 consecutive below-knee revascularizations in patients with critical limb ischemia at the Department of Vascular Surgery, University of Florence (Florence, Italy). Early and long-term results in terms of survival, graft patency, and limb salvage were studied. Group 1 contained 105 patients (75%) who underwent a primary intervention and group 2 contained the remaining 35 patients (25%), who received a secondary intervention for a late (<30 days) bypass graft thrombosis. One patient died in the early postoperative period and the 30-day thrombosis and amputation rates were poorer in group 2 than group 1 (17.1% and 4.8%; 37.1% and 16.2%, respectively). After 60 months there were no significant differences (NS) between the two groups in terms of survival (90.1% and 90.9%, respectively; P = NS) and primary patency (43.5% and 31.9%, respectively; P = NS). The estimated limb salvage rate was significantly poorer in group 2 than in group 1 (64.1% and 77.7%, respectively; P = 0.05). The researchers concluded that redo below-knee revascularization in patients with critical limb ischemia provides acceptable results in terms of primary and secondary patency, but limb salvage was worse in patients who underwent redo procedures.

Modified from Troisi N et al: Below-knee revascularization in patients with critical limb ischemia: long-term comparison of redo vs. primary interventions, *J Cardiovasc Surg* 49:489-496, 2008.

Operative Procedures

Exploration of Common Femoral Artery

1. A vertical incision, extending downward about 3 to 5 inches along the medial aspect of the thigh, is made by the surgeon over the femoral artery below the inguinal area, and the field is exposed with a self-retaining retractor.
2. The surgeon locates the common femoral artery and dissects it in both directions for complete exposure.
3. The surgical technologist supplies moist umbilical tapes or vessel loops, which the surgeon passes around the common femoral, the superficial femoral, and the deep femoral arteries.

Exploration of Above-Knee Popliteal Artery

1. The surgeon makes a vertical incision along the medial aspect of the lower area of the thigh. If the popliteal artery is diseased, an additional incision below the knee is made to expose the distal popliteal artery.
2. A Weitlaner retractor is used to retract the muscles and expose the artery.
3. The surgeon flexes the patient's knee, dissects the popliteal artery, and passes a moist umbilical tape around the popliteal artery. Arteriograms may be performed at this time if doubt exists about the patency of the popliteal artery or distal arterial tree.
4. The saphenous vein is exposed via joined femoral and popliteal incisions the length of the thigh or through multiple short incisions along the medial area of the thigh. If the vein is suitable, the surgeon resects the necessary length or prepares it for in situ grafting. If a prosthesis will be used, the surgeon determines the length and size and the surgical technologist preclots the graft as previously described.
5. The surgeon ligates the side branches of the saphenous vein with fine silk. Finally, because of venous valves, the vein is reversed so that the end originally in the groin is anastomosed to the popliteal artery.
6. If a synthetic graft is used, the surgeon passes a tunneling device beneath the sartorius muscle from the popliteal fossa to the groin.
7. The graft is carefully pulled through the tunnel and positioned to prevent kinks or twists.
8. The anesthesia provider administers IV heparin to the patient before the surgeon applies a vascular clamp to the femoral artery. An incision is made into the femoral artery with a #11 knife blade and extended with a Potts angulated scissors.
9. The graft is anastomosed to the artery with fine vascular sutures.
10. The patient's knee is flexed, and the surgeon places vascular clamps on the popliteal artery at the site of the distal anastomosis.
11. An incision is made into the popliteal artery as explained for femoral arteriotomy.
12. The graft is sutured to the popliteal (or tibial) artery, and before completion the femoral occluding clamp is momentarily opened to eliminate air and debris.
13. All occluding clamps are removed, and the graft is assessed for anastomotic leaks.
14. The incision is closed as described previously.

FEMORAL-POPLITEAL BYPASS IN SITU

In situ femoral-popliteal bypass is the restoration of blood flow to the leg, bypassing an occluded portion of the femoral artery with the patient's saphenous vein, which remains in place. The procedure includes incising the venous valves and interrupting the venous tributaries. The adequacy of the patient's saphenous vein may be validated before the surgical procedure by an ultrasound duplex scan. Varicose veins or a previous saphenous vein ligation and stripping are contraindications to the procedure. The advantages of a vein-bypass procedure include increased graft availability and improved patency. A disadvantage is the time-consuming aspect of this technique.

Procedural Considerations

The surgeon uses microvascular scissors, a valvulotome, or a leather in situ valve cutter kit to incise the valves within the vein. An angioscope may be used to monitor the lysis of valve leaflets.

Operative Procedure

1. The procedure is similar to that for a femoral-popliteal bypass. The surgeon extends the groin incision downward over the course of the saphenous vein. A skin bridge may be left between the groin and the popliteal incisions.
2. The saphenous vein is exposed and divided at its proximal and distal ends. Venous tributaries are occluded with vessel clips, such as hemoclips, or fine nonabsorbable sutures.
3. The surgeon passes a valvulotome from below to the top, usually through side branches. The valvulotome is used to incise the internal valve (see Figure 23-6). In angioscopically assisted bypass, valve lysis is done under direct vision.
4. The saphenous vein is distended with heparinized saline, papaverine, or heparinized blood to identify any valvular obstruction or open venous tributary. Another pass of the valve cutter alleviates the obstruction. Open branches of the saphenous vein can also be ligated with vessel clips or fine nonabsorbable sutures.
5. The incompetent saphenous vein is used to bypass the occluded segment of the femoral artery (see steps 8 through 14 of the femoral-popliteal bypass procedure described under Exploration of Above-Knee Popliteal Artery).

FEMOROFEMORAL BYPASS

Femorofemoral bypass is an extraanatomic (a route that is outside the normal path) bypass that is performed to restore blood flow to one leg when an inflow procedure is necessary but a major aortic procedure is not desired. This type of bypass procedure is also used when the surgical risks for the patient are high because of a complicated medical condition or there are technical problems with the procedure (Figure 23-10). Studies continue to examine the long-term patency rate and outcomes for this patient population. Severe cardiac or pulmonary disease may prevent the patient from undergoing a more extensive procedure. Subcutaneous vascular grafting is an option in these conditions because the procedure bypasses normal vascular anatomy and can be performed using a local anesthetic with adjunct moderate sedation and analgesia. The patient must have one good iliac artery for inflow for a femorofemoral bypass to be considered. Another extraanatomic procedure that can be done in these instances is an axillofemoral bypass involving the subcutaneous placement of a prosthesis from the axillary artery to the femoral artery on the same side (Figure 23-11).

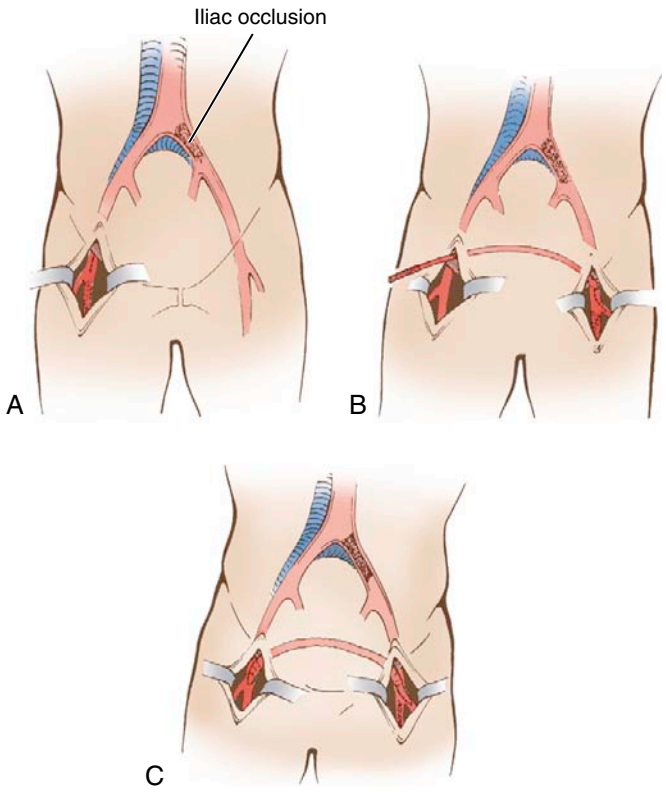


FIGURE 23-10 Femorofemoral bypass to restore blood flow to left leg. **A**, Left iliac artery occlusion and right femoral artery exposure. **B**, Exposure of the right and left femoral arteries: tunneling device creating a path for the graft in the subcutaneous tissue. **C**, Femorofemoral bypass graft in place.

Procedural Considerations

The perioperative nurse assists with positioning the patient supine on the OR bed with a small pad placed under each knee. The area prepped for surgery extends from the umbilicus to midthigh area. The genitalia are covered with a sterile towel.

Operative Procedure

1. A longitudinal incision is made by the surgeon over each femoral artery from the inguinal ligament to just below the femoral bifurcation.
2. Each common femoral artery, superficial femoral artery, and deep femoral artery are dissected free, mobilized, and secured with umbilical tapes or vessel loops.
3. The surgeon creates a graft tunnel between the two femoral arteries across the symphysis pubis in the subcutaneous tissue with digital dissection, scissors dissection, or the passage of a clamp or tunneling device across the preperitoneal space.
4. A Dacron or PTFE vascular graft is passed through the subcutaneous tunnel with care to prevent kinking of the graft.
5. The anesthesia provider administers IV heparin, and the surgeon places vascular clamps on the common femoral, superficial femoral, and deep femoral arteries. A longitudinal arteriotomy is made in the common femoral artery.

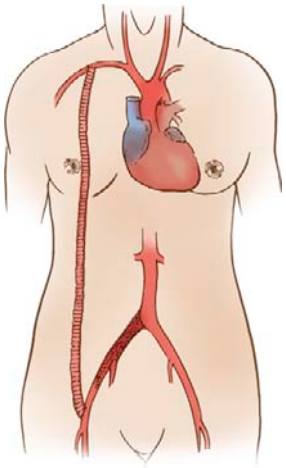


FIGURE 23-11 Axillofemoral bypass graft for right iliac artery occlusion.

6. The surgeon performs an end-to-side anastomosis using nonabsorbable vascular sutures to join the graft with the common femoral artery. A similar anastomosis is done on the other side.
7. After the clamps are released and flow is restored, the patient's pulses are checked with a sterile Doppler; the perioperative nurse may be asked to assess the patient's feet for warmth and color.
8. The femoral incisions are closed.

ARTERIAL EMBOLECTOMY

Arterial embolectomy entails an incision made in the affected artery to remove thromboembolic material and restore blood flow. Emboli may be clot particles, a foreign body, air, fat, or a tumor that circulates through the bloodstream and becomes lodged as the vessel decreases in size. More often the direct source is a cardiac mural thrombus, associated with cardiac or vascular disease. Pain or numbness distal to the obstruction is the initial symptom, accompanied by other signs of vascular occlusion, such as pallor and absence of pulses.

Procedural Considerations

The patient is placed in the supine position, the skin area is prepped, and draping is completed to permit access to the affected area. The instrument setup includes the basic instrument and vascular sets, including embolectomy catheters and irrigation catheters. Heparinized saline is required.

Operative Procedure—Femoral Embolectomy

1. After making a groin incision the surgeon exposes the femoral artery to permit the application of vascular clamps (Figure 23-12, *A* and *B*).
2. An incision is made into the artery with a #11 blade and a Potts scissors. An embolectomy catheter is carefully inserted beyond the point of clot proximally and distally. The balloon is inflated, and the catheter is withdrawn along with the detached clot (Figure 23-12, *C* and *D*).
3. As backflow is obtained, the surgeon applies a vascular clamp below the arteriotomy (Figure 23-12, *E*).
4. The artery may be flushed by injection of heparinized saline solution through a small irrigating catheter. Angioscopy or an arteriogram may or may not be requested at this time.
5. The arterial closure is completed with vascular sutures (Figure 23-12, *F*). The wound is closed, and dressings are applied.

AMPUTATION

Amputations involving the lower extremity are performed to eliminate ischemic, gangrenous, necrotic, or infected tissue; relieve pain; and promote maximum independence. Amputations may be necessary because of trauma or malignancy or when the lower limb cannot be salvaged by arterial reconstruction. In the immediate postoperative period, patients may experience phantom limb pain, described as shooting, burning, throbbing, stabbing, or squeezing. Phantom limb pain may recur, but less frequently, in the months following surgery (Hanley et al, 2006).

Procedural Considerations

It is critical to verify the correct limb for this procedure. Because amputations are often performed with the patient administered a regional anesthetic, the perioperative nurse must be sure that the patient does not witness the wrapping or transport of the amputated limb. Toes or partial foot amputations may be done in certain instances, but often a below-knee (BK) or above-knee (AK) amputation is indicated. Syme's amputation, through the ankle, is seldom performed because of improved prosthetics and rehabilitation that favor mid-calf amputation. The level is based on the health of the patient, level of vascularity, and potential for healing and rehabilitation. Severe infection or toxemia may require amputation as a lifesaving procedure. Operative risks for amputation are higher than those for reconstruction, possibly because of more extensive vascular disease. BK amputations are best done at the junction of the upper and middle thirds of the lower leg. This allows for an immediate postoperative prosthesis, aids in better healing, and may reduce phantom limb pain. AK amputations may be at the middle or lower third of the thigh. Flaps are tailored to provide fascial and skin coverage to cushion the smoothed end of the bone. Meticulous hemostasis and drainage are needed to decrease hematoma formation, since healing is both problematic and critical in these patients. Persons with diabetes are at highest risk for amputation because of their neuropathy, altered response to infection, and vascular insufficiency.

Operative Procedure

1. The surgeon determines the level of amputation, and marks the incision line to create a long posterior flap for a BK amputation. For an AK amputation, the anterior and posterior flaps are fairly equal in size (Figure 23-13).
2. Blood loss may be reduced by using a sterile tourniquet after the leg is raised to drain venous blood. The tourniquet is inflated and the surgeon makes the incision and divides the muscle and soft tissue. The periosteum is raised with an elevator.
3. The surgeon cuts the bones—the tibia with a Gigli or oscillating saw and the fibula with a bone cutter—and bevels their anterior aspect and smoothes them with a rongeur and rasp. The specimen is handed off the field.

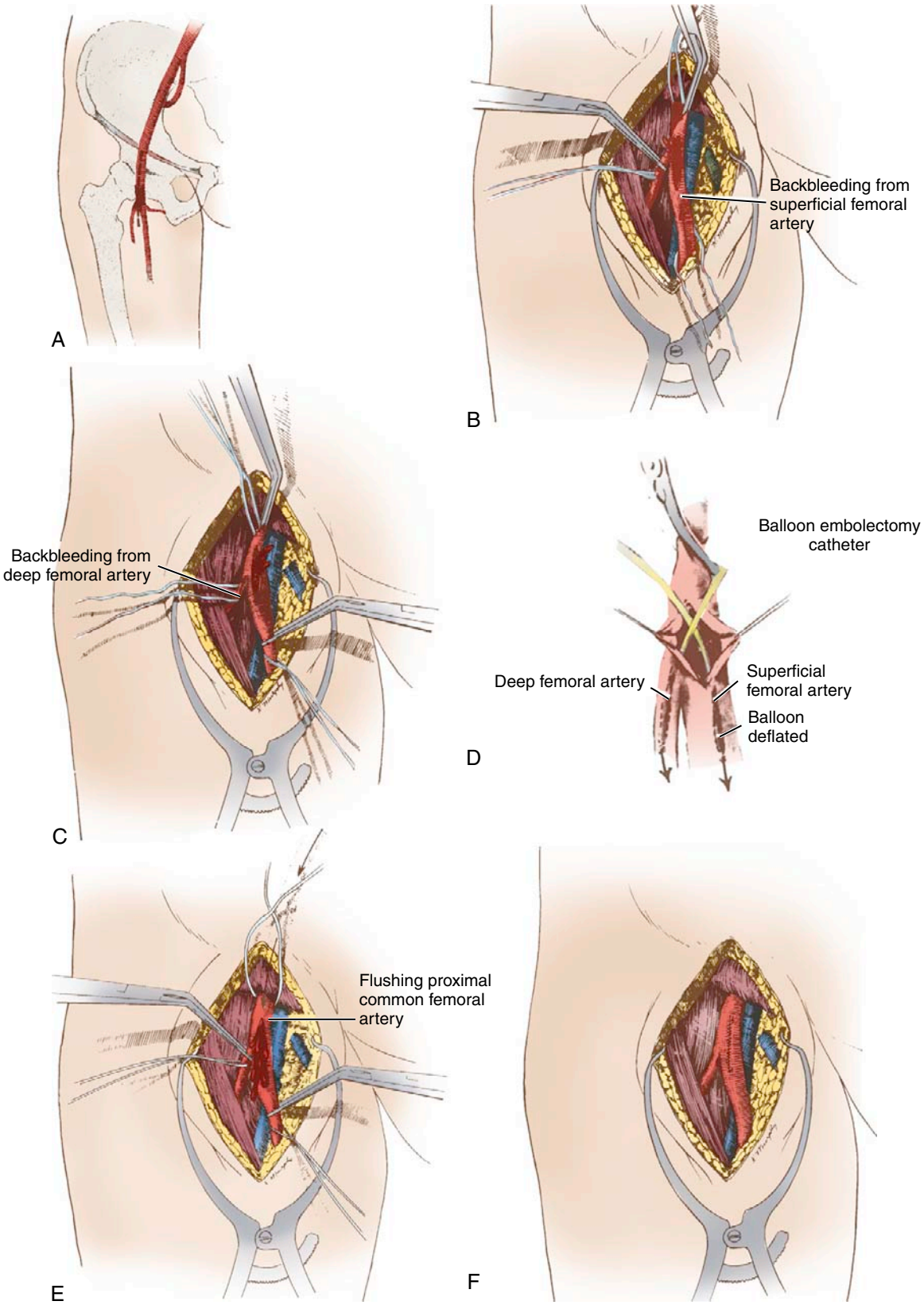


FIGURE 23-12 Femoral embolectomy. **A**, Femoral arteriotomy. **B**, Clamp on common femoral and deep femoral (profunda femoris) arteries. Backflow of blood from superficial femoral artery (SFA) is checked. **C**, Clamp on common femoral artery and SFA. Backflow of blood from deep femoral artery is checked. **D**, Balloon embolectomy catheters are passed into SFA and profunda. **E**, Proximal (common femoral) artery is unclamped and flushed. **F**, Arteriotomy is closed.

4. The stump is gently irrigated, and hemostasis is achieved.
5. A closed-wound drainage system may be inserted.
6. Fascia is closed with interrupted sutures.
7. Skin is approximated and closed with interrupted suture or staples.
8. An immediate postoperative stump dressing may be applied to prevent flexion contracture.

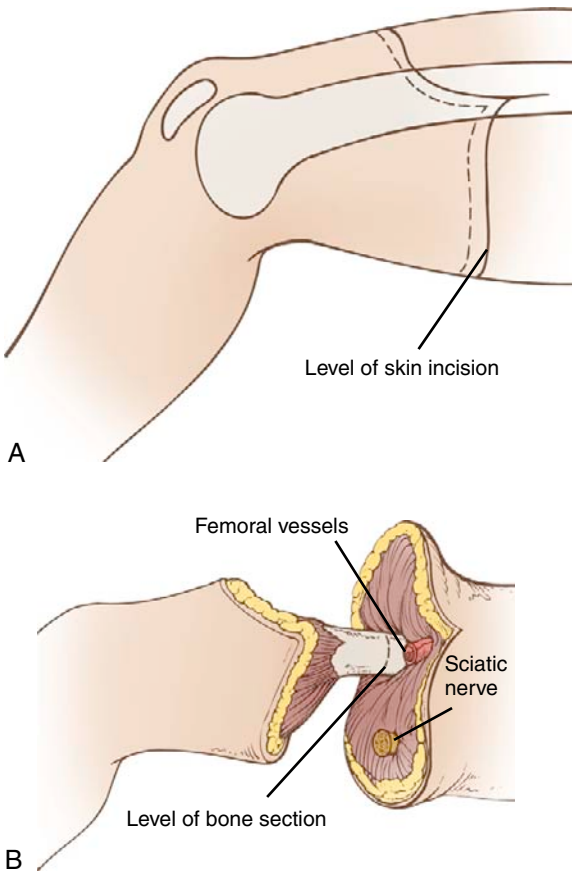


FIGURE 23-13 Leg amputation, above knee, through the middle third of the thigh. **A**, Level of skin incision. **B**, Level of bone resection.

CAROTID ENDARTERECTOMY (CEA)

CEA is the removal of an atheroma (plaque) at the carotid artery bifurcation to increase cerebral perfusion and decrease the risk of embolization and consequent stroke (Liu et al, 2009) (Rapid Response Team box). In most settings, the patient is discharged on the first postoperative day. Lessening the likelihood of any transient or permanent neurologic deficit is a major concern during a CEA. The use of a temporary carotid artery shunt (Figure 23-14), such as an Argyle or Javid shunt, allows for continuous blood flow through the carotid artery and to the brain. Some disadvantages in using this temporary device are that additional dissection is necessary for its placement and that there is a possibility of dislodging debris when the shunt is inserted. Also, it is difficult to view the endarterectomy endpoint and suturing a patch is more difficult.

Two techniques that facilitate continual assessment of cerebral perfusion are the use of a cervical plexus block for anesthesia and the use of electroencephalography. A conscious patient with a cervical plexus block can be observed for neurologic deficits encountered during the procedure. The patient who is administered a general anesthetic can be monitored with an EEG. If either method demonstrates reduced cerebral perfusion, the surgeon may decide to use a temporary carotid artery shunt. The shunting device should always be available and sterile at the beginning of the procedure.

Procedural Considerations

The perioperative nurse assists with positioning the patient supine on the OR bed with the head supported on a head support. The head is turned away from the operative side, and the neck may be slightly hyperextended. A roll may be placed between the scapulae.

RAPID RESPONSE TEAM

Stroke continues to be a significant cause of morbidity and mortality in the United States. Approximately 750,000 Americans have a new or recurrent stroke each year. Stroke remains the third leading cause of death and is the leading cause of disability in the United States (Schwamm, 2006) when considered independently from other cardiovascular diseases. Major advances have been made during the past several decades in stroke prevention, treatment, and rehabilitation. Despite successes in delivering effective new therapies, significant obstacles remain in ensuring that scientific advances are consistently translated into clinical practice. A best practice (often referred to as evidence-based practice [EBP]) is using "best evidence" to make clinical decisions and eliminate inappropriate or ineffective care. Patients with asymptomatic carotid stenosis have a low risk of stroke. However, carotid disease includes stenosis as well as stable and unstable plaque formation. Patients with cerebral ocular events, an irregular plaque surface, recent ischemic events, and carotid stenosis are likely candidates for surgery.

In 2005 the American Stroke Association formed a task force on the development of stroke systems of care. One critical element of the multidisciplinary stroke system is the hospital-based acute stroke team. The team should consist of neuroscience nurses and neurologists who work in conjunction with the primary care nurse and physician through prompt recognition and intervention of stroke symptoms in hospitalized patients. Acute stroke teams facilitate the rapid evaluation and treatment of acute stroke patients that result in improved patient outcomes.

Part of the recommendations related to acute treatment includes the following:

- Acute stroke teams
- Written care protocols
- Continuing medical education
- Interface with Emergency Medical Service (EMS)
- A stroke unit for stroke admissions
- Neuroimaging and laboratory services
- Access to neurosurgical services

Modified from Mathiesen C et al: Best practices in stroke rapid response, *Medsurg Nurs* 15(6):364-369, 2006; Schwamm L et al: *Recommendations from the American Stroke Association's task force on the development of stroke systems*, available at www.stroke.ahajournals.org. Accessed April 17, 2009.

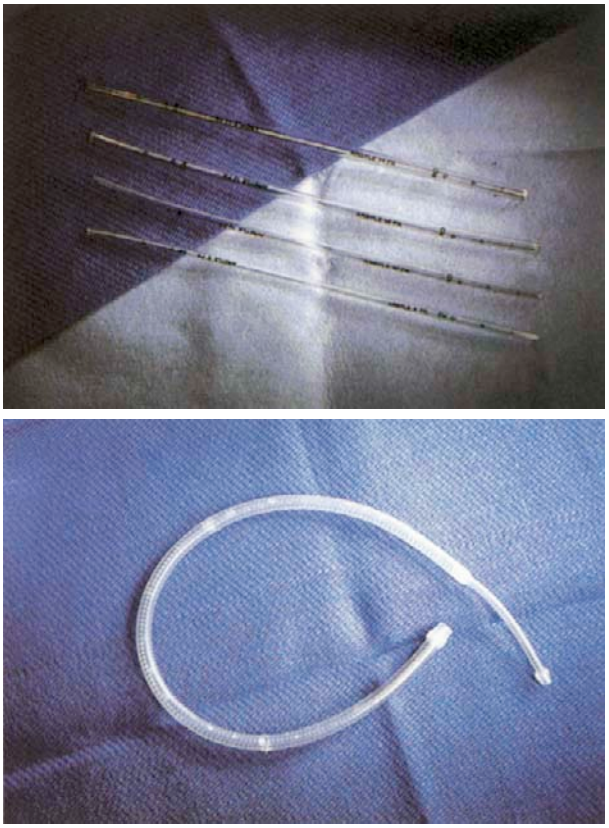


FIGURE 23-14 Example of temporary carotid artery shunts that are used to permit blood flow during carotid endarterectomy procedures.

Operative Procedure

1. The surgeon makes a longitudinal incision over the area of the carotid bifurcation (Figure 23-15, *A*) and places a Weitlaner self-retaining retractor for exposure.
2. With Metzenbaum scissors, the surgeon dissects the soft tissue to expose the carotid artery and its bifurcation (Figure 23-15, *B*).
3. A moistened umbilical tape or vessel loop is passed around the vessel for ease of handling. Systemic heparin is given to the patient by the anesthesia provider.
4. The surgeon clamps the external, common, and internal carotid arteries.
5. The surgeon uses a #11 knife blade to create an arteriotomy over the stenotic area and lengthens the incision with a Potts angulated scissors to expose the full extent of the occluding plaque.
6. Using a blunt dissector, the surgeon dissects the plaque or plaques free from the arterial wall. Heparin solution is used as an irrigant to clean the intima.
7. The surgeon closes the arteriotomy with fine vascular sutures. A synthetic (polyester or PTFE) or autogenous (vein) patch graft may be used to restore the arterial lumen if it is small (Figure 23-16). Before complete closure, blood flow is temporarily restored through the arteries to wash away any free plaques, air, or thrombi. For this to be done, the occluding clamps are opened and closed individually, with flushing of any debris away from the internal carotid artery. The closure of the arteriotomy is completed (Figure 23-17).

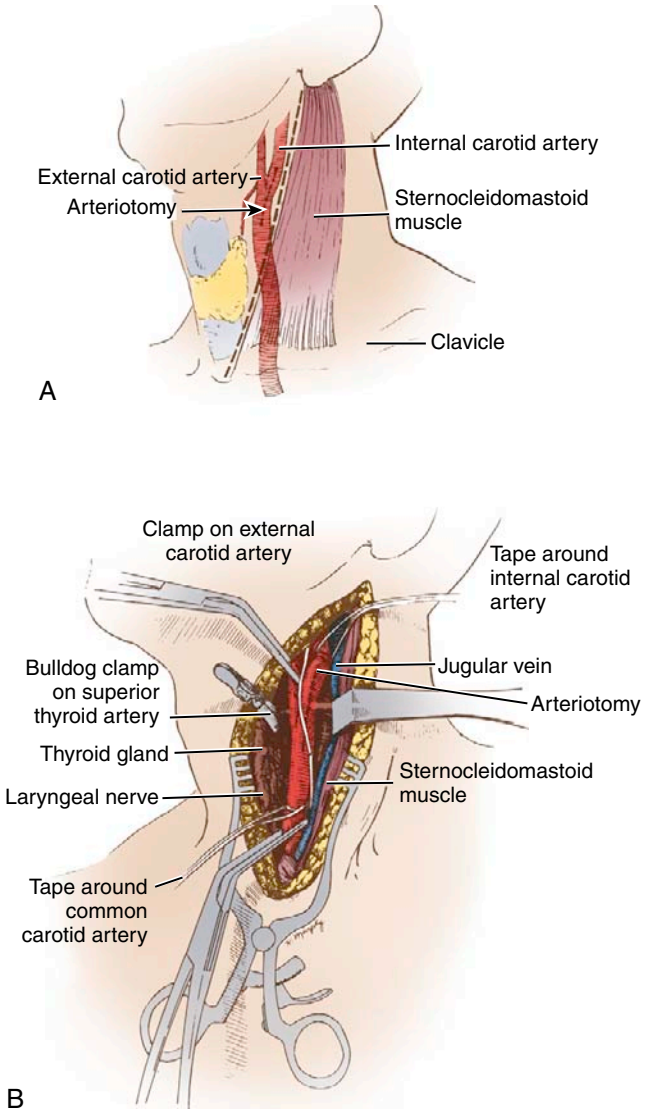


FIGURE 23-15 Left carotid endarterectomy. **A**, Incision and anatomy. **B**, Exposure of carotid bifurcation.

8. The occluding clamps are removed from the external and common carotid arteries; the internal carotid artery clamp is removed last. This sequence ensures that any minor debris missed will be flushed harmlessly into the external rather than the internal carotid artery.
9. Additional interrupted sutures may be needed to control leakage.
10. A closed drainage system is inserted by way of a separate stab incision.
11. The wound is closed, and dressings are applied.

CAROTID ENDARTERECTOMY WITH SHUNT

Operative Procedure

1-5. The first five steps as described for carotid endarterectomy are followed.

6. To maintain cerebral blood flow the surgeon inserts either a piece of tubing (polyethylene or Silastic) with a suture tied around its center or a commercially prepared shunt device

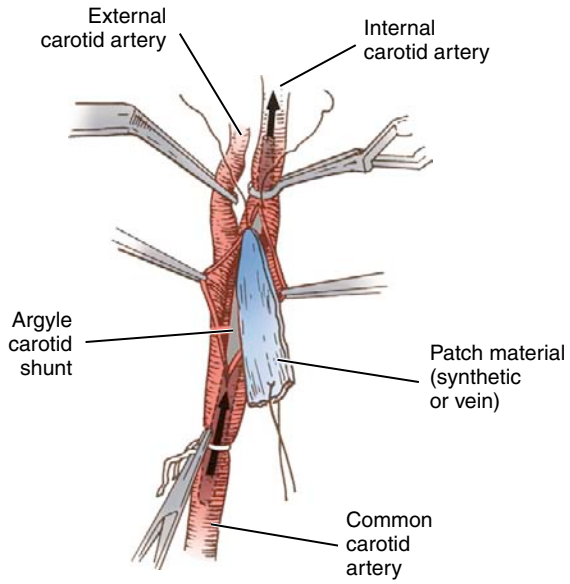


FIGURE 23-16 Left carotid endarterectomy illustrating initial placement and suturing of a patch (a shunt is in place).

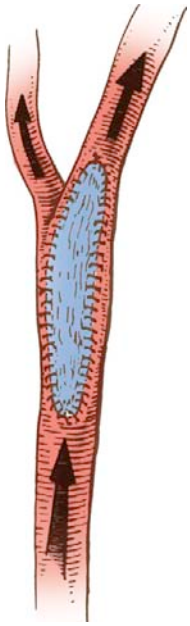


FIGURE 23-17 Left carotid endarterectomy (patch angioplasty) with patch sewn in place.

into the common carotid artery and the internal carotid artery. The surgeon then stabilizes the tube or shunt with vessel loops or shunt clamps (Figure 23-18).

7. The surgeon removes the plaque as described for carotid endarterectomy and the arteriotomy is closed with or without a patch.
8. Before the arteriotomy closure is completed, the surgeon releases the shunt clamp or vessel loop on the internal carotid artery and removes the shunt. The external carotid occluding clamp is removed, followed by the common carotid artery clamp, and, last, the internal carotid artery occluding clamp.
9. The wound is closed, and dressings are applied.

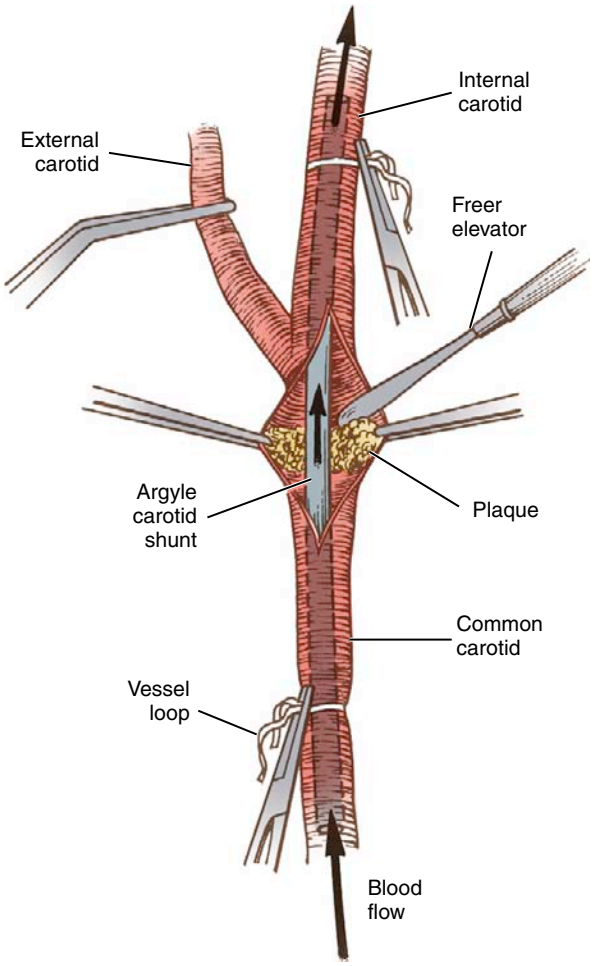


FIGURE 23-18 Left carotid endarterectomy. Argyle carotid shunt in place to allow blood flow to the brain. Stenotic plaque being removed with Freer elevator.

ARTERIOVENOUS FISTULA

Arteriovenous fistulas—direct connections between an artery and a vein—are the standard means of vascular access for long-term renal dialysis. The dilated vein can then be used for direct cannulation with large-bore needles for hemodialysis. This method is preferable to an external shunt, which carries a high risk of thrombosis and infection. The best access is achieved using the patient's own vessels and creating a subcutaneous connection between the artery and vein, referred to as an arteriovenous shunt, or bridge fistula. Other choices include using a bovine carotid artery, a human umbilical vein graft, or a synthetic vascular graft, usually PTFE. Four anastomoses that can be created between the artery and vein are side of artery to side of vein, end of artery to side of vein, end of vein to side of artery, and end of vein to end of artery (Parker et al, 2008) (Figure 23-19). The Brescia-Cimino fistula is a connection between the radial artery and cephalic vein at the wrist (Figure 23-20). A basic principle of creating a fistula is to start in the distal arm and move proximally with subsequent fistulas. These include ulnar artery to basilic vein and brachial artery to brachial or cephalic vein (Figure 23-21).

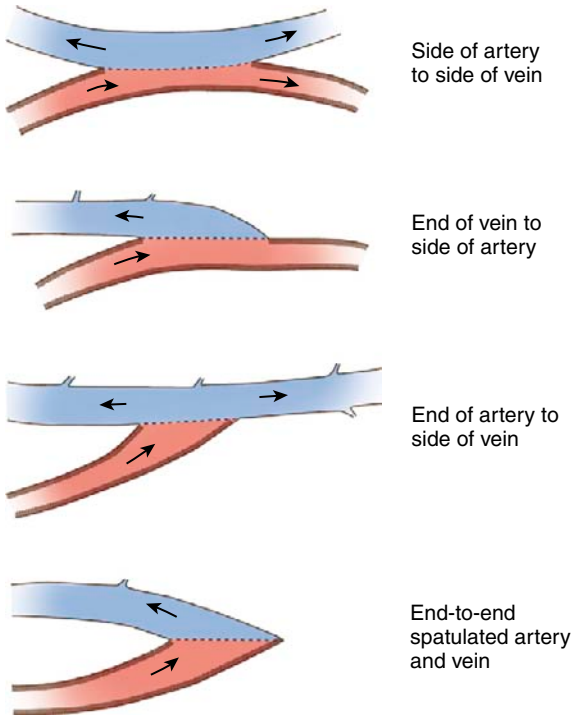


FIGURE 23-19 Four types of anastomoses between radial artery and cephalic vein.

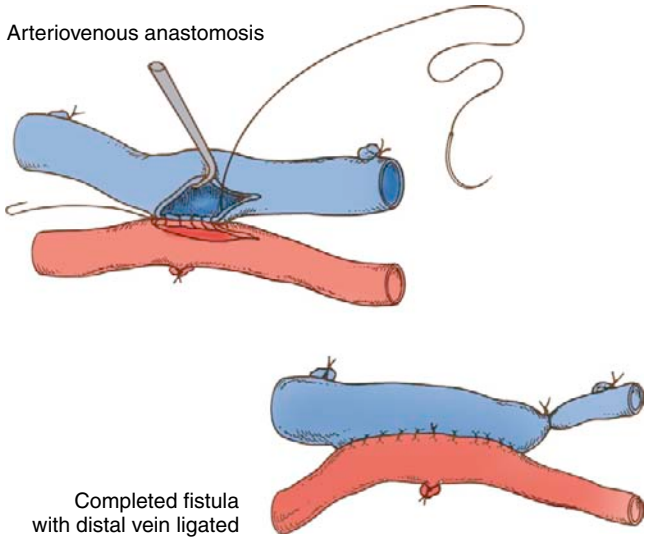


FIGURE 23-20 Arteriovenous anastomosis. The artery is anastomosed to the vein.

Arteriovenous shunts are indicated for long-term renal dialysis access. Patients with end-stage renal disease have their creatinine clearance levels observed. When the creatinine clearance level falls to 10 ml/min, a Cimino fistula may be created in anticipation of the need for dialysis. A Cimino (or Brescia-Cimino) type of fistula has proved to have the longest patency and lowest infection rate. It is created to connect the patient's artery to a vein that will dilate and become thick-walled (its muscle layer hypertrophies). This occurs from the high rate of blood flow delivered by the connection to the artery. The arterialization, or maturation process, necessary to allow the

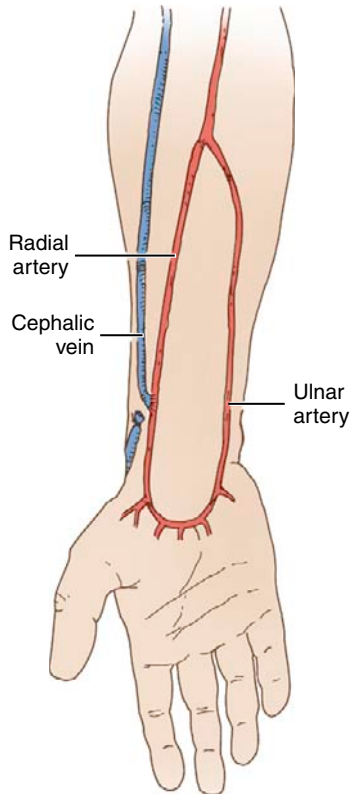


FIGURE 23-21 End of the cephalic vein anastomosed to the side of the radial artery at a site superior to the usual location of the radiocephalic fistula. This technique can be useful if the distal radial artery is small or the cephalic vein at the wrist is thrombosed.

fistula to withstand the repeated needle punctures of dialysis takes about 3 weeks.

Bridge fistulas do not need to mature and therefore are available for immediate dialysis use. For connections between an artery and a vein that are in proximity, a U-shaped graft is placed. Grafts that are far apart require a straight or slightly curved graft. Although the saphenous vein, an umbilical vein graft, and the bovine carotid artery are used, the PTFE grafts work the best and are most commonly used for bridge fistulas. Some surgeons prefer to use a specially designed PTFE step-graft, or tapered graft. These have a short segment of 4 mm in diameter at one end and the majority of the graft with a 7-mm diameter. This graft may avoid an output or flow rate that is so high it causes cardiac overload. Primary sites for bridge fistulas include the upper arm between the brachial artery and axillary vein and the forearm between the brachial artery and antecubital vein or between the brachial artery and basilic vein (Figure 23-22). The axillofemoral graft for dialysis is reserved for those patients who have exhausted other fistula sites. A regular-walled (versus a thin-walled) graft is placed from the axillary artery to the common femoral vein. PTFE grafts can be used immediately, but it may be better to wait 2 weeks for anastomotic healing to occur.

The side-to-side fistula was the original subcutaneous method introduced by Brescia in 1966. The side-to-side fistula is technically the easiest to perform and creates the highest flow rate. The arterial end-to-vein side fistula has a lower flow rate. The arterial side-to-vein end fistula is technically more

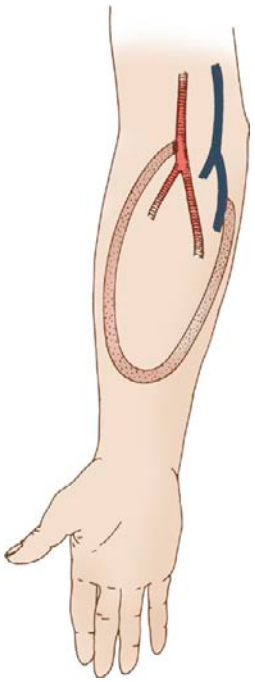


FIGURE 23-22 An example of a loop fistula. A synthetic graft has been used to create a loop brachiocephalic fistula.

difficult to create but has a lower incidence of venous hypertension. The end-to-end construction has the lowest rate of venous hypertension but also has the lowest flow rate. There is a trend toward performing fewer side-to-side fistulas and more artery side-to-vein end fistulas.

Since the patency of fistulas is limited, dialysis patients return for revision or embolectomy in attempts to salvage their function. Unfortunately, the success rate for salvage is low and access may be better managed by the creation of another site or a bridge fistula. Risk factors for complications include female gender, African American race, older than 65 years, and presence of diabetes. Treatment for the most common complication, stenosis, is surgery. Stenosis usually results in thrombosis. Stenosis most often involves the venous anastomosis, and a patch angioplasty is usually performed to revise a thrombosed fistula. Other complications include aneurysm and pseudoaneurysm formation, infection, subclavian steal syndrome, and high-output CHF.

VENA CAVA FILTER INSERTION

Vena cava filter (VCF) insertion entails the partial occlusion of the inferior vena cava with an intravascular filter, such as a Greenfield filter, inserted under fluoroscopy using a local anesthetic or moderate sedation and analgesia (monitored anesthesia care). VCFs are generally placed in the OR or angiography suite with fluoroscopic guidance. The Greenfield device offers the option of jugular or femoral vein insertion, and the correct kit must be selected. Box 23-3 gives indications for a caval filter. Several types of filters have been used during the past 20 years, as illustrated in Figure 23-23. The Greenfield filter is the most successful and widely used device, and the mortality and morbidity have been extremely low. The device has progressed from an early design that required an incision and venotomy

BOX 23-3

Indications for a Vena Cava Filter

- Recurrent thromboembolism despite "adequate" anticoagulation
- Deep venous thrombosis in a patient with contraindications to anticoagulation
- Chronic pulmonary embolism and resultant pulmonary hypertension
- Complications of anticoagulation
- Propagating iliofemoral venous thrombus in anticoagulation

From Chung J, Owen R: Using inferior vena cava filters to prevent pulmonary embolism, *Can Fam Physician* 54:49-55, 2008.

to the current percutaneous titanium vena cava filter. The filter maintains a patent vena cava but prevents PE by trapping the emboli at the apex of the device.

Procedural Considerations

The perioperative nurse assists the patient to the supine position on a radiopaque OR bed to permit fluoroscopic visualization at the level of the renal veins. This procedure may be performed in the OR, radiology suite, or ICU for critical patients. The head is turned to the left for jugular vein insertion, or the groin is exposed for femoral vein insertion. The right femoral vein is preferred over the left because the anatomy of the left vein often makes threading the filter more difficult. The nurse ensures that local anesthetic, heparinized saline to flush the device, and contrast media are available.

Operative Procedure

1. The right groin area is prepped and draped and infiltrated with local anesthetic.
2. An 18-gauge entry needle is used for right femoral venotomy.
3. The surgeon inserts the guidewire and advances it to a level above the renal veins under fluoroscopic guidance.
4. The sheath or dilator is inserted over the guidewire after all device lumens have been flushed with heparin solution.
5. The surgeon removes the sheath, and inserts and advances the introducer catheter to the implantation site.
6. The introducer catheter carries the preloaded, radiopaque carrier capsule. The sheath is retracted, the filter is discharged, and the sheath is removed.
7. Pressure is applied to the puncture site for approximately 5 minutes or until hemostasis is achieved.

VARICOSE VEIN EXCISION AND STRIPPING

Varicose veins are enlarged and distended veins that are visible and palpable beneath the skin. Varicose veins are described as primary or secondary. Primary varicose veins are more prevalent and are not associated with a pathologic condition of the deeper venous system, that is, post-thrombotic syndrome or a history of DVT. Secondary varicose veins are believed to be a result of insufficiency of the deep venous system. Disease may prevent the normal functioning of these valves, resulting in distention; as the vein wall weakens and dilates, venous pressure increases and the valves become incompetent. The veins

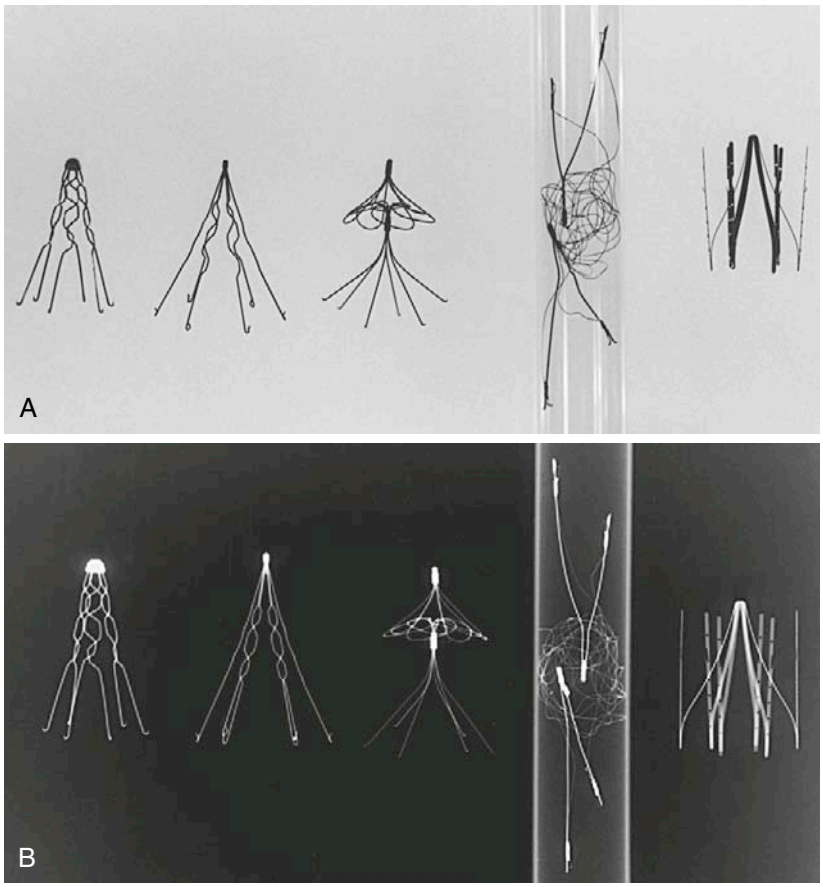


FIGURE 23-23 Vena cava filters. **A**, Actual filters. **B**, Radiographic images. *Left to right,* Kimray-Greenfield, titanium Greenfield, Simon nitinol, Gianturco bird's nest, and Vena Tech.

gradually become dilated. Veins in the lower extremities are most frequently affected, particularly the long saphenous vein. Risk factors include female gender, increased age, pregnancy, geographic location, and race (more prevalent in Caucasians).

Dilation of the saphenous vein produces venous stasis, which may be followed by secondary complications, such as stasis ulcers. Venous obstruction causes an increase in venous pressure, which leads to an increase in capillary pressure. This causes fluid to leak from the capillaries and produce edema. The objective of surgical intervention is to remove the diseased veins, thus preventing ulceration, secondary edema, pain, and fatigue in the extremity.

Procedural Considerations

Before sedation or entrance into the OR, the patient should stand and the varicose veins should be marked with an indelible marker. This ensures adequate visualization for complete removal of the varicosities, since the patient is often placed in the Trendelenburg position intraoperatively to decrease venous congestion, which could interfere with visualization of the varicosities. The perioperative nurse assists with positioning the patient on the OR bed in a supine position with the legs slightly abducted. Ligation or stripping of the lesser saphenous veins and branches may require placing the patient in the prone position. In the stab avulsion technique, multiple small (2 to 3 mm) incisions are made over the identified varicosities, and the affected vein segments are removed (Figure 23-24). Stripping indicates removal of a long segment of vein by means of a special device (Figure 23-25). Drapes are placed to enable flexing and lifting at the knee. Instruments include a basic minor instrument setup, plus the following: Weitlaner self-retaining retractors, #11 blades, skin hooks, mosquito hemostats, vein strippers with various tips available, and elastic bandages. Endovenous laser ablation (EVLA) is an innovative nonsurgical procedure for varicose veins and offers patients an alternative treatment to surgical vein stripping (Ambulatory Surgical Considerations).

Operative Procedure

1. The surgeon makes an incision in the upper area of the thigh, parallel to the crease in the groin, and clamps and ligates any bleeding vessels.
2. The saphenous vein is identified and isolated. Margins of the wound are separated with a Weitlaner self-retaining retractor.
3. The surgeon double ligates the saphenous vein branches with black silk ties, or they are transfixed, clamped, and divided. The proximal stump is dissected upward to the point at which it enters the femoral vein, where it is carefully ligated.
4. If the saphenous vein is to be excised, the surgeon makes an incision at its distal portion at the ankle, and the vein is identified, ligated, and divided.

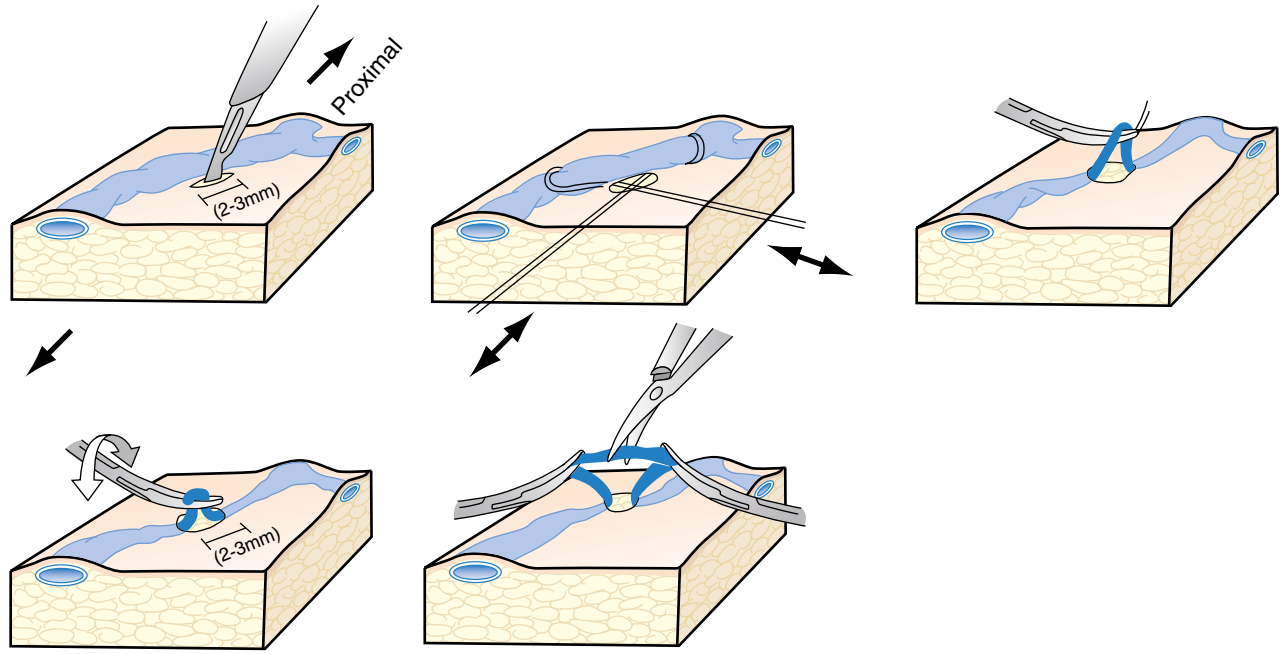


FIGURE 23-24 Technique of stab avulsions of varicosities.

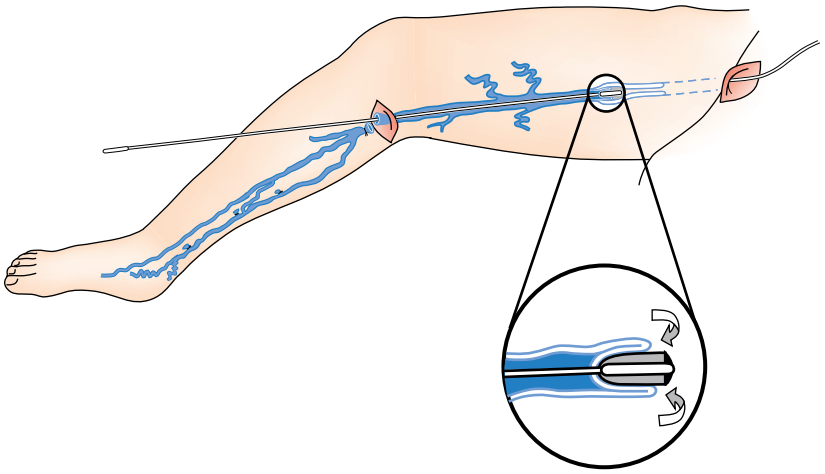


FIGURE 23-25 Inversion stripping of the saphenous vein for superficial venous reflux caused by an incompetent saphenofemoral junction.

AMBULATORY SURGERY CONSIDERATIONS

Post-Discharge Follow-Up: Endovenous Laser Ablation for Varicose Veins

Endovenous laser ablation (EVLA) is an innovative nonsurgical procedure for varicose veins that offers an alternative treatment to the often painful surgical ligation (or stripping) of veins, which is performed with the patient administered a general anesthetic and often has a long recovery time. During EVLA, by delivering laser energy through a fiberoptic catheter a particular vein is sealed to prevent blood flow. The catheter is inserted into the vein with ultrasound guidance. The entire procedure can be done in 1 hour as an ambulatory surgery procedure with the patient administered a local anesthetic. Once the procedure is completed, the skin puncture site is approximated with an adhesive strip. A graduated compression stocking or wrap is applied to the affected extremity from the base of the toes to the groin; it is constantly kept in place for 2 weeks and thereafter for 6 weeks when ambulatory to help maintain occlusion of the vein. Immediate and frequent ambulation is encouraged to decrease the incidence of DVT formation.

An important consideration for vascular procedure patients in the ambulatory setting is postoperative and discharge education. Patients need detailed instructions regarding recovery and convalescence since this phase is not complete upon discharge. Those instructions should include possible complications, activity level, wound care, pain management, and the plan for follow-up. Postoperative phone calls, 24 to 48 hours after discharge, have proven beneficial to identify any adverse events and answer patient questions. In a study by Forster and colleagues (2008), an automated system was developed for follow-up. Several patients requested to speak to a nurse directly for worsening postoperative symptoms and for additional clarification of the discharge instructions. Although all patients received detailed education, new questions arose. The post-discharge phone call can stress the importance of wearing the compression stocking or wrap to prevent complications.

Modified from Orenstein BW: Replacing vein stripping, *Radiol Today* 6(12):22-27, 2005; Forster AJ et al: Automated patient assessments after outpatient surgery using an interactive voice response system, *Am J Manag Care* 14(7):429-436, 2008.

5. A vein stripper is inserted and advanced to the proximal end of the vein in the groin, where it is secured with a heavy suture, and the tip is attached.
6. As the surgeon pulls the stripper up the leg, external compression is applied by the assistant or surgical technologist.
7. Tributaries may be excised through numerous small incisions along the course of the vein.
8. The surgeon closes the groin wound in layers, and other small incisions are closed with skin sutures or staples. Dressings and circular compression bandages are applied.

REFERENCES

Alberto P et al: Prevalence of risk factors, coronary and systemic atherosclerosis in abdominal aortic aneurysm: comparison with high cardiovascular risk population, *Vasc Health Risk Manag* 4:877–883, 2008.

Association of periOperative Registered Nurses (AORN): Recommended practices skin antisepsis; preoperative patients. In *Perioperative standards and recommended practices*, Denver, 2009, The Association.

Crum BG: Revised national patient safety goal on medication handling, *AORN J* 83(4):955–957, 2006.

Denholm B: Tucking patient's arms and general positioning, *AORN J* 89(4):755–757, 2009.

Egorova N et al: National outcomes for the treatment of ruptured abdominal aortic aneurysm: comparison of open versus endovascular repairs, *J Vasc Surg* 48:1092–1100, 2008.

Faisal A, Cooper L: Peripheral arterial disease: diagnosis and management, *Mayo Clin Proc* 83(8):944–949, 2008.

Federal Interagency Forum on Aging-Related Statistics: *Older Americans 2004: Key Indicators of Well-Being.* Federal Interagency Forum on Aging-Related Statistics, Washington, DC, March 2008, U.S. Government Printing Office.

Gloviczki P, Ricotta JJ: Aneurysmal vascular disease. In Townsend CM et al, editors: *Sabiston textbook of surgery*, ed 18, Philadelphia, 2008, Saunders.

Hanley MA et al: Self-reported treatments used for lower-limb phantom pain: descriptive findings, *Arch Phys Med Rehabil* 87:270–277, 2006.

Hawn MT et al: Timely administration of prophylactic antibiotics for major surgical procedures, *J Am Coll Surg* 203:803–811, 2006.

Ignatavicius DD, Walicek SH: Interventions for clients with vascular problems. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care*, ed 6, St Louis, 2010, Saunders.

Linsky RA et al: Contemporary management of peripheral arterial disease: a review, *Med Health R I* 91(10):305–308, 2008.

Liu Z et al: Carotid artery stenting versus carotid endarterectomy: systematic review and meta-analysis, *World J Surg* 33:586–596, 2009.

Lloyd-Jones D et al: Heart disease and stroke statistics—2009 update: a report from the American Heart Association Statistic Committee and Stroke Statistics Committee, *Circulation* 119:e21–e181, 2009.

Makary MA et al: Operating room briefings and wrong site surgery, *J Am Coll Surg* 204:236–243, 2007.

Nguyen MC, Garcia LA: Recent advances in atherectomy and devices for treatment of infra-inguinal occlusive disease, *J Cardiovasc Surg* 49: 167–177, 2008.

Parker FM et al: Access and ports. In Townsend CM et al editors: *Sabiston textbook of surgery*, ed 18, Philadelphia, 2008, Saunders.

Pearce WH: The endovascular repair of abdominal aortic aneurysms: what's new in ACS Surgery, available at www.medscape.com. Accessed February 5, 2005.

Rosen P, Karmy-Jones RC: Endovascular interventions on the superficial femoral and popliteal arteries, The Cardiothoracic Surgery Network, available at www.ctsnet.org/potals/endovascular/procedures101/article-3.html. Accessed March 20, 2009.

Schermerhorn ML et al: Endovascular vs. open repair of abdominal aortic aneurysms in the Medicare population, *N Engl J Med* 358:464, 2008.

Wu HW et al: Improving patient safety through informed consent for patients with limited health literacy, NQF Project Brief, 2005, available at www.qualityforum.org/projects/completed/informed_consent.asp. Accessed April 14, 2009.

Zeller T et al: New techniques for endovascular treatment of peripheral artery disease with focus on chronic critical limb ischemia, *VASA* 38(1):3–12, 2009.

CHAPTER 24

Cardiac Surgery

PATRICIA C. SEIFERT

Cardiac surgery (History box) reflects individual and collaborative innovation, risk-taking, and problem-solving. Anastomotic techniques to join blood vessels, advances in the development of atraumatic vascular instruments, endovascular approaches in the repair of great vessels, and improvements in myocardial protection strategies represent a few of the many advances that have led to remarkable achievements in the surgical repair of congenital and acquired cardiovascular diseases (Stoney, 2008). Cardiac surgeries continue to evolve and reflect societal mandates for personal safety, enhanced functional outcomes, institutional efficiency, staff competence, and operational cost-effectiveness (Lytle, 2008). Evidence of these achievements can be seen in the rapid growth of endoscopic and robotic technology, minimally invasive procedures, off-pump techniques, combined (hybrid) surgical and percutaneous interventions, and molecular-level treatments for cardiovascular disease. Many newer procedures require smaller incisions, promote faster healing, and enable patients to achieve their desired functional outcomes more quickly.

These trends have not replaced the need for traditional techniques; rather, they have expanded treatment options for coronary artery disease (CAD), valvular dysfunction, thoracic aneurysms, conduction disturbances, congenital abnormalities (Sommer et al, 2008a, b, c), heart failure, intracardiac masses (Kuchukarian et al, 2007), and end-stage cardiac disease. Therapeutic options may employ laser, radiofrequency, and cryo energies. Stem cell therapy, used to induce cardiac neorevascularization at the cellular level (Menasche, 2009), and mechanical assist devices are effective alternatives to allograft transplant organs, which are in scarce supply. Great strides have been made to reduce mortality from coronary artery disease (Gardner, 2009; American Heart Association, 2009a), but significant challenges associated with the aging population, obesity, diabetes, and other risk factors continue to affect the cardiovascular system and the need for surgical treatment.

Surgical Anatomy

The heart (Figure 24-1) is a four-chamber muscular pump that propels blood into the systemic and pulmonary circulatory systems. It is enclosed in a pericardial sac within the mediastinum, which lies between the lungs, posterior to the sternum, and anterior to the vertebrae, esophagus, and descending portion of the aorta. The diaphragm is positioned below the heart (Figure 24-2). The cardiac wall is composed of three layers: the epicardium, the outer lining; the myocardium, or muscular layer, which is the important functional layer; and the endocardium, the inner lining (Figure 24-3).

Two thirds of the heart is located to the left of the midline, and the remaining one third is to the right. Although functionally divided into right and left halves, the heart is rotated to the left, with the right side located anteriorly and the left side situated relatively posteriorly. Each half of the heart contains an upper and a lower communicating chamber: the atrium and the ventricle, respectively. The right atrium (RA) receives desaturated blood from the inferior and superior venae cavae and from the coronary circulation by way of the coronary sinus. The left atrium (LA) receives oxygenated blood from the lungs by way of the pulmonary veins. From the atria, blood flows through the atrioventricular (AV) valves into the ventricles.

The left ventricle (LV) pumps blood into the major vessels of the *systemic circulatory system* by way of the aorta and its main branches to the head, upper extremities, abdominal organs, and lower extremities. The right and left internal (thoracic) mammary arteries, used as grafts during coronary bypass surgery, branch off the subclavian arteries and course behind and parallel to the edges of the sternum. The arteries of the circulatory system subdivide into arterioles and eventually into capillaries, where internal respiration and metabolic exchange occur. From the capillary beds, desaturated blood flows into the venules and veins and finally returns to the RA.

In the *pulmonary circulatory system,* blood is pumped from the right ventricle (RV) through the pulmonary valve into the main pulmonary artery (PA). The PA divides into the right and left pulmonary arteries, which further subdivide into the arterioles and capillaries of the lungs. External respiration occurs in the capillary beds and the alveoli, where carbon dioxide is exchanged for oxygen. Freshly oxygenated blood from the lungs flows through the pulmonary veins into the left atrium.

Coronary circulation (Figure 24-4) supplies oxygen and nutrients to, and removes metabolic waste from, the myocardium; internal respiration occurs in the *myocytes*. The heart receives its blood supply from the left and right coronary arteries, which originate in the sinuses of Valsalva behind the cusps of the aortic valve in the ascending aorta. The left main coronary artery divides into the left anterior descending (LAD) coronary artery and the circumflex coronary artery; along with the right coronary artery (RCA), these arteries represent the three main vessels of the coronary arterial system. In coronary arteries affected by coronary artery disease (CAD), focal or diffuse atherosclerotic plaques develop and progressively enlarge, jeopardizing myocardial blood flow and oxygenation, producing ischemic pain (in many, but not all, cases). Occlusion of an artery by expanding atherosclerotic lesions causes myocardial

infarction (MI) and irreversible damage to the region of the myocardium perfused by the obstructed artery. Coronary artery bypass procedures increase blood flow to the affected ischemic areas by attaching a bypass graft conduit to the artery distal to the narrowed portion of the artery. A totally occluded (infarcted) artery does not benefit from bypass surgery because the myocardial injury is irreversible.

The main coronary arteries are situated in the epicardium, which facilitates accessibility during coronary bypass procedures. From these arteries arise the septal perforators and other branches that penetrate the entire myocardium. The cardiac veins empty into the right atrium by way of the coronary sinus; the thebesian veins, prominent in the walls of the right atrium and the right ventricle, open directly into these chambers.

HISTORY

History of Cardiac Surgery

Although the notion of the heart as the seat of the soul is an ancient concept, cardiac surgery is one of the youngest clinical specialties, partly because of religious restrictions and partly because of physiologic constraints. Rehn's suture repair of a right ventricular stab wound in 1896 opened the door to the specialty of cardiac surgery. The introduction of positive-pressure endotracheal anesthesia allowed surgeons to access the heart and enter the pleural cavities without causing the lungs to collapse; the introduction of electrical defibrillation and chemical arresting solutions made it possible to stop, and then restart, the heart with predictability. Diagnostic techniques to visualize anatomy and physiology of the heart, record electrical activity, measure blood pressure and flow, and assess ventricular function expanded opportunities to precisely identify the cardiac pathologic condition and to tailor the surgical intervention to the needs of the patient. The ability to isolate the heart and lungs from the circulation without producing irreversible cerebral anoxia was first demonstrated in 1953 when Gibbon repaired an atrial septal defect using extracorporeal circulation with a pump oxygenator that he and his wife had designed. Anastomotic techniques devised by Carrel in the early twentieth century made it possible for numerous advances, including innovations in the repair of aortic aneurysms developed by DeBakey and Cooley in the 1950s, direct myocardial revascularization with the internal mammary artery and saphenous vein introduced by Favaloro and others in the mid-1960s, and cardiac transplantations presented by Barnard and Shumway in the late 1960s. The development of plastics, polyesters, and new metal compounds fostered the creation of prosthetic implants for cardiac valve replacement, first performed in 1960 by Harkin and Starr for the aortic and the mitral valves, respectively. Implantation of a long-term total artificial heart by DeVries in 1988 was possible in no small part because of developments in the chemical industry and laid the foundation for subsequent devices now widely employed to provide mechanical support—or replacement—for one or both failing ventricles. Perioperative nurses along with their surgeon colleagues contributed to these advances by actively participating in the design of equipment, supplies, and instruments (e.g., vascular clamps that would be both atraumatic and secure in clamping vascular structures). Nurses also made significant contributions by coordinating the complex operational and staffing requirements of a cardiac service, characteristic of collaborative team efforts in delivering quality care to perioperative patients.

Adapted from Lytle BW: Who we are—who we will be, *J Thorac Cardiovasc Surg* 135(5):965-975, 2008; Stoney WS: *Pioneers of cardiac surgery,* Nashville, Tenn, 2008, Vanderbilt University Press; Westaby S: *Landmarks in cardiac surgery,* Oxford, England, 1997, Isis Medical Media.

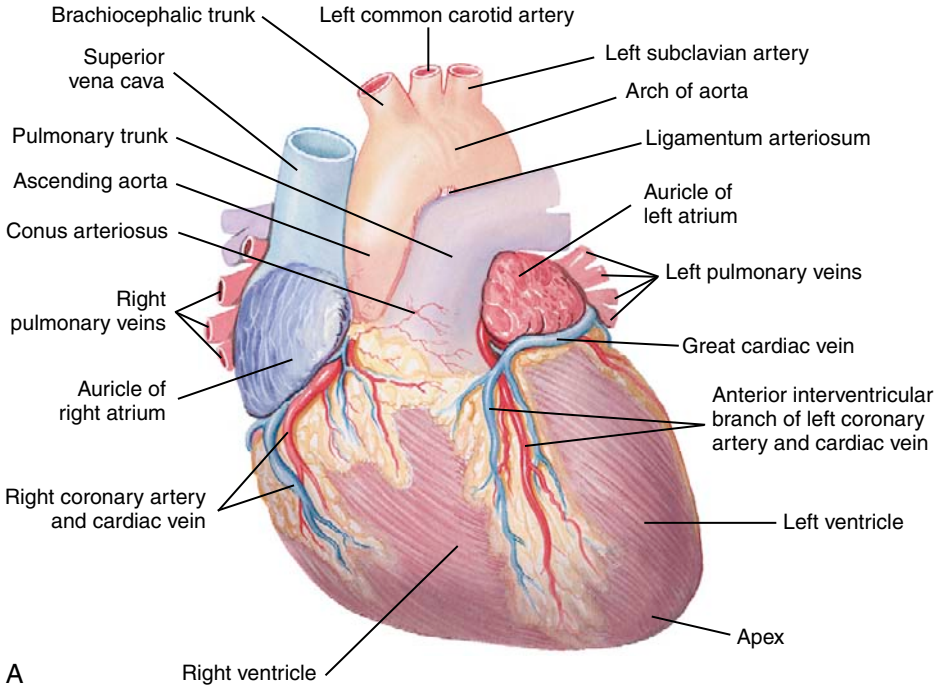


FIGURE 24-1 A, Anterior view of heart illustrates major vessels and chambers.

Continued

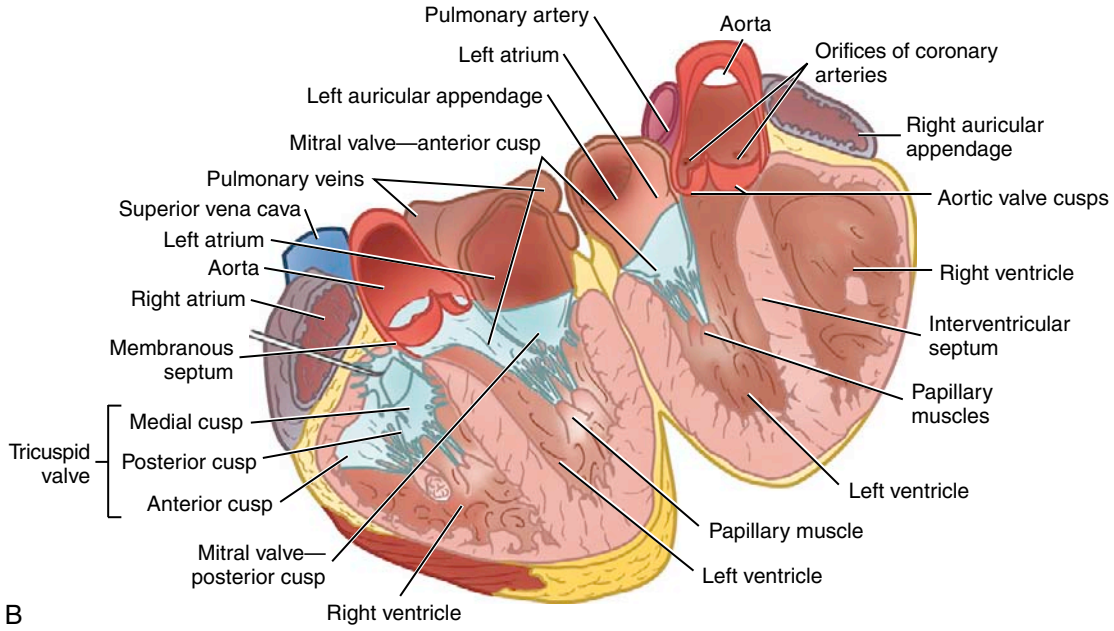


FIGURE 24-1, cont'd **B**, Drawing of a heart split perpendicular to the interventricular septum illustrates the anatomic relationships of the leaflets of the atrioventricular and aortic valve, and the receiving chambers (atria) and the pumping chambers (ventricles). Systemic venous blood returns to the heart by way of the inferior and superior venae cavae. It enters the right atrium, flows through the tricuspid valve into the right ventricle, and is ejected through the pulmonic valve (not shown) into the pulmonary circulation. The blood is oxygenated in the lungs and returns to the left atrium through the pulmonary veins. From the left atrium, it flows through the mitral valve into the left ventricle, where it is ejected through the aortic valve into the aorta and the systemic circulation.

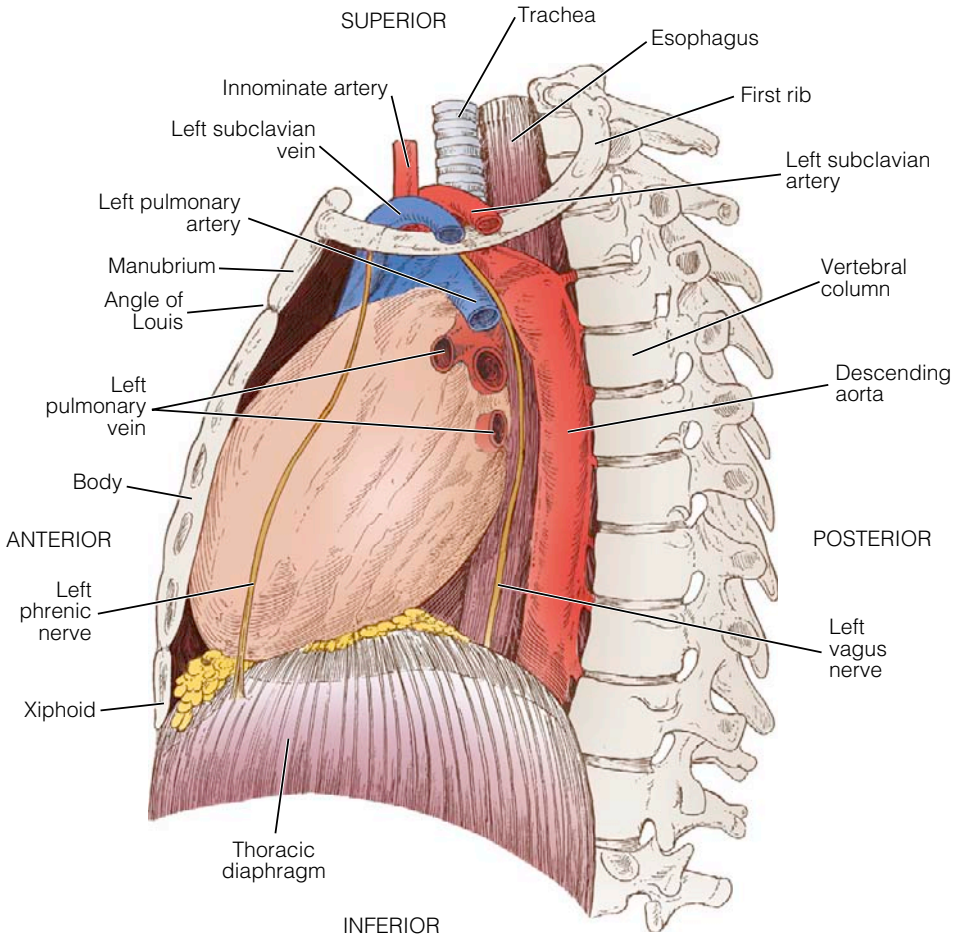


FIGURE 24-2 Regions of the mediastinum.

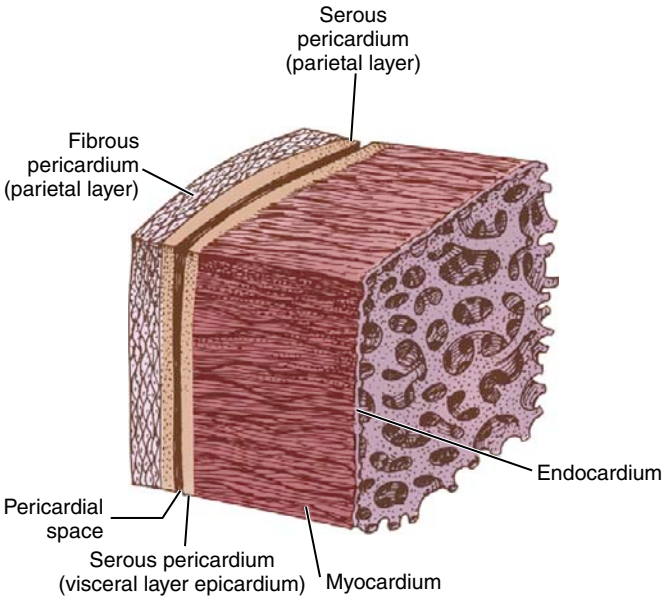


FIGURE 24-3 Cross section of cardiac muscle showing its three layers (endocardium, myocardium, epicardium) and pericardium.

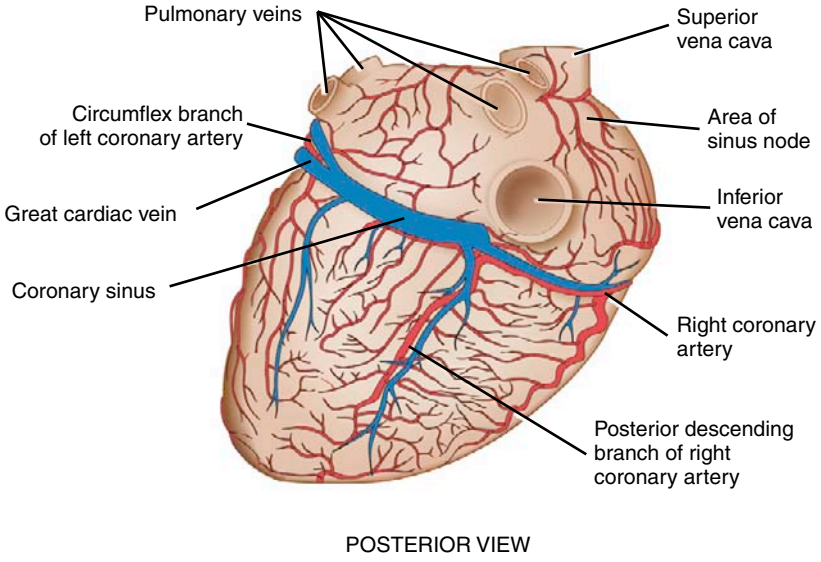


FIGURE 24-4 Anterior and posterior surfaces of the heart, illustrating the location and distribution of the principal coronary arteries and veins.

Nerve impulses to the heart travel from the medulla oblongata along the middle cervical nerve, composed of sympathetic fibers, and the vagus nerve, composed of parasympathetic fibers. Sympathetic fibers increase the force and rate of contraction, while parasympathetic fibers control heart rate. Running vertically along the right and left sides of the pericardium are major branches of the phrenic nerve, which innervate the diaphragm and stimulate it to contract. Identifying this nerve is important to protect the diaphragm in procedures in which the lateral pericardium is incised or excised. Within the myocardium itself, certain areas of tissue are modified to form a *conduction system* (Figure 24-5). The process of excitation and contraction originates in the sinoatrial (SA) node, located in the area where the superior vena cava (SVC) meets the right atrium. The impulse spreads to the atria through internodal pathways and travels to the AV junction (which contains the AV node) located medial to the entrance of the coronary sinus in the right atrium, close to the tricuspid valve. From the AV junction, the impulse spreads to the bundle of His, which extends down the right side of the interventricular septum. The bundle of His divides into the right and left bundle branches, which terminate in a network of fibers called the *Purkinje system*. Purkinje fibers are spread throughout the inner surface of both ventricles and the papillary muscles, which when stimulated produce contraction of the heart muscle. The location of conduction tissue is clinically significant during surgical repair of atrial or ventricular septal defects.

During myocardial contraction and relaxation, spiral fibers of the heart contract and relax (Figure 24-6, *A*). To prevent regurgitation of blood, the four cardiac valves (Figure 24-6, *B* and *C,* and Figure 24-7) open and close to maintain unidirectional blood flow. The AV valves are located between the atria and the ventricles. The right AV valve is called the *tricuspid valve* and contains three leaflets. The left AV valve, called the *mitral valve,* consists of two leaflets (see Figure 24-6). Each AV valve is a complex system consisting of a fibrous annulus surrounding the valve orifice, the valve leaflets (or cusps), the chordae tendineae, the atrium, and the papillary muscles, which anchor the valve to the inner ventricular wall (see Figure 24-1). The mitral valve annulus is a dynamic structure with a three-dimensional "saddle" shape, which has stimulated the design of newer prosthetic annuloplasty rings (Fedak et al, 2008). When the ventricle contracts, these muscles and the chordae tendineae, connected to the valve leaflets, prevent the leaflets from everting into the atrium. All parts of the system must function for the valve to work properly. If the shape of the ventricle has been changed by dilatation or hypertrophy, for example, the altered geometry of the ventricle impairs ventricular function. Conditions such as hypertension, myocardial injury, and aortic stenosis promote a pathologic *remodeling* of the heart that can lead not only to valvular dysfunction but also to heart failure and malignant dysrhythmias (Hill and Olson, 2008).

The semilunar valves are at the outlets of the left and right ventricles. These valves are known as the *aortic* and *pulmonic* valves, respectively. They are less complex than the AV valves, and they open and close passively with cyclic fluctuations in the blood pressure and volume that occur during systole and diastole.

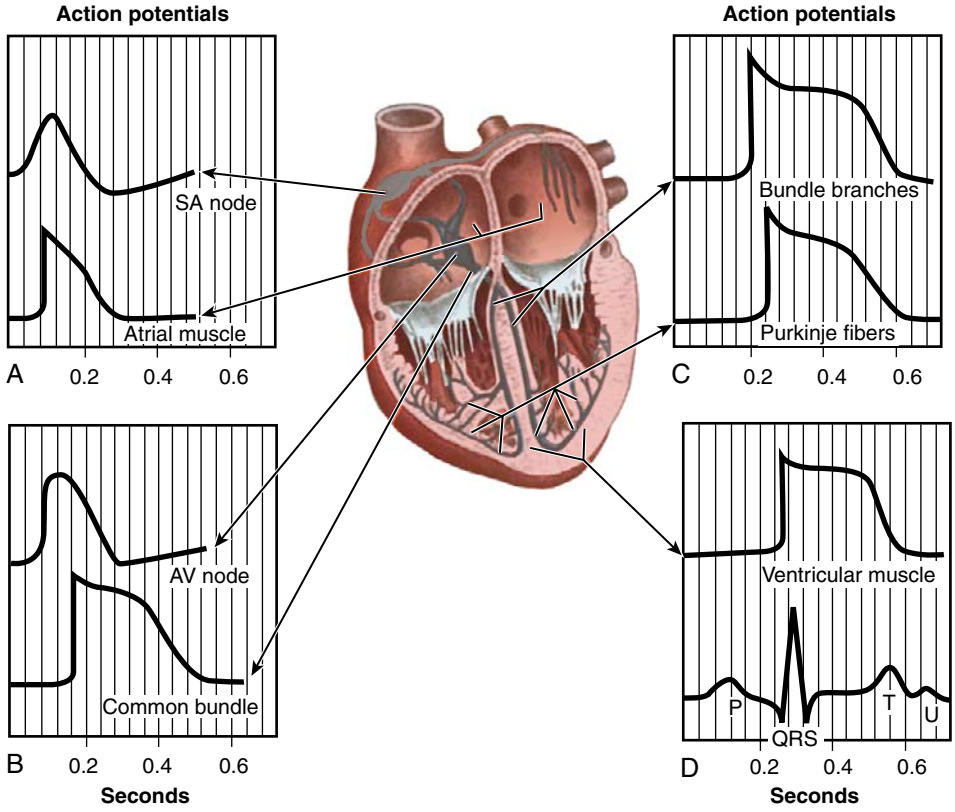


FIGURE 24-5 Heart with normal conduction pathways and transmembrane action potential of sinoatrial *(SA)* node, **A**; atrioventricular *(AV)* node (AV junction), **B**; bundle branches, **C**; and ventricular muscle, **D**.

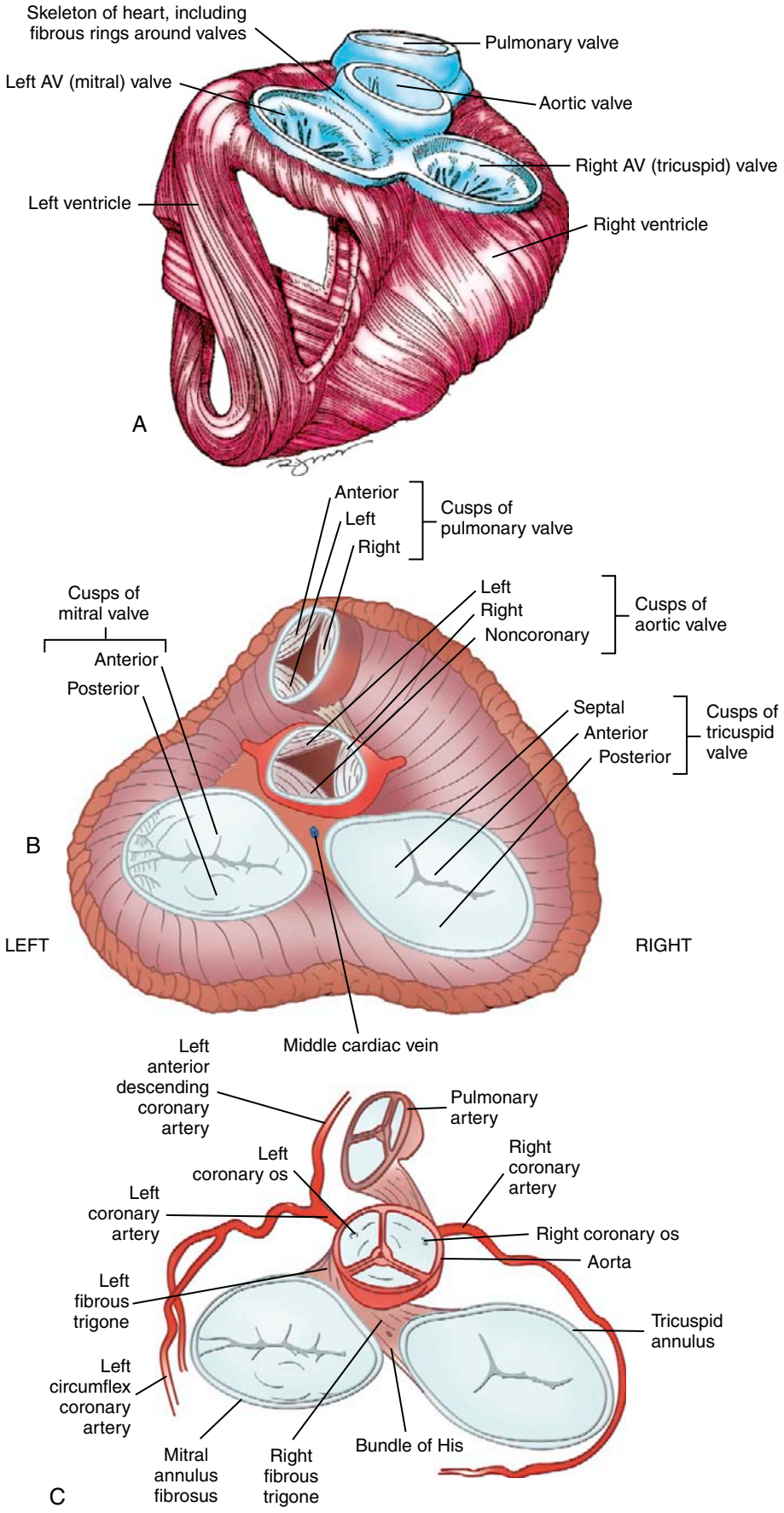


FIGURE 24-6 **A**, Location of the heart valves in relation to the spiral fibers of the myocardium. *AV,* Atrioventricular. **B**, Superior view of cardiac valves: pulmonary *(top)*; aortic *(middle)*; mitral *(bottom left)*; and tricuspid *(bottom right)*. **C**, Superior view of valves in relation to coronary arteries and conduction tissue.

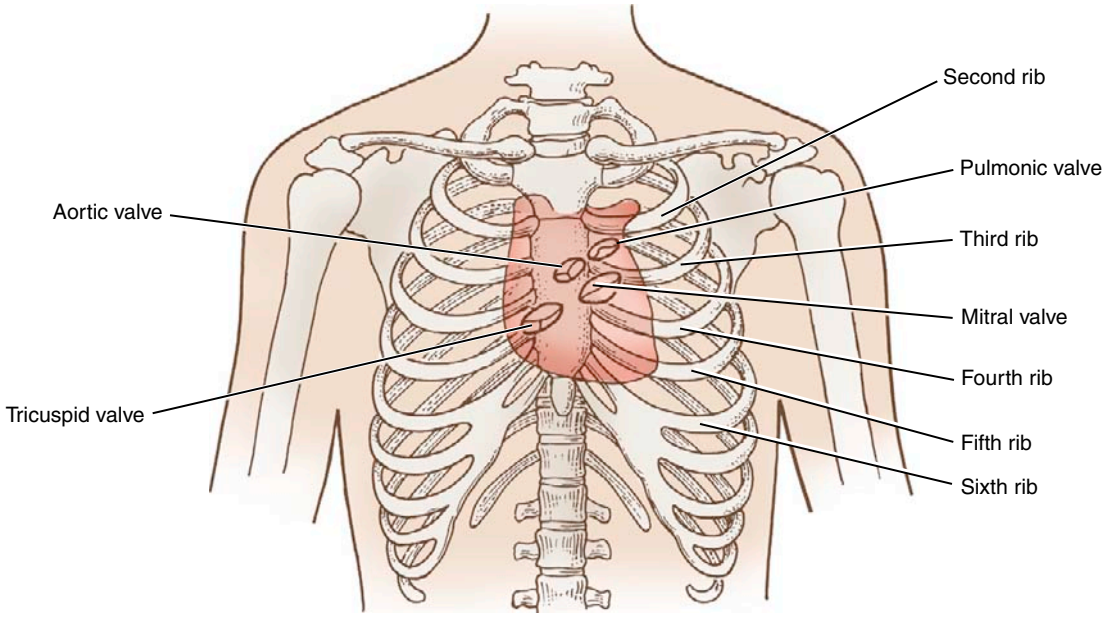


FIGURE 24-7 Anatomic position of cardiac valves. Note relationship of left ventricular apex to fourth and fifth ribs—a frequent site for minimally invasive incisions.

Abnormalities such as stenosis, insufficiency, or a combination of both impair the mechanical function of the valves. Stenosed valves have leaflets that are fibrous and stiff, with uneven and adherent margins. Regurgitant, insufficient, or incompetent valves, such as those with leaflet degeneration or perforations, dilated annuli, or ruptured chordae tendineae, produce regurgitation of blood into the originating chamber. These conditions, or a combination of stenosis and insufficiency, strain the myocardium by increasing intracardiac pressure, volume, and workload. The sound of blood flowing through a narrowed or incompetent valve produces an abnormal sound called a *murmur*.

Any of the four valves may be congenitally deformed. Acquired valvular heart disease most commonly affects the mitral and aortic valves and is believed to be exacerbated by increased stress associated with the higher pressures within the left chambers of the heart.

Perioperative Nursing Considerations

Specialized nursing considerations that are indicated for thoracic surgery (see Chapter 22) and vascular surgery (see Chapter 23) also often apply to cardiac surgical patients. Pediatric cardiac procedures are discussed in Chapter 25.

Assessment

Because the severity of pathologic changes varies among patients throughout the life span, knowledge of physical status, psychosocial concerns, and functional health patterns enables the perioperative nurse to plan and manage patient care. The perioperative nursing database should include the patient's biopsychosocial history, the physical examination, and results from laboratory and diagnostic imaging tests.

BOX 24-1

New York Heart Association's Functional Classification System (NYHA Classes) and Associated Objective Evidence*

Class I	Patients with cardiac disease do not display symptoms of syncope, undue fatigue, dyspnea, or anginal pain with ordinary physical activity; no objective evidence of cardiovascular disease (e.g., normal electrocardiogram).
Class II	Patients with cardiac disease are comfortable at rest but display the above symptoms during ordinary physical activity; objective evidence of minimal cardiovascular disease (e.g., minimal mitral valve regurgitation on echocardiography).
Class III	Patients with cardiac disease, although comfortable at rest, are considerably limited functionally and display symptoms with less-than-ordinary exercise; objective evidence of moderately severe cardiovascular disease (e.g., ischemic electrocardiographic changes).
Class IV	Patients with cardiac disease are unable to engage in any physical activity without discomfort and may have symptoms of cardiac insufficiency even at rest; objective evidence of severe cardiovascular disease (e.g., enlarged heart shadow on x-ray).

* *Objective evidence* refers to measurements such as electrocardiograms, stress tests, x-rays, echocardiograms, and radiologic images.
Modified from The Criteria Committee of the New York Heart Association: *Nomenclature and criteria for diagnosis of diseases of the heart and great vessels,* ed 9, pp 253-256, Boston, 1994, Little, Brown; *American Heart Association review of 1994 revisions to classification of functional capacity and objective assessment of patients with diseases of the heart,* available at www.americanheart.org/presenter.jhtml?identifier=1712. Accessed July 5, 2009.

History. The history includes information about the patient's health status as well as the response to the disease and the recommended intervention or interventions. Patients with cardiac disease may display symptoms including ischemic chest pain (angina pectoris), fatigue, dyspnea, and syncope. Depending on their severity, these *subjective* symptoms affect the patient's functional status and ability to engage in activities of daily living; the New York Heart Association's Functional Classification System (Box 24-1) is often used to assess functional ability. Updates to the classification system also include *objective* measurements such as x-rays and echocardiograms (The Criteria Committee of the New York Heart Association, 1994; AHA, 2009b,c). The Canadian Cardiovascular Society Classification System (Box 24-2) specifically grades the amount of activity producing angina pectoris (Campeau, 1975; Fang and O'Gara, 2008).

Atypical ischemic chest pain is more likely in women than in men, and angina may be attributed to vasospastic angina, mitral valve prolapse, or psychologic factors. CAD is unusual in premenopausal women, but after cessation of menses the risk is similar to that of men (McSweeney and Lefler, 2008; Mosca et al, 2007). Estrogen hormone replacement therapy is not recommended in postmenopausal women, according to the *Evidence-Based Guidelines for Cardiovascular Disease Prevention in Women: 2007 Update* (Mosca et al, 2007) (Evidence for Practice).

A cardiovascular disease risk factor profile (Box 24-3) is helpful in planning care for hospitalization and discharge by focusing on areas that might require further patient education. For example, the presence of diabetes is notable because diabetes affects the vascular system and may retard healing and predispose the patient to infection. Of special concern are the epidemic growth of type 2 diabetes in particular and

BOX 24-2

Canadian Cardiovascular Society Classification System for Angina Pectoris

Class 0	Patient has no angina.
Class I	Walking, climbing stairs, and other ordinary physical activity do not produce angina. Angina may occur with strenuous, prolonged, or rapid exertion.
Class II	Ordinary activity may be slightly limited. Angina may occur with moderate activity, such as walking rapidly, walking uphill, or walking after meals or in cold weather.
Class III	Ordinary activity is markedly limited. Angina may occur after walking one or two blocks on level ground or climbing one flight of stairs at a normal pace.
Class IV	Angina may be present at rest. Any physical activity produces discomfort.

Modified from Libby P et al, editors: *Braunwald's heart disease,* ed 8, Philadelphia, 2008, Saunders; Campeau L: Grading of angina pectoris, *Circulation* 54:522, 1975.

EVIDENCE FOR PRACTICE

Practice Guidelines for Females Undergoing Coronary Artery Bypass Surgery

Numerous inconsistencies surround the issue of gender-based differences between the outcomes of women and men undergoing coronary artery bypass grafts (CABGs). The Society of Thoracic Surgeons (STS) Workforce on Evidence-Based Surgery reviewed published information and proposed the following guidelines that focus specifically on *perioperative* management and are based on available evidence. Additional recommendations, not reviewed here, are incorporated in the guidelines.

1. Use of the internal mammary artery (IMA)
   - a. IMA underused in women
   - b. Use of IMA associated with significant reduction in mortality (compared with CABG using venous conduits alone)
   - c. At least one IMA used to bypass stenotic coronary artery
2. Management of hyperglycemia
   - a. Diabetes more common in women than in men undergoing CABG
   - b. Adverse effects of diabetes more pronounced in women
   - c. Hyperglycemia produced incremental risk in CABG
   - d. Maintain blood glucose levels below 180 mg/dl
3. Intraoperative management of anemia
   - a. Hematocrits below 22% associated with operative mortality
   - b. Strategies to increase red blood cell concentration: hemoconcentration, ultrafiltration, minimizing pump prime volume, rapid autologous priming
   - c. Maintain adequate hematocrit level at or greater than 22%
4. Use of off-pump CABG
   - a. Improved outcomes after off-pump CABG versus on-pump CABG may be related to increased use of IMA with off-pump CAB
   - b. No major differences in outcomes associated with *valve* surgeries
   - c. Absent of firm evidence that off-pump CABG is superior, the guidelines suggest that the indications for off-pump CABG are the same for women as for men
5. Optimization of thyroxine treatment for women with hypothyroidism
   - a. Hypothyroidism associated with impaired contractility and increased risk of myocardial infarction
   - b. Greater incidence of women with hypothyroidism (compared with men) undergoing CABG
   - c. Maintain in a euthyroid state during surgery
6. Consideration of preoperative hormone replacement therapy (HRT)
   - a. HRT not a significant predictor of mortality in multivariate analyses
   - b. HRT associated with complications such as thromboembolism
   - c. HRT not used for postmenopausal women undergoing CABG

Modified from Edwards FH et al: Gender-specific practice guidelines for coronary artery bypass surgery: perioperative management, *Ann Thorac Surg* 79:2189-2194, 2005; Puskas JD et al: Off-pump techniques benefit men and women and narrow the disparity in mortality after coronary bypass grafting, *Ann Thorac Surg* 84:1447-1456, 2007; Toumpoulis IK et al: Assessment of independent predictors for long-term mortality between women and men after coronary artery bypass grafting: are women different from men? *J Thorac Cardiovasc Surg* 131:343-351, 2006, available at http://jtcs.ctsnetjournals.org/cgi/content/full/jtcs;131/2/343. Accessed July 4, 2009.

BOX 24-3

Risk Factors for Coronary Artery Disease

NONMODIFIABLE
- Age
- Male gender (but postmenopausal women have risk similar to that of men)
- Heredity, genetic makeup, family history
- Race
- Menstrual status (estrogen levels may be modifiable; postmenopausal women have risk similar to that of men)

MODIFIABLE
- Elevated levels of serum cholesterol and other lipids
- Hypertension
- Cigarette smoking
- Obesity, metabolic syndrome
- Diabetes mellitus
- Psychologic stress
- Personality type
- Physical inactivity

NEWER, NOVEL CONTRIBUTING FACTORS
- Elevated homocysteine levels (increase platelet aggregation)
- Inflammation (the atherosclerotic process is inflammatory)
- High C-reactive protein level (CRP is a marker for inflammation associated with atherogenesis)
- Periodontal disease (a marker for inflammation and possible infection)
- Atrial and ventricular natriuretic peptides (hormones secreted by the atria and ventricles in response to volume expansion and fluid retention; predictive of a variety of cardiac problems)

Modified from Libby P et al, editors: *Braunwald's heart disease,* ed 8, Philadelphia, 2008, Saunders; Moser DK, Riegel B, editors: *Cardiac nursing: a companion to Braunwald's heart disease,* St Louis, 2008, Saunders; Hlatky MA et al: Criteria for evaluation of novel markers of cardiovascular risk: a scientific statement from the American Heart Association, *Circulation* 119:2408-2416, 2009; Seymour GJ et al: Infection or inflammation: the link between periodontal and cardiovascular diseases, *Future Cardiol* 5(1):5-9, 2009, available at www.medscape.com/viewarticle/587591. Accessed April 3, 2009; American Heart Association, 2009; Daniels LB, Maisel AS: Natriuretic peptides, *J Am Coll Cardiol* 50 (25), 2007, available at www.medscape.com/viewarticle/567064. Accessed January 17, 2008.

the role of hyperglycemia in general. Although type 2 diabetes was formerly considered an adult-onset disease, children are increasingly vulnerable because of a greater incidence of increased body weight, sedentary lifestyle, and accelerated insulin resistance in this population (Warziski et al, 2008). Altered glucose metabolism (in the absence of diagnosed diabetes mellitus) has shown a significant correlation to atherosclerosis (Lamendola, 2008), and control of hyperglycemia during coronary bypass surgery is an important strategy to reduce the risk of adverse clinical outcomes (Lorenz et al, 2005). This information should become an integral component of patient assessment, especially in patients at risk.

Inflammation has been increasingly implicated in the development of coronary artery disease; in particular, elevated homocysteine levels (which increase platelet aggregation) and high C-reactive protein (CRP) levels (CRP is a biologic marker for inflammation and is associated with increased risk for CAD) have been implicated (Ruz and Lennie, 2008; Seymour et al, 2009). Targeting low-density lipoprotein ("bad" cholesterol) levels of less than 100 mg/dl is often recommended (Grundy, 2008); some authors also stress the importance of increasing the levels of high-density lipoproteins ("good" cholesterol) (Superko and King, 2008).

Additional recognized risk factors include metabolic syndrome (central obesity, hypertension, insulin resistance, and dyslipidemia) and obesity (Lamendola, 2008). Hypertension and obesity increase the workload of the heart; obesity may also increase the risk for postoperative infection because adipose tissue is poorly vascularized. Patients who are obese and those who are underweight (compared with patients in the high-normal and overweight categories) have a higher risk of death after coronary artery bypass surgery (Jin et al, 2005).

Among the newer biomarkers denoting cardiovascular diseases are the *natriuretic peptides*—cardiac hormones synthesized and secreted by the atrium (atrial natriuretic peptide [ANP]) and the ventricle (B-type natriuretic peptide [BNP]). Discovered in 1981, the natriuretic peptides have a regulatory effect that causes myocardial relaxation in response to acute increases in ventricular volume. Measurement of circulating peptides is increasingly used to identify heart failure and sudden cardiac death (Korngold et al, 2009; Hlatky et al, 2009). Another biomarker under intensive study as a risk factor is lipoprotein(a) (Lp[a]), which has been identified from genetic studies as a causal link to myocardial infarction. According to the researchers (Kamstrupp et al, 2009), Lp(a) levels need to be tested only once in a lifetime as the levels do not change over time. Optimal therapy has not been established, but niacin has been shown to reduce the level of Lp(a) in some individuals.

The risk for complications and major adverse cardiac events (MACE) after cardiac surgery has also shown some gender differences (Puskas et al, 2007; Edwards et al, 2005). Investigations of risk factors in men and women for sternal wound infection showed that three significant risk factors were identified and occurred at significantly different rates in men and women: smoking, use of a single internal mammary artery (IMA), and age more than 70 years. Smoking and the use of a single IMA for bypass grafting were more common risk factors in men compared with women; women tended to be older than men at the time of surgery (Hussey et al, 2001). Fewer MACE were seen in women undergoing coronary bypass surgery without the use of cardiopulmonary bypass (CPB) compared to surgery with CPB (Puskas et al, 2007); however, malignant ventricular dysrhythmias (e.g., ventricular tachycardia), a calcified aorta, or preoperative renal failure were poor prognostic signs in women (Gray and Sethna, 2008). These findings can be incorporated into patient/family teaching plans with recommendations for lifestyle changes as indicated.

Other risk factors associated with postoperative infection include previous cardiac surgery, extensive length of surgery, use of cardiopulmonary bypass (CPB) and/or blood transfusion, amount of postoperative blood loss, and length of preoperative hospitalization. Female gender, obesity, and arterial occlusive disease of the legs are related to impaired wound healing at the saphenous venectomy site after coronary bypass surgery; bilateral IMA grafts in patients with diabetes, obesity, and postoperative inotropic support have also been implicated (Newby and Douglas, 2008; Pradhan et al, 2008).

A history of rheumatic fever or frequent tonsillitis as a child is significant because the sequelae of rheumatic fever and streptococcal infections can lead to damage of the cardiac

valves. Although the incidence of rheumatic fever has declined significantly in wealthy countries, rheumatic heart disease is a significant problem in less industrialized countries (Carapetis, 2007). Given the increasing number of immigrants to the United States, it is expected that treatment for rheumatic heart disease will continue to grow.

In addition to risk factors and health status, the perioperative nurse reviews the patient's medication history with particular attention to vasoactive drugs, anticoagulants, and other medications that can affect the surgery. Nurses should note that patients taking aspirin and other antiplatelet drugs (such as 2b/IIIa inhibitors) may require intraoperative replacement of platelets (Miller and Beauman, 2008). Lipid-lowering drugs (statins) may affect postoperative coronary bypass graft patency; angiotensin-converting enzyme inhibitors (ACEIs), used for patients with a history of MI or heart failure, may induce labile postoperative blood pressures (Miller and Beauman, 2008). Patients taking herbal medicines may be at risk for increased bleeding, hypoglycemia, or other complications, depending on the specific side effects of some herbal drugs (Surgical Pharmacology).

Patients' knowledge and understanding of cardiovascular disease and related risk factors and their effect on functional, physiologic, and psychologic status should also be part of the perioperative nursing assessment. The patient's personal strengths, external resources, and coping strategies should be determined. The perioperative nurse should note any cultural, ethnic, spiritual, or religious beliefs that are relevant to perioperative patient care.

Physical Examination. The physical assessment provides the perioperative nurse with baseline data and information about potential problems that might require intervention. Table 24-1 lists some normal, age-specific changes in the very young and the elderly populations that should be differentiated from pathologic conditions (Hayman, 2008; Rich, 2008; Association of periOperative Registered Nurses [AORN], 1997a,b,c,d).

In addition to age-specific changes, there are a growing number of adults with acquired heart disease who underwent surgery in childhood for repair of congenital cardiac lesions (Moons et al, 2008). For example, patients with a previous Blalock-Taussig shunt for tetralogy of Fallot (see Chapter 25) may have altered pulmonary and subclavian artery anatomy; patients with a mechanical closure device inserted for an atrial septal defect may be at risk for endocardial injury if the heart is retracted or otherwise manipulated too forcefully. The nurse should be aware that anatomic anomalies associated with the original congenital defect, or its subsequent repair, may alter the current surgical plan. Consultation with the surgeon can alert the staff to anticipate different anatomy (and surgical landmarks), special supplies and prosthetic materials, and potential complications.

Before a review of systems is initiated, it is helpful to assess the patient's functional capacity. How are activities of daily living accomplished? What are the barriers that make independent living difficult? How are activities performed when there are disabilities? What support systems are available? What educational resources are available? These and other questions will alert the clinician to the need for referrals and other resources to help the patient achieve optimal outcomes.

The review of systems often starts with the skin. The appearance of the skin offers clues to cardiovascular status. Dryness, coolness, diaphoresis, paleness, edema, poor capillary refill, bruising, and petechiae can reflect impaired cardiovascular function. Visual problems and headaches may be related to inadequate cardiac output, atherosclerotic disease, peripheral vascular disease, aortic valve stenosis, or medications such as digitalis. The presence of chronic or local infection should be identified; if untreated, these may become potential sources of postoperative infection. Nutritional status (including metabolic syndrome) is assessed to determine increased risk for infection, skin breakdown, impaired wound healing, or other complications.

The patient's level of consciousness, memory, comprehension, and emotional status should be assessed. Confusion, restlessness, slurred speech, numbness, and paralysis can signal impaired perfusion. Their presence preoperatively should be

SURGICAL PHARMACOLOGY

Perioperative Effects of Herbal Medicines

Agent	Pharmacologic Action	Concerns and Considerations
Echinacea (purple coneflower root)	Activates cell-mediated immunity.	Decreases effectiveness of immunosuppressants; should not be taken by organ transplant patients.
Ephedra	Increases heart rate and blood pressure through sympathomimetic effects.	Increases risk of stroke and myocardial ischemia; may cause intraoperative hemodynamic instability.
Garlic	Inhibits platelet aggregation; increases fibrinolysis.	Increases risk of bleeding, especially in combination with other platelet inhibitors.
Ginger	Inhibits platelet aggregation; antiemetic.	Increases risk of postoperative bleeding.
Gingko	Inhibits platelet activation.	Increases risk of bleeding, especially in combination with other platelet inhibitors.
Ginseng	Inhibits platelet activation; lowers blood glucose level; has many diverse effects.	Increases risk of bleeding; has potential to decrease anticoagulant effect of warfarin; may cause hypoglycemia.
St. John's wort	Inhibits neurotransmitter reuptake.	Induces enzymes that affect warfarin and many other drugs; may affect calcium channel blockers and decrease serum digoxin levels.

Modified from Drain CB: Basic principles of pharmacology. In Drain CB, Odom-Forren J, editors: *Perianesthesia nursing,* ed 5, St Louis, 2009, Saunders; Association of periOperative Registered Nurses (AORN): *Safe medication administration tool kit,* Denver, 2005, The Association, available at www.aorn.org.

TABLE 24-1

Physiologic Features of the Very Young and the Very Old (Compared with Others)

Very Young	Very Old
CARDIOVASCULAR SYSTEM	
Myocardium	
Less contractile tissue	Increased subendocardial fat
Less compliant	Increased heart weight
Cardiac output increased by faster heart rate	Reduced resting cardiac output
Valves	
Less tension created by papillary muscle	Fibrous thickening; calcification of leaflets and annulus
Coronary Arteries	
Rarely, anomalies of coronary arteries	Coronary arteriosclerosis, atherosclerosis; tortuous epicardial arteries
CONDUCTION SYSTEM	
Impulse conduction faster	Impulse conduction slower
BLOOD VOLUME	
Total circulating small amount; volume per kilogram of body weight relatively greater	Reduced plasma volume; reduced blood water content
RESPIRATORY SYSTEM	
Inadequate cough reflex	Decreased ability to eliminate secretions
Increased chest wall compliance; decreased pulmonary compliance	Increased chest wall rigidity; decreased lung compliance
Higher oxygen consumption	Reduced vital capacity and maximum ventilation volume
Short, narrow airway obstructed easily	
RENAL SYSTEM	
Glomeruli small and immature	Fewer functional glomeruli
Tubular concentration of fluids and electrolytes diminished	Reduced renal blood flow and glomerular filtration rate
Inability to excrete increased electrolytes and hydrogen ions (acids)	Impaired ability to excrete increased amount of water and electrolytes; reduced ability to secrete hydrogen ions
OTHER	
Temperature Control	
Immature regulating system: rapid heat loss	Decreased control
Metabolic Rate	
Higher	Lower
Stress Response	
Decreased phagocytic capability of leukocytes	Limited capability to retain homeostasis
Immature immunoglobulin synthesis	Decreased adrenal activity
Physical Appearance	
Good grooming suggests attentive care	Good grooming suggests positive mental status, ability to perform activities of daily living

Modified from Association of periOperative Registered Nurses: *The geriatric patient: AORN's age-specific competencies series,* Denver, 1997, The Association; Association of periOperative Registered Nurses: *The neonate, infant, and toddler patient: AORN's age-specific competencies series,* Denver, 1997, The Association; Association of periOperative Registered Nurses: *The premature infant patient: AORN's age-specific competencies series,* Denver, 1997, The Association; Association of periOperative Registered Nurses: *The preschool, school-age, and adolescent patient: AORN's age-specific competencies series,* Denver, 1997, The Association.

noted by the perioperative nurse and communicated to the nurses receiving the patient postoperatively.

During respiratory assessment the perioperative nurse should note the use of accessory muscles or nostril flaring and should auscultate breath sounds. Adventitious sounds, such as crackles and wheezes, may point to pulmonary edema. Orthopnea, shortness of breath, or dyspnea may require elevation of the head of the stretcher and assistance during transfer onto the OR bed. If the patient is receiving oxygen, the flow rate and method of administration should be observed. Alleviating pain is a prime consideration in the care of the cardiovascular patient because pain is a myocardial stressor. A patient with angina may arrive in the OR after nitroglycerin tablets have been administered or transdermal patches have been applied. Cold also increases the workload of the heart because the shivering that accompanies chilling elevates the metabolic rate; the patient should be kept warm.

Heart sounds, murmurs, and friction rubs provide clues to congenital, ischemic, valvular heart disease, or pericarditis. The patient may experience palpitations. Apical, radial, and femoral pulses also reflect cardiac function; their rate, rhythm, and quality should be determined. The presence of cyanosis or peripheral edema should be noted.

The blood pressure may be high, normal, or low. The hypertensive patient may have left ventricular hypertrophy, and the hypotensive patient may display changes in neurologic, gastrointestinal, and renal function. Blood pressures should be checked bilaterally. Unequal pressures in the arms may be a

BOX 24-4

Diagnostic Tests Commonly Performed for Cardiovascular Disorders

NONINVASIVE*
- Resting ECG
- Exercise ECG (stress test)
- Chest radiography
- Echocardiogram (TTE, TEE)
- Carotid Doppler echocardiogram
- Resting MUGA
- Exercise thallium
- Exercise MUGA
- CT scan
- PET scan with stress
- CMRI, MRA

INVASIVE
- Aortography
- Arteriography
- Digital subtraction angiography
- Electrophysiology
- Cardiac catheterization
- Ventriculography
- Endomyocardial biopsy

*When dye is injected into the vascular system, the test is considered semiinvasive.
CT, Computerized tomography; *CMRI,* cardiovascular magnetic resonance imaging; *ECG,* electrocardiogram; *MRA,* magnetic resonance angiogram; *MUGA,* multiple uptake gated acquisition; *PET,* positron emission tomography; *TEE,* transesophageal echocardiogram; *TTE,* transthoracic echocardiogram.
Modified from Libby P et al, editors: *Braunwald's heart disease,* ed 8, Philadelphia, 2008, Saunders; Pagana KD, Pagana TJ: *Mosby's diagnostic and laboratory test reference,* ed 9, St Louis, 2009, Mosby.

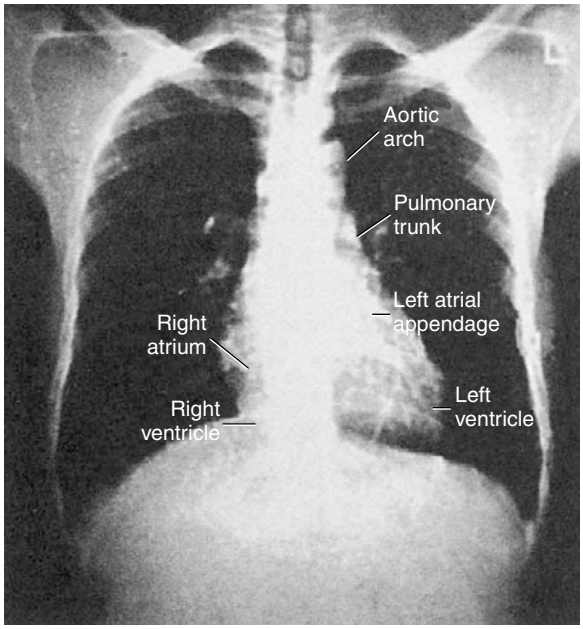


FIGURE 24-8 Anteroposterior chest radiograph (normal).

contraindication for the use of the IMA as a bypass graft on the side of the lower blood pressure, where perfusion may not be optimal. Radial and ulnar artery pulses should be checked bilaterally when the radial artery is to be used as a bypass graft. Patients with dissections or aneurysms may have unequal carotid, femoral, brachial, or radial artery blood pressures when the lesion occludes one or more of these vascular branches.

Because cardiac function affects all the body's organ systems, assessment of the patient should be comprehensive whenever possible. A thorough assessment also alerts the physician and perioperative nurse to the need for special diagnostic tests and laboratory procedures.

Diagnostic Studies. Most patients referred for surgery have had clinical evaluations including both invasive and noninvasive studies (Box 24-4). After the history and physical assessment, a resting electrocardiogram (ECG) is ordered. An exercise ECG (stress test) is often performed because ST-segment changes indicating myocardial ischemia may be apparent only during or after exercise. In patients with intractable dysrhythmias, electrophysiology (EP) studies may be performed to locate the site of irritable atrial or ventricular foci that can be surgically ablated, excised, or controlled with pharmacologic therapy. EP studies are also performed to determine the need for internal defibrillators or antitachycardia devices. Bradycardia may be an indication for pacemaker insertion.

Chest radiography provides information about the size of the cardiac chambers, thoracic aorta, and pulmonary vasculature as well as the presence of calcium in valves, pericardium, coronary arteries, and aorta (Figure 24-8). Lateral chest radiographs of patients with prior sternal operations show the chest wires and extent of pericardial adhesions. Magnetic resonance imaging (MRI) is used to assess myocardial viability and can also be employed to image vascular structures with MRI angiograms that provide great clarity (Figure 24-9, *A*). In patients with suspected aortic or other vascular abnormalities, a computerized tomography (CT) scan of the chest with intravenous injection of a contrast medium is used to create x-ray serial "slices" of the body area under study (Figure 24-9, *B*), and CT angiography is especially useful for imaging the aorta and great vessels. CT scans may be contraindicated in very unstable patients because the patient's position in the tubelike scanner makes patient access difficult. Less frequently performed is arteriography with radiographic contrast material (dye) to determine the size and location of the lesion and the site of the intimal tear in aortic dissections (Figure 24-10); digital subtraction angiography (DSA) provides clear images and requires less contrast material (Libby et al, 2008).

Echocardiography is a noninvasive test that evaluates both the structure and the function of the heart by transmitting sound waves to the heart and measuring those sound waves reflected back to the transducer (Figure 24-11). The sound waves are processed by the transducer, which creates visual images of the structure's movements. This test is commonly used to assess ventricular and valvular function before, during, and after surgery and to determine the degree of valvular stenosis or regurgitation. It can also demonstrate a tumor, thrombus, or air in the ventricular or atrial cavities. Two-dimensional and color-flow Doppler techniques have greatly enhanced the functional assessment of valvular performance and carotid artery stenoses. Echocardiography is the gold standard for diagnosing mitral stenosis, and it is widely used to assess other valvular

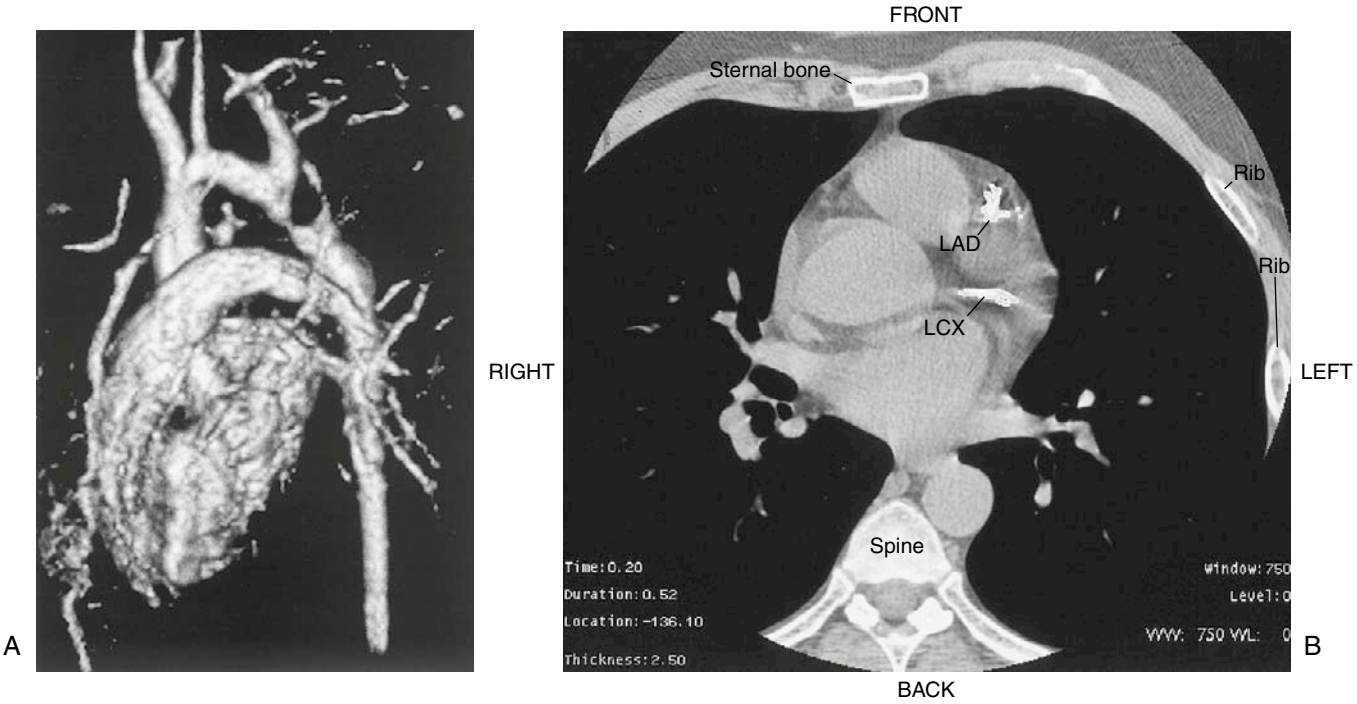


FIGURE 24-9 **A**, Three-dimensional reconstruction of a contrast medium–enhanced magnetic resonance angiogram of the thoracic aorta, illustrating a severe coarctation (narrowing) of the aorta. **B**, High-resolution cross-sectional computed tomography (CT) scan of the heart, illustrating calcification within the left anterior descending *(LAD)* coronary artery and left circumflex *(LCX)* coronary artery.

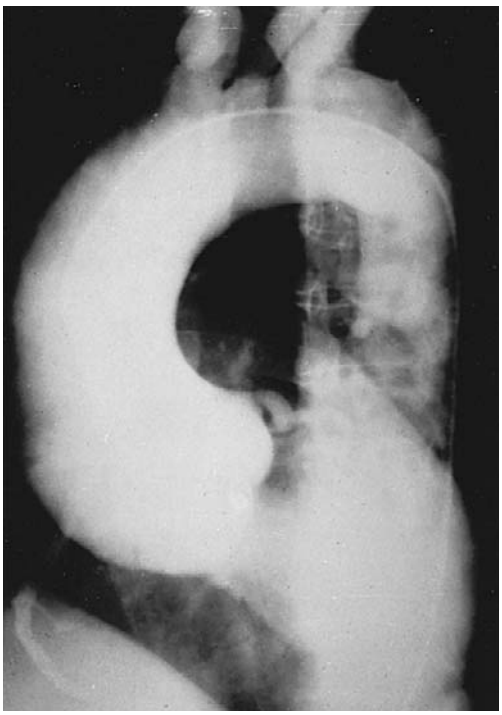


FIGURE 24-10 Aortogram of ascending aortic dissection, with aortic valve insufficiency. Note regurgitation of dye into left ventricle.

disorders and congenital heart disease. Transesophageal echocardiography (TEE) is also employed to evaluate the effectiveness of valve repairs and other surgical procedures.

Radionuclide imaging is employed to illustrate wall motion and blood flow through the heart and to quantify cardiac function. These noninvasive techniques are generally well tolerated by patients, especially when patients may be too unstable to withstand a cardiac catheterization. These techniques may also be used as a complement to catheterization.

Cardiac catheterization provides definitive information about the extent and location of ischemic heart disease and is an adjunct to echocardiography for diagnosing valvular heart disease (Todd and Phippen, 2009). A radiopaque plastic catheter is inserted retrograde through the aortic valve into the left side of the heart by a percutaneous puncture or a cutdown to the vessels of the brachial artery (Sones technique) or the femoral artery (Judkins technique). The right side of the heart is approached percutaneously by the superior or inferior vena caval route. To perform coronary angiography that demonstrates intracoronary anatomy, a contrast medium is injected into the coronary ostia. Obstructions (Figure 24-12), flow, and distal perfusion can be assessed. Ventriculography illustrates contractile weaknesses of the ventricles as well as shunting and regurgitation of blood. These studies are used to assess the degree of myocardial dysfunction and to plan interventions such as coronary artery bypass grafting, valve repair or replacement, repair of congenital anomalies, and cardiac transplantation. The cardiologist can compute the orifice of a stenosed valve or determine the degree of regurgitation of an incompetent valve.

Ventricular, atrial, and pulmonary pressures are recorded, and cardiac output and ejection fraction are estimated (Box 24-5

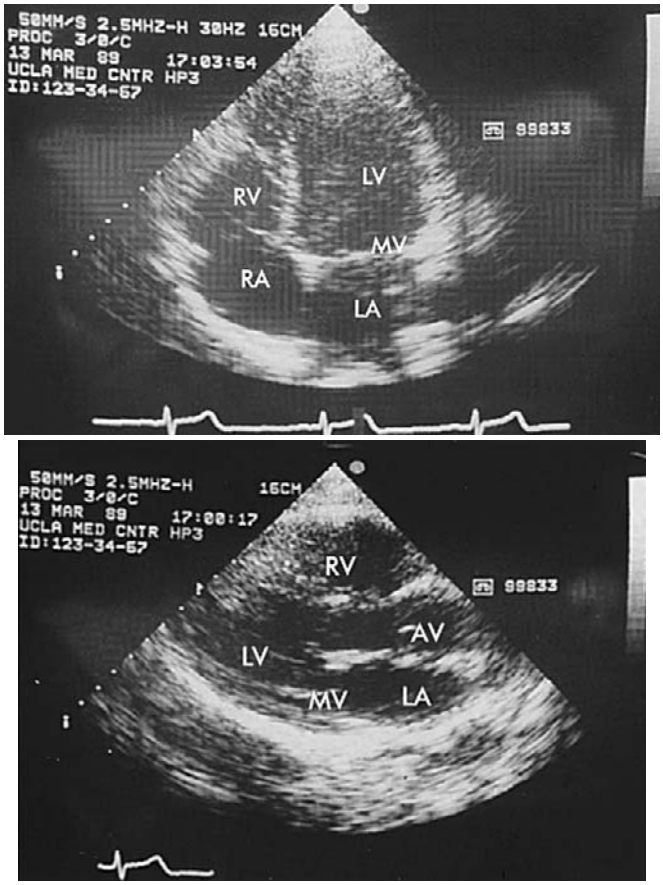


FIGURE 24-11 Two-dimensional echocardiography showing two views of the cardiac chambers. *LA,* Left atrium; *LV,* left ventricle; *MV,* mitral valve; *RA,* right atrium; *RV,* right ventricle.

and Table 24-2). Oxygen saturation of cardiac chambers and the ratio of pulmonary to systemic blood flow (Q_p/Q_s) are calculated for patients with shunts and congenital or acquired defects. Cinearteriograms record the movement of the heart, and cut films or digitized versions of the cines may be displayed during surgery.

The cardiac catheterization laboratory also performs percutaneous coronary interventional (PCI) therapies for evolving and acute myocardial infarctions (Leeson et al, 2008). Coronary thrombolysis with fibrinolytic drugs can dissolve fresh blood clots and reopen, or recanalize, the artery; antiplatelet agents such as aspirin, dipyridamole, and clopidogrel are often prescribed to block platelet aggregation that can lead to restenosis. Percutaneous transluminal coronary angioplasty (PTCA) followed by insertion of intracoronary (bare metal or drug-eluting) stents is often performed to dilate and maintain the patency of the recanalized artery. Laser angioplasty and atherectomy to excise intraluminal plaque may also be employed (Todd and Phippen, 2009). In many instances these interventions may obviate the need for surgical bypass grafting, although the progressive nature of CAD may eventually lead to patients requiring surgical revascularization. OR availability may be recommended for unstable patients undergoing stent insertion and atherectomy, but the need for on-site cardiac surgical availability has been questioned. One study demonstrated that patients undergoing PCI at facilities without surgical backup had rates of morbidity, emergency cardiac surgery, and mortality related to emergency surgery that were similar to those in facilities with surgical backup (Kutcher et al, 2009).

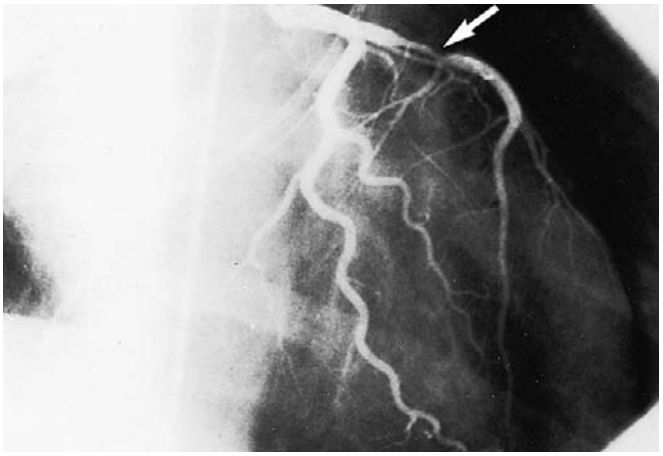


FIGURE 24-12 Right anterior oblique (RAO) view of left coronary artery injection demonstrating high-grade stenosis of the left anterior descending coronary artery *(arrow)* at the lead of the first septal perforator.

BOX 24-5

Hemodynamic Concepts

Cardiac output	Amount of blood (in liters) ejected by left ventricle per minute; product of heart rate times stroke volume.
Cardiac index	Cardiac output corrected for differences in body size.
Preload	Volume and pressure of blood in the ventricle at the end of diastole. Central venous pressure (CVP) measures right-sided heart preload; pulmonary artery wedge pressure (PAWP) indirectly measures left-sided heart preload.
Afterload	Impedance, or resistance, the heart must overcome to pump blood into the systemic circulation; left ventricular wall tension during systole; systemic vascular resistance.
Contractility	Inotropic state of the heart; ability of the ventricle to pump.
Ejection fraction	Percentage of end-diastolic volume ejected into systemic circulation; indicator of ventricular function.

EP studies are performed to diagnose conduction disturbances and to provide therapeutic interventions, such as radiofrequency or cryologic ablation of foci producing atrial fibrillation or accessory pathways seen in Wolff-Parkinson-White syndrome. Insertion of a pacemaker for bradydysrhythmias or an internal cardioverter defibrillator for ventricular tachydysrhythmias is commonly performed in EP laboratories. However, insertion of these devices may require an OR when percutaneous access is unfeasible or when concomitant cardiac surgery is being performed.

Laboratory Tests. Preoperative laboratory tests are used to assess physiologic function (Table 24-3). Hematologic tests include a detailed coagulation profile to uncover hemorrhagic

TABLE 24-2

Cardiac Catheterization Data

Hemodynamic Data	Normal Values		
FLOW			
Cardiac output (CO)	3.0-6.0 L/min		
Cardiac index (CI)	2.8-4.2 L/min/m^2		
Ejection fraction (EF)	60%-70%		
Left ventricular end-diastolic volume (LVEDV)	90-180 ml		
Stroke volume (SV)	60-130 ml/beat		
Stroke volume index (SVI)	35-70 ml/beat/m^2		
	Systolic	**Diastolic**	**Mean**
RESISTANCES (WOOD UNITS)			
Systemic vascular resistance (SVR)	<20		
Total pulmonary resistance	<3.5		
Pulmonary vascular resistance (PVR)	<2.0		
SHUNTS (Q_P/Q_S)			
Pulmonary flow/systemic flow		1:1	
% OXYGEN SATURATION			
Venae cavae		70	
Right atrium		70	
Right ventricle		70	
Pulmonary artery		70	
Pulmonary veins		97	
Left atrium		97	
Left ventricle		97	
Aorta		97	
VALVE ORIFICES (ADULT) (cm^2)			
Aortic	2-4		
Mitral	4-6		
Tricuspid	10		
PRESSURES (mm Hg)			
Venae cavae			0-5
Right atrium (RA)			2-6
Right ventricle (RV)	20-30	0-5	
Pulmonary artery (PA)	15-28	5-16	10-15
Pulmonary artery wedge pressure (PAWP)			4-12
Left atrium (LA)			4-12
Left ventricle (LV)	90-140	0-5	
Left ventricular end-diastolic pressure (LVEDP)			4-12
Aorta	120-140	60-80	70-90
Brachial artery	90-140	60-90	
Femoral artery	125	75	

	Findings
ANGIOGRAPHIC DATA	
Coronary arteries	Anatomy/function of coronary vascular bed; distal coronary flow; arteriovenous (AV) fistula; atherosclerosis; anomalous origin of coronary arteries
Ventriculography	Anatomy/function of ventricles and associated structures; LV aneurysm; congenital abnormalities; valvular stenosis/regurgitation; shunts
Valvular angiography	Intact mitral/tricuspid complex; valvular incompetence/stenosis/regurgitation
Pulmonary angiography	Pulmonary embolism; congenital abnormalities
Aortography	Patency of aortic branches; normal mobility, competence, and anatomy of aortic valve; aneurysms: saccular, fusiform; origin of aortic dissection; shunts or anomalous connections; congenital defect or obstructions

Modified from Pagana KD, Pagana TJ: *Mosby's diagnostic and laboratory test reference,* ed 9, St Louis, 2009, Mosby; Libby P et al, editors: *Braunwald's heart disease,* ed 8, Philadelphia, 2008, Saunders; Leeson A et al: *Cardiac catheterization and coronary intervention (Oxford Specialist Handbooks),* New York, 2008, Oxford University Press.

TABLE 24-3

Laboratory Data

Test	Conventional Values
ARTERIAL BLOOD GASES	
pH	7.35-7.45
Po_2	95-100 mm Hg
Pco_2	35-45 mm Hg
BLOOD CHEMISTRY	
Glucose (fasting)	70-110 mg/dl
Protein (total)	6.8-8.5 g/dl
Blood urea nitrogen (BUN)	8.0-25 mg/dl
Uric acid	3.0-7.0 mg/dl
CARDIAC ENZYMES	
Creatine phosphokinase (total CPK)	Male: 55-170 units/L; female: 30-135 units/L
CPK-BB (isoenzyme, CPK_1)	0%
CPK-MB (isoenzyme, CPK_2)	0%
CPK-MM (isoenzyme, CPK_3)	100%
Troponin T	<0.2 mcg/L
Troponin I	<0.03 mcg/L
COAGULATION PROFILE	
Platelet count	150,000-400,000/mm^3
Prothrombin time (PT)	Depends on thromboplastin reagent used; typically 9.5-12.0 sec
Thrombin time	Depends on concentration of thrombin reagent used; typically 20-29 sec
Partial thromboplastin time (PTT)	Depends on phospholipid reagent used; typically 60-70 sec
Activated PTT (aPTT)	Depends on activator and phospholipid reagents used; typically 30-40 sec
Fibrinogen	200-400 mg/dl
Fibrinogen split products	10 mg/dl
COMPLETE BLOOD CELL COUNT	
Hemoglobin (Hgb)	
1-3 days old	14-24 g/dl
2 mo old	10-17 g/dl
6-18 yr old	10-15.5 g/dl
Adult	
Male	14-18 g/dl
Female	12-16 g/dl
Hematocrit (Hct)	
2 days old	44%-64%
2 mo old	35%-50%
Adult	
Male	42%-52%
Female	37%-47%
Red Blood Cells (RBCs)	
1 wk old	4.8-7.1 × $10^6/\mu l$
3-6 mo old	3.5-5.5 × $10^6/\mu l$
2-6 yr old	4.0-5.5 × $10^6/\mu l$
Adult	
Male	4.7-6.1 × $10^6/\mu l$
Female	4.2-5.4 × $10^6/\mu l$
White Blood Cells (WBCs)	
1 day old	9000-30,000/mm^3
1 mo old	6200-17,000/mm^3
Adult	5000-10,000/mm^3
CREATININE (URINE, 24-HOUR)	
Male	107-139 ml/min
Female	87-107 ml/min
ELECTROLYTES	
Potassium (K^+)	3.5-5.0 mEq/L
Sodium (Na^+)	136-145 mEq/L
Chloride (Cl^-)	98-106 mEq/L
Magnesium (Mg^{++})	1.3-2.1 mEq/L
LIPIDS	
Cholesterol	<100 mg/dl*
Triglycerides	10-190 mg/dl
Phospholipids	150-380 mg/dl
Free fatty acids	9.0-15.0 mM/L
C-reactive protein	<1.0 mg/dl
Homocysteine	4-14 μmol/L
LIVER FUNCTION	
Albumin (serum)	3.5-5 g/dl
Alkaline phosphatase	30-120 units/L
Globulin (serum)	2.3-3.4 g/dl
Serum bilirubin (total)	0.3-1.0 mg/dl
PULMONARY FUNCTION	
	Normal values vary depending on patient's age, gender, weight, and race. The following are generally calculated: Residual volume (RV) Tidal volume (TV) Expiratory reserve volume (ERV) Inspiratory reserve volume (IRV) Total lung capacity (TLC) Vital capacity (VC)
URINALYSIS	
Color	Amber, yellow
Clarity	Clear
pH	4.6-8
Specific gravity (SG)	1.005-1.030
Protein	0.0-8 mg/dl
Sugar, ketones, RBCs, WBCs, casts	Negative

*Current recommendations are to target cholesterol levels below 100 mg/dl. See LaRosa JC et al: Intensive lipid lowering with atorvastatin in patients with stable coronary artery disease, *New Engl J Med* 352:1425-1435, 2005.

Modified from Pagana KD, Pagana TJ: *Mosby's diagnostic and laboratory test reference,* ed 9, St Louis, 2009, Mosby.

disorders. In patients who have been taking aspirin or dipyridamole, platelet activity is decreased; this alerts the perioperative nurse to anticipate prolonged bleeding necessitating replacement of this blood product. The patient's blood type is also determined, and the appropriate order is placed with the blood bank. Precautions are taken to test the blood for viral contamination and for cold antibodies that could produce agglutination of the patient's blood during surgery when the patient is cooled to hypothermic temperatures. Blood is brought to the OR suite before the start of surgery and stored in a monitored blood refrigerator. Although the use of bank blood products has been reduced with autotransfusion techniques, the occasional, emergent need for blood necessitates the immediate availability of bank blood packed red blood cells.

Liver and kidney function test results may be abnormal in patients with chronic heart failure, possibly because of congestion related to right heart failure in the former and reduced blood flow in the latter. Progressive improvement in hepatic and renal function is anticipated with successful operative intervention. The use of statins and other cholesterol-reducing drugs that can adversely impair hepatic function also alerts the nurse to review liver function laboratory results (Pagana and Pagana, 2009). Blood glucose levels are tested, monitored, and controlled, especially in patients with impaired glucose metabolism and both type 1 and type 2 diabetes mellitus.

Additional perioperative laboratory examinations may include arterial blood gases and enzyme biomarkers of myocardial damage (e.g., troponin I and troponin T; creatine kinase MB isoenzyme, known as *MB bands*), especially in the presence of persistent angina (Moser and Riegel, 2008). Pulmonary function tests may be performed to determine baseline data and to plan postoperative care. Postoperative respiratory function may be impaired as a result of the use of extracorporeal circulation and the associated inflammatory response, and stasis of lung secretions that accompany prolonged surgery.

Ongoing genetic studies have created a burgeoning body of knowledge about genetic mutations associated with risk factors such as C-reactive protein and possible pathways linking inflammatory processes with CAD (Elliott et al, 2009). It is likely that genetic information will become a common component of the history and review of systems performed during patient assessment.

Nursing Diagnosis

After a comprehensive review of individual patient data, the perioperative nurse identifies relevant nursing diagnoses, from which the perioperative plan for patient care is derived (see the Sample Plan of Care on pp. 1019-1020).

Nursing diagnoses related to the care of patients undergoing cardiac surgery might include the following (AORN, 2008; Petersen, 2007; Seifert, 2008, 2009; Seifert and Collins, 2009):

- Decreased Cardiac Output related to emotional (fear), sensory (pain), or physiologic (electrical, mechanical, or structural) factors
- Risk for Infection related to surgical incision(s), catheters and intravascular lines, and altered cardiac function
- Risk for Perioperative Positioning Injury
- Risk for Bleeding related to surgical incision(s), tissue dissection, altered coagulation function, and inadvertent hypothermia
- Deficient Knowledge related to the physiologic effects of the cardiac disorder, proposed surgical procedures, and immediate perioperative events
- Risk for Impaired Tissue Integrity (myocardial, peripheral, renal, and cerebral) related to surgery, hypothermia, CPB, or surgical particulate or air emboli

Outcome Identification

Outcomes identified for the selected nursing diagnoses could be stated as follows:

- The patient's cardiac function will be consistent with or improved from baseline levels established preoperatively as evidenced by hemodynamic indicators (blood pressure, oxygenation, ECG) within expected range; warm, dry skin; and urine output more than 30 ml/hr.
- The patient will be free from signs and symptoms of infection at the surgical or other incisional sites as evidenced by absence of redness, edema, purulent incisional drainage, or untoward postoperative temperature elevation.
- The patient will be free from signs and symptoms of injury related to surgical position as evidenced by the absence of acquired neuromuscular impairment and tissue necrosis.
- The patient will be free from excessive bleeding as evidenced by chest tube drainage less than 100 ml/hr, dressings dry and intact, normal coagulation function studies (or undergoing replacement treatment for deficient clotting factors), and normal body temperature.
- The patient will demonstrate knowledge of the physiologic responses to the cardiac disorder (at his or her level of understanding), the proposed surgical treatment, and the immediate perioperative events as evidenced by verbalization of disease state, purpose of surgery, sequence of events, anticipated outcomes, and recovery process.
- The patient's myocardial, peripheral, renal, and cerebral tissue integrity will be adequate or improved as evidenced by absence of new electrocardiograph manifestations of infarction, the presence of palpable peripheral pulses, adequate urine output, and a clear or improving sensorium postoperatively.

Additional nursing diagnoses, based on individual patient assessment, should have a corresponding outcome statement. The outcome should be measurable, with criteria by which to evaluate its achievement. For example, for the outcome "The patient's cardiac function will be consistent with or improved from baseline levels established preoperatively as evidenced by blood pressure within expected range; warm, dry skin; and urine output more than 30 to 50 ml per hour," the perioperative nurse might identify criteria such as vital signs and hemodynamic status consistent with or better than preoperative parameters; fluid and electrolyte balance consistent with preoperative levels; adequate urine output; normal temperature and pink mucosa; absence of rate, rhythm, or conduction disturbances; absence of iatrogenic injury to the heart; and normal levels of clotting parameters. Each of these criteria becomes evidence that the outcome was achieved. When outcomes are evaluated, they should be documented in the perioperative record. Some outcomes will have been achieved at the conclusion of the surgical procedure; others require ongoing evaluation in the postoperative period to be adequately measured. The Evaluation section indicates the requirement for ongoing goal measurement by the use of the word "will" rather than stating the outcome as "having been" achieved.

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS

Decreased Cardiac Output related to emotional (fear), sensory (pain), or physiologic (electrical, mechanical, or structural) factors

OUTCOME

The patient's cardiac function will be consistent with or improved from baseline levels established preoperatively as evidenced by hemodynamic indicators (blood pressure, oxygenation, ECG) within expected range; warm, dry skin; and urine output more than 30 ml/hr.

INTERVENTIONS

- Identify baseline cardiac status.
- Use monitoring equipment to assess cardiac status.
- Identify and report the presence of implantable cardiac devices.
- Institute anxiety-reduction measures; address fear-producing concerns; clarify misconceptions, and answer questions.
- Measure pain level with pain scale; provide comfort measures and pharmacologic interventions as ordered; confirm and document degree of pain relief, measures used, and any medications administered.
- Check results of clotting function, coagulation profile, and electrolyte values; report abnormalities.
- Monitor blood pressures (arterial, central venous pressure [CVP], pulmonary artery wedge pressure [PAWP]) and ECG.
- Maintain adequate supply of and assist with administration of replacement blood or blood products.
- Follow institutional protocol for allergic blood reaction; document same according to institutional protocol.
- Have inotropic and antidysrhythmic medications available; assist with administration; document same according to institutional protocol.
- Monitor, report, and record urine output and chest tube drainage; keep tubes and catheters patent.
- Have available defibrillator (with appropriate internal and external paddles and settings), fibrillator, external pacemaker, temporary epicardial pacemaker leads, and appropriate ECG cables for cardioversion and intra-aortic balloon pump.
- Evaluate postoperative cardiac status.

NURSING DIAGNOSIS

Risk for Infection related to surgical incision(s), catheters and intravascular lines, and altered cardiac function

OUTCOME

The patient will be free from signs and symptoms of infection at the surgical or other incisional sites as evidenced by absence of redness, edema, purulent incisional drainage, or untoward postoperative temperature elevation.

INTERVENTIONS

- Administer prescribed prophylactic treatments.
- Verify that prescribed preoperative prophylactic antibiotic has been administered within 1 hour of the surgical incision; document same according to institutional protocol.
- Assess individual patient risk factors for infection.
- Encourage/reinforce previous teaching regarding deep-breathing and coughing exercises.
- Classify surgical wound; document same according to institutional protocol.
- Implement and maintain aseptic technique.
- Initiate and maintain traffic control.
- Minimize length of invasive procedure by prioritizing, organizing, and planning care.
- Completely drape central line insertion sites.
- Dress all invasive arterial and venous lines.
- Perform skin preparation, using care to prevent pooling of solution; implement fire safety precautions during prepping. Prepare anatomic area to knees (or lower if leg vein needed) with antimicrobial antiseptic agent; document same according to institutional protocol.
- Use depilatories or electric clippers to remove hair at the surgical site; avoid shaving with razors.
- Monitor aseptic technique; correct breaks; accurately reclassify surgical wound on perioperative nursing record if a break in technique occurs.
- Have available prescribed topical antibiotics; document their administration according to institutional protocol.
- Manage culture specimen collection as indicated; use safe specimen management practices. Document specimens collected according to institutional protocol.
- Protect from cross-contamination.
- If the OR bed is raised, lowered, or turned from side to side, take measures to maintain sterility of field.
- Confine and contain instruments used in groin or leg; change gown and gloves when moving from lower extremities to chest.
- Protect sterility of closed urinary drainage system.
- Maintain continuous surveillance.
- Provide/apply surgical dressings to wound and invasive device sites.
- Maintain sterility of instrument setup until patient is discharged from the OR.
- Document implants according to institutional protocol.
- During patient rewarming, avoid excessive heat loss: cover exposed areas, irrigate with warm solutions, and increase room temperature.
- Use forced warm air systems before and after period of induced hypothermia.
- Monitor for signs and symptoms of infection.

NURSING DIAGNOSIS

Risk for Perioperative Positioning Injury

OUTCOME

The patient will be free from signs and symptoms of injury related to surgical position as evidenced by the absence of acquired neuromuscular impairment and tissue necrosis.

INTERVENTIONS

- Obtain and prepare appropriate positioning accessories; verify that these are clean and in working order.
- Identify any physical alterations that require additional precautions for procedure-specific positioning.
- Verify presence of prosthetics or corrective devices; document same according to institutional protocol.
- Position the patient, maintaining proper body alignment.
- Pad and protect vulnerable neurovascular bundles and dependent pressure areas.
- Prevent pooling of skin preparation agents at bedlines.
- Pad thermia blanket.
- Keep all OR bed surfaces dry and wrinkle-free.
- Ensure patency and security of peripheral and central lines, catheters, and ESU dispersive pad on positional changes.
- Have adequate personnel to assist with patient transfer to and from the OR bed and positional changes; lift (do not pull) patient during all positioning maneuvers.
- Safely secure patient to OR bed; ensure that safety straps are not too tightly placed yet maintain patient stability.

Continued

SAMPLE PLAN OF CARE—cont'd

INTERVENTIONS—cont'd

- Confirm correct position during time-out.
- Evaluate for signs and symptoms of injury as a result of positioning.

NURSING DIAGNOSIS

Risk for Bleeding related to surgical incision(s), tissue dissection, altered coagulation function, and inadvertent hypothermia

OUTCOME

The patient will be free from excessive bleeding as evidenced by chest tube drainage less than 100 ml/hr, dressings dry and intact, normal coagulation function studies (or undergoing replacement treatment for deficient clotting factors), and normal body temperature.

INTERVENTIONS

- Review results of clotting function and coagulation profile; report abnormalities.
- Check patient history for use of anticoagulant medication and other drugs affecting bleeding time and clotting function.
- Measure and report blood loss (e.g., suction, sponges).
- Use autotransfusion system per protocol.
- Have topical hemostatic agents available.
- Monitor, report, and record chest tube drainage; keep tubes patent.
- Before postoperative transfer, alert surgeon to chest tube drainage in excess of 100 ml/hr.
- Maintain adequate supply and assist with administration of replacement blood, blood products, clotting factors.
- Follow institutional protocol for allergic blood reaction.
- Adjust room temperature as needed; room temperature should be warm (20° to 24° C) or (68° to 75° F) before and after completion of cardiopulmonary bypass.
- Apply dressings to all incision sites (chest incision, conduit excision sites, and central line insertion sites).
- Monitor for development of inadvertent hypothermia.
- Evaluate for signs and symptoms of excessive bleeding.

NURSING DIAGNOSIS

Deficient Knowledge related to the physiologic effects of the cardiac disorder, proposed surgical procedures, and immediate perioperative events

OUTCOME

The patient will demonstrate knowledge of the physiologic responses to the cardiac disorder (at his or her level of understanding), the proposed surgical treatment, and the immediate postoperative events as evidenced by verbalization of disease state, purpose of surgery, sequence of events, anticipated outcomes, and recovery process.

INTERVENTIONS

- Explain or describe the following events; solicit feedback from patient:
  - Purpose and expectations of surgery
  - Disease state producing need for surgery
  - Sequence of events during perioperative period
  - Recovery and rehabilitation process
  - Nothing-by-mouth (NPO) status
  - Administration and effects of preoperative medication
  - Transport to OR
  - Preoperative unit
  - Insertion of peripheral, arterial, and venous lines
  - OR environment (temperature, room furniture and equipment, sounds of monitors and other machines, staff functions, induction of anesthesia)
  - Skin preparation
  - Anticipated length of surgery
  - Minimally invasive versus standard cardiac procedures
  - Surgical ICU and patient status (e.g., unable to talk while intubated and plans for alternative methods of communication)
- Assess knowledge regarding wound care and phases of wound healing.
- Provide information about wound care and anticipated phases of wound healing.
- Determine patient's desire for additional knowledge (respect denial).
- Answer questions; clarify misperceptions.
- Know where family or significant others will be waiting during surgery; provide communication per institutional protocol.
- Evaluate response to information about wound care and phases of wound healing.

NURSING DIAGNOSIS

Risk for Impaired Tissue Integrity (myocardial, peripheral, renal, and cerebral) related to surgery, hypothermia, CPB, or surgical particulate or air emboli

OUTCOME

The patient's myocardial, peripheral, renal, and cerebral tissue integrity will be adequate or improved as evidenced by absence of new electrocardiograph manifestations of infarction, the presence of palpable peripheral pulses, adequate urine output, and a clear or improving sensorium postoperatively.

INTERVENTIONS

- Identify baseline tissue perfusion.
- Assess factors related to risks for ineffective tissue perfusion.
- Place padded thermia blanket on OR bed.
- Preoperatively, provide warm blankets as required.
- Expose only those body areas required for surgical intervention.
- Use forced warm air systems during period requiring normothermia (keep patient warm before and after arrest; warm throughout for "warm heart" surgery).
- Monitor patient's temperature (esophageal, pulmonary, rectal, bladder, or ventricular septal).
- Adjust room temperature as needed.
- Inspect cardiopulmonary bypass lines for patency and presence of particulate matter; alert surgeon as indicated.
- Use solutions of appropriate temperature when irrigating the heart (cold during hypothermia arrest; warm before and after arrest); warm throughout for "warm heart" surgery.
- Avoid large ice particles on heart.
- Evaluate postoperative tissue perfusion.
- Evaluate progress of wound healing as applicable.

The nursing interventions in the Sample Plan of Care incorporate data elements from the Association of periOperative Registered Nurses' (AORN's) Perioperative Nursing Data Set (PNDS) (Petersen, 2007). With increasing emphasis on correlating patient outcomes with clinical interventions, the PNDS is a valuable resource for demonstrating the nurse's ability to influence positive patient outcomes.

Planning

Once the diagnoses and outcomes have been established, a plan of care (see Sample Plan of Care) is devised that will enable the perioperative nurse to achieve the goals that have been set. Patient and family needs, elicited from interviews when possible, should be integrated into the planning. The

perioperative nurse should identify criteria specific to the patient for each of the stated outcomes in the Sample Plan of Care.

Implementation

Some considerations, in addition to those previously mentioned, can be useful in implementing the perioperative plan of care for patients undergoing cardiac surgery.

Safety Considerations. The safety of the perioperative patient is a primary responsibility of the nurse. Equipment should be functioning properly and undergo routine testing by the biomedical engineering department. Supplies should be used according to manufacturers' instructions, and instruments should be regularly scrutinized to ensure that there are no burrs that could injure tissue, that the jaws of vascular and other clamps align properly, and that small items are accounted for at the end of surgery. Toxic material, such as the glutaraldehyde storage solution of bioprosthetic valves, should be thoroughly rinsed before implantation. Monitoring the aseptic practices of team members as well as visitors is an important safety consideration.

Staff safety is also important. Protective personal equipment should be consistently and properly worn. Gloves should be used by personnel whenever contact can occur with blood or other body fluids. The effects of electrical, chemical, and other potentially hazardous materials within the OR can be minimized by reinforcing safe practices to decrease the risks of injury.

Special Facilities. The OR must be large enough to accommodate bulky, highly specialized equipment while maintaining aseptic technique. Multiple electrical outlets, auxiliary lighting, and additional suction outlets should be available. Ceiling-mounted, mobile booms for housing electrosurgical units (ESUs), headlight sources, suction, medical gases, electrical outlets, and other items can reduce floor clutter and enhance the safety of the environment for patients and staff.

A growing number of hybrid suites have been designed that combine the traditional surgical controlled environment and the fluoroscopic imaging capabilities of interventional cardiologic laboratories. A typical hybrid procedure may consist of a surgical coronary anastomosis under direct vision or with a robot that is combined with percutaneously inserted coronary artery stents under fluoroscopy (Jansens et al, 2009).

Instrumentation and Equipment. The basic setup described for thoracic procedures (see Chapter 22) is used, along with some specialized cardiovascular instruments and equipment.

Vascular clamps, which are designed to occlude blood flow partially or completely, must be maintained in good condition if they are to prevent fracture of the delicate tunica intima of the blood vessels and still retain their specific holding qualities. There are many variations in construction of vascular instruments. The jaws may consist of single or double rows of fine, sharp, or blunt teeth or special crosshatching or longitudinal serrations. The working angles of the clamps also vary. All clamps are designed to hold the vessels securely and without trauma (Figure 24-13).

Minimally invasive procedures require special instrumentation to access the heart by way of smaller incisions in the anterior and/or lateral aspects of the chest wall (Figure 24-14). Retractors, dissecting instruments, suturing devices, coronary artery stabilizers, and vascular clamps are available.

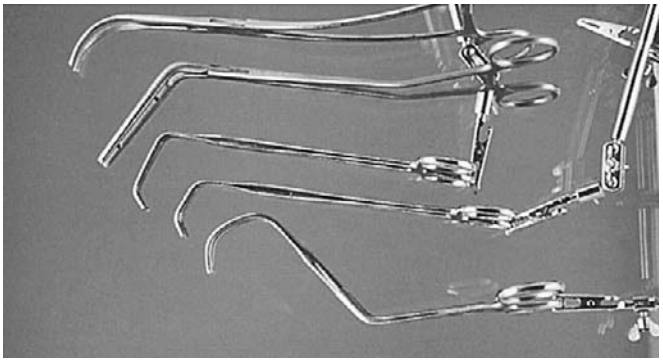


FIGURE 24-13 Cardiovascular clamps *(top to bottom):* Semb suture passer, Fogarty cross-clamp (angled), Beck partial occlusion clamps (medium and small), Lambert-Kay partial occlusion clamp.

Sternal and rib retractors are available to meet specific needs. IMA retractors expose the retrosternal artery bed by elevating the sternal border (Figure 24-15). Some sternal retractors have attachments that provide improved exposure of the left atrium during mitral valve replacement (MVR) (Figure 24-16). Exposure of the left or right atrium or the aortic root may also be accomplished with handheld retractors. Special rib spreaders provide exposure for mini-thoracotomy procedures. Coronary artery stabilizer systems with left ventricular apical suction retractors (Figure 24-17) are widely employed for beating heart coronary bypass surgery.

Other equipment commonly used (or available) for cardiac surgery may include the following:

- Sternal saw and motor
- Irrigation fluid cooling/warming machine
- Autotransfusion/cell saver system
- Electrical fibrillator
- Direct current (DC) defibrillator with internal paddles (Figure 24-18) and adhesive external pads
- Thermia unit (mattress or forced-air warming)
- External and internal pulse pacemaker generator (single and dual chamber)
- Pump oxygenator/CPB machine
- Epicardial pacemaker leads (temporary and permanent)
- Fiberoptic headlight and light source
- Intra-aortic balloon pump (IABP)
- Mechanical ventricular assist devices (VADs)
- Cryoablation energy ablation source (for atrial fibrillation surgery)
- Radiofrequency energy ablation source (for atrial fibrillation surgery)
- Ultrasonic cutting/coagulation device (Harmonic scalpel)
- TEE probe and monitor
- Minimally invasive, video-assisted vein-harvesting system
- Thoracoscopic equipment
- Video equipment

Lasers (for transmyocardial laser revascularization) and robots (for valve repair; retraction during port-access, video-assisted procedures) increasingly are also part of the equipment found in a cardiac OR.

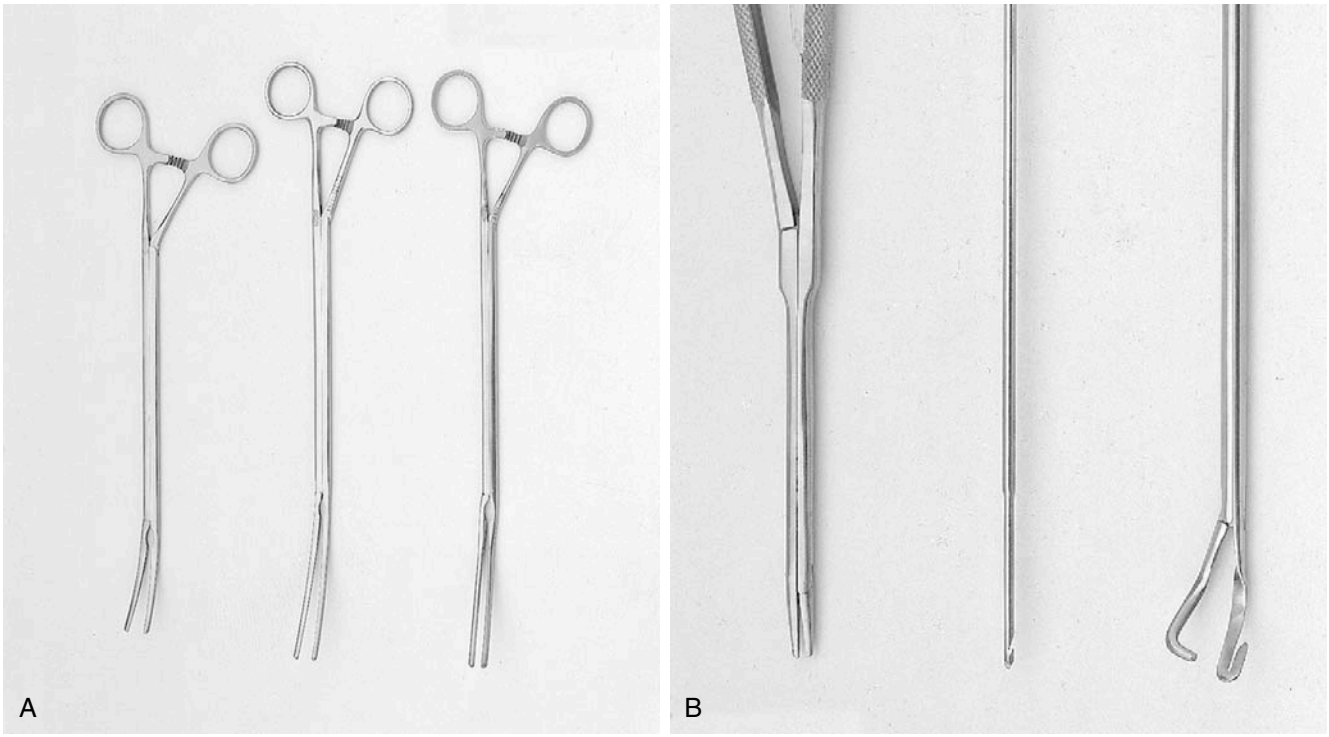


FIGURE 24-14 **A**, Transthoracic DeBakey vascular clamps are designed to pass through the chest wall by way of smaller incisions for minimally invasive procedures. **B**, Close-up views of minimally invasive needle holder, trocar/suture puller, and knot slider.

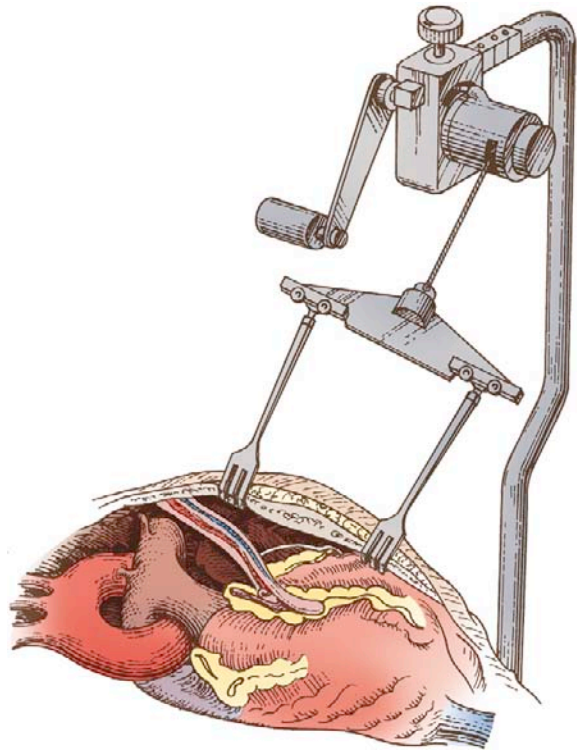


FIGURE 24-15 Retractor used to elevate sternal border for exposure of the internal mammary artery.

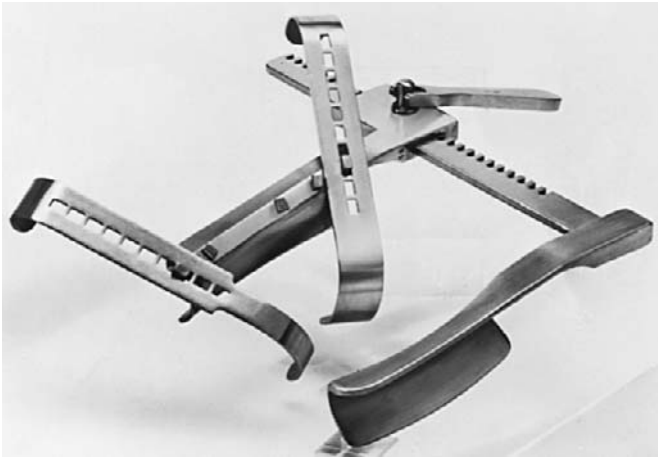


FIGURE 24-16 Sternal self-retaining retractor with attachments for left atrial retraction during mitral valve replacement.

Suture Materials. A variety of nonabsorbable cardiovascular sutures with atraumatic needles are available from most suture manufacturers. Synthetic sutures of Teflon, Dacron, polyester, or polypropylene are usually selected for insertion of prostheses and for vascular anastomoses. Most sutures are double armed with a needle on each end. Because of the number of stitches required for prosthetic valve repair and replacement, alternately colored suture and slotted, numbered suture holders may be helpful to avoid confusion. Polytetrafluoroethylene (PTFE) sutures can be used for replacement of mitral valve chordae. Vessel loops and umbilical tapes are commonly used

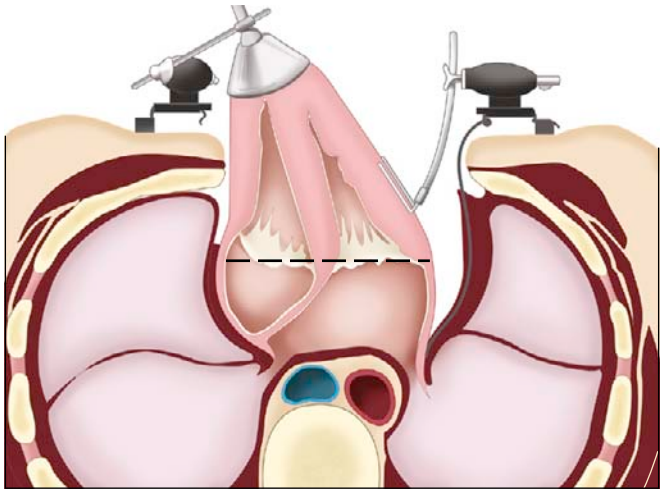


FIGURE 24-17 Cross-section of chest showing *(top left)* left ventricular apical suction cup to expose lateral and posterior coronary arteries for bypass grafting during off-pump surgery. The platform stabilizer *(top right)* isolates and immobilizes the section of the coronary artery to be anastomosed.

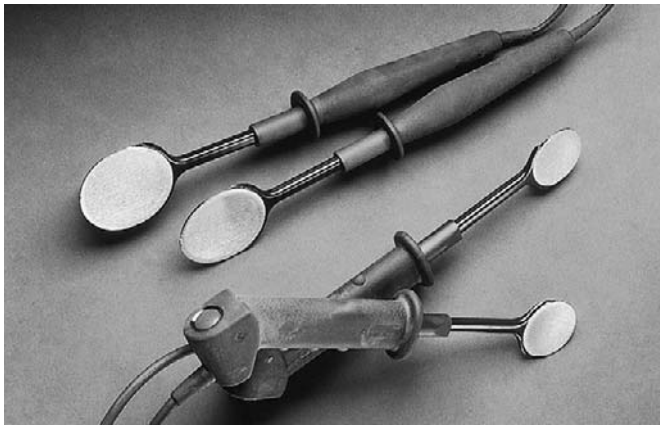


FIGURE 24-18 Internal defibrillator paddles are available in an array of sizes and designs: the paddles may be activated through the handles or by pressing the button on the defibrillator. Smaller internal paddles are used for infants and children.

to identify and to retract blood vessels and other structures. Wire (monofilament or twisted cable) commonly is used to approximate the sternum (Figure 24-19), with plastic, metal, or nylon bands occasionally added to reinforce fragile bone. Skin staplers may be used to close skin incisions; a staple remover must accompany the patient to the postanesthesia area if staples have been used to close the chest.

Supplies

The following supplies are generally used in most cardiac procedures. Depending on the surgeon's preference, other items may be added or substituted.

- Rubber shods (placed on the tips of hemostats to protect suture clamped by the hemostat)
- Pill sponges (gauze dissectors)
- Various-sized Silastic or polyvinyl chloride tubing
- Tourniquet catheters

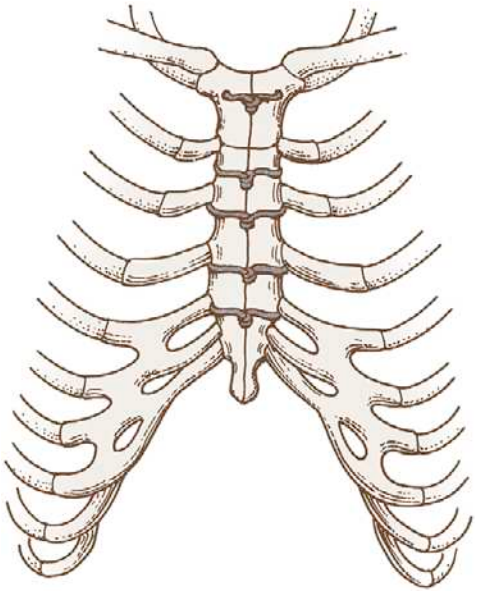


FIGURE 24-19 Technique for wire closure of the sternum. A variety of closing mechanisms have become available. These may consist of monofilament wire (shown), twisted wire cables, or (in some instances) plates and screws. In selected patients in whom disruption may be anticipated, such as elderly, obese, or malnourished patients, two or more heavy bands of nylon may be passed around the sternum and secured by a twisted stainless-steel wire in addition to the wire sutures. A figure-of-eight technique may also be employed.

- Disposable drapes
- Foot-control and hand-control ESU pencils, ultrasonic scalpel
- Adapters, connectors, stopcocks
- Extra syringes and needles for injections, infusions, and blood samples
- Sterile marking pen to identify anastomotic sites and mark grafts
- Irrigation cannulae
- Disposable vascular (bulldog) clamps
- Coronary occluders and stabilizers
- Autotransfusion supplies
- Chest tubes, chest drainage system
- Topical hemostatic agents
- Femoral arterial blood pressure supplies (hypodermic needle, guidewire, stopcocks, pressure tubing)
- Intra-aortic balloon pump (IABP) insertion supplies (hypodermic needle, guidewire, vascular dilators, stopcocks, pressure tubing, IABP catheter)
- CPB and myocardial protection cannulae, tubing, connectors, stopcocks

Prosthetic Material. In addition to these general supplies, special supplies are needed for repair or replacement of cardiovascular structures. Intracardiac patches, heart valves, and synthetic grafts should be handled with care to prevent damage or the introduction of foreign materials. Teflon, a fluorocarbon fiber, and Dacron, a polyester fiber, are available in a variety of meshes, fabrics, felts, tapes, and sutures and are also combined with other materials in prosthetic heart valves (Figure 24-20).

FIGURE 24-20 Assorted prosthetic materials to repair intracardiac and extracardiac defects: tapes, Teflon and Dacron patches, and pledgets.

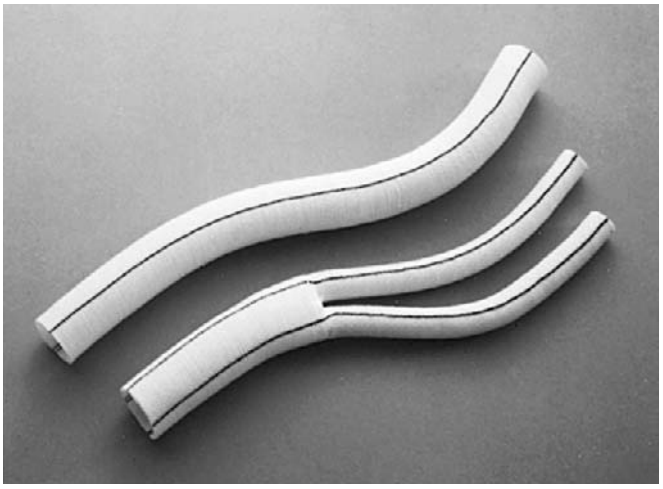


FIGURE 24-21 Straight and bifurcated arterial tube grafts.

FIGURE 24-22 Thoracic aortic endovascular stented prosthesis made from expanded polytetrafluoroethylene (PTFE). The compressed device is inserted percutaneously through the femoral artery by way of a delivery catheter and guided to the desired position in the thoracic aorta under fluoroscopy. When the correct position has been confirmed, the device expands automatically after it is deployed from the delivery catheter. The delivery catheter is then withdrawn, and hemostasis of the femoral incision site achieved.

Teflon patches are made in a variety of forms for intracardiac and outflow tract use. Varying degrees of firmness, thickness, and porosity are available for specific uses. Low reactivity, strength retention, and tissue acceptance are important properties to be considered in the selection of such patches.

Dacron arterial tube grafts are commonly used in cardiac surgery, although reinforced expanded PTFE grafts are also available. There are two types of Dacron grafts: knitted and woven. Woven prosthetic grafts are usually employed when the patient has been fully heparinized because the interstices of woven grafts are tighter than those in knitted grafts and bleeding is usually reduced. Compared to woven grafts, the advantages of knitted grafts are that they do not fray as readily, they are easier to handle, and they reendothelialize more quickly. Grafts are available in a variety of sizes and may be straight or bifurcated (Figure 24-21). Knitted and woven grafts impregnated with collagen to reduce interstitial bleeding are useful in the thoracic aorta and do not have to be preclotted, even when the patient is fully heparinized for cardiopulmonary bypass. Graft sizers are available for determining the correct size.

Specially designed tube grafts for the aortic arch incorporate prosthetic branches for the head vessels (bracheocephalic, left common carotid, and subclavian arteries); and tube grafts for replacement of the aortic root and ascending aorta are available with preformed sinuses of Valsalva incorporated into the prosthesis (Cameron et al, 2009).

Endovascular, expandable stented tube grafts are available for both the abdominal aorta and the descending portion of the thoracic aorta (Figure 24-22). The endovascular graft is inserted percutaneously into the femoral artery and advanced to the desired position in the abdominal or descending thoracic aorta, where the prosthesis is opened, implanted, and secured (Tinkham, 2009; Thompson and Bertling, 2009).

Valve Prostheses. Valve prostheses are selected according to their hemodynamics, thromboresistance, durability, ease of insertion, anatomic suitability, and patient acceptability; cost, patient outcome, and value are also important considerations (Rahimtoola, 2003, 2004). Most mechanical prostheses employ a tilting disk design. The ball-and-cage prosthesis was the first implanted mechanical valve (Starr and Edwards, 1961) but currently is implanted infrequently. Prosthetic valves allow complete closure with slight regurgitation to prevent stasis of blood (Figures 24-23 to 24-26).

Bioprostheses are derived from porcine, bovine, or equine tissue (Figures 24-27 to 24-29). Porcine valves consist of an aortic valve from a pig that can be sutured to a Dacron-covered

FIGURE 24-23 St. Jude Medical bileaflet tilting disk valve prosthesis.

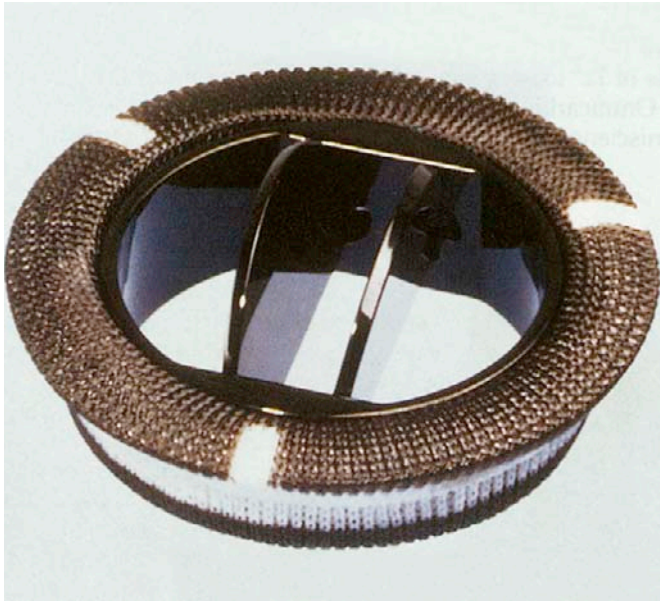
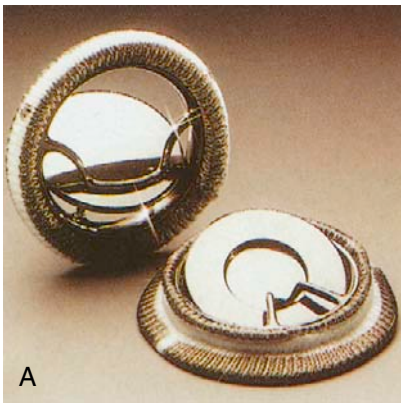


FIGURE 24-24 CarboMedics supraannular aortic prosthesis designed for the small aortic root.

FIGURE 24-25 Starr-Edwards ball-and-cage aortic valve prosthesis.



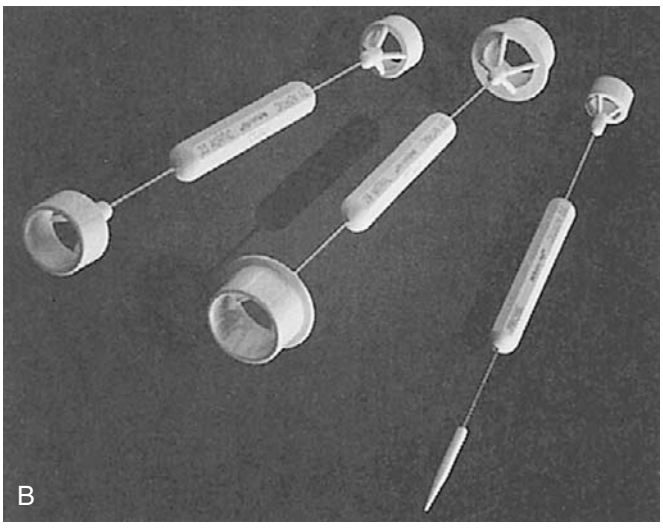


FIGURE 24-26 **A**, Medtronic-Hall tilting disk valve prosthesis. **B**, Double-ended sizing obturators for the Medtronic-Hall prosthesis *(left and center)* and probe *(right)* to test leaflet movement. All valve prostheses have sizing obturators specific to the prosthesis itself.

stent (Figure 24-27, *A*), or the porcine aortic valve may be "stentless" (without a sewing ring) to enhance the hemodynamics, especially in patients with a small aortic root (i.e., orifice less than 21 mm) (see Figure 24-27, *B*) (Pepper et al, 2009). The bovine (calf) (see Figure 24-28) pericardial bioprosthesis is created by cutting leaflet-shaped pieces from the pericardium and sewing them onto a Dacron ring; the equine (horse) (see Figure 24-29, *A*) pericardial prosthesis is created by cutting pieces of the pericardium, shaping the pieces into a tube, and attaching the prosthesis to a ring of Dacron material. The advantage of these biologic valves is that administration of long-term anticoagulants is not necessary in most patients. Obturators for sizing prosthetic valves as well as valve holders are specific to the prostheses (see Figures 24-26, *B*, and 24-29, *B*). Tables 24-4 and 24-5 compare mechanical and biologic prosthetic heart valves. Tissue-engineered heart valves may offer a future potential cure for valvular heart disease (Hjortnaes et al, 2009).

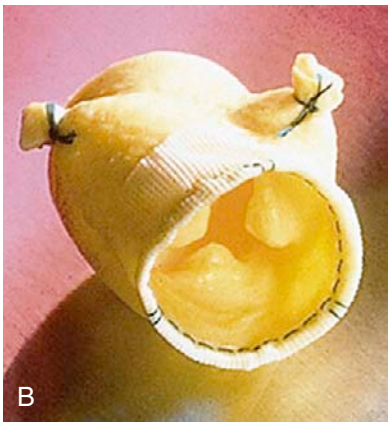


FIGURE 24-27 **A**, Medtronic Mosaic porcine aortic *(top)* and mitral *(bottom)* bioprostheses. **B**, Stentless porcine aortic valve. The absence of a stent and sewing ring provides a greater orifice area through which blood can flow.

Aortic valve allografts (homografts) have little or no risk of thromboembolism, optimal hemodynamic function, no need for anticoagulation drugs, and no risk of sudden catastrophic failure. Moreover, they demonstrate a lower incidence of infective endocarditis than that found in mechanical or biologic valves and their long-term durability is comparable with that of bioprostheses. Allograft root replacement is also a valuable technique in the setting of prosthetic valve endocarditis. The entire ascending aorta and valve (Figure 24-30) or the valve alone (Figure 24-31) may be inserted. Allografts are cryopreserved and must be thawed in saline according to the vendor's protocol before implantation. Because stentless aortic valves (see Figure 24-27, *B*) are more easily available than allografts, they are increasingly preferred for aortic root replacement.

Conduits consisting of mechanical or biologic aortic valves attached to a tube graft (Figure 24-32) are used in procedures such as repair of aortic dissections requiring replacement of the aortic valve and ascending aorta. If vein grafts must be inserted into the conduit or if a direct coronary ostial anastomosis is required, an eye electrocoagulator is used to make the opening

FIGURE 24-28 Carpentier-Edwards bovine pericardial aortic bioprosthesis.

FIGURE 24-29 **A**, ATS Medical equine pericardial aortic prosthesis. **B**, Obturators for ATS Medical 3f prosthesis.

into the graft and at the same time heat-seal the cut edges of the prosthesis. Conduits with *biologic* valves interposed between tube graft materials may be used when patients are at increased risk for bleeding complications associated with the need for chronic anticoagulation therapy. Allograft conduits may be used for these procedures as well.

Although allografts and stentless bioprostheses avoid the complications associated with prosthetic mechanical valve replacement, valve repair rather than replacement is preferred,

TABLE 24-4

Mechanical Valve Prostheses*

	Ball-and-Cage (Rarely Used)	Tilting Disk	
	Starr-Edwards	**Medtronic-Hall, Omniscience**	**St. Jude Medical, CarboMedics**
Model/description	6120 Mitral 1260 Aortic	Spherical (single) tilting disk	Bileaflet tilting disk
Advantages	Long-term durability Good hemodynamics Inaudible Least risk of sudden thrombosis	Long-term durability Good hemodynamics in all sizes Low profile	Long-term durability Good hemodynamics in all sizes Low profile Low TE rate for mechanical valve
Disadvantages	Anticoagulation required Higher incidence of TE than disk valves Large profile Suboptimal hemodynamics in small aortic sizes (less than 23 mm) High profile not optimal in small LV or aortic root Higher risk of TE in mitral position	Anticoagulation required Potential for sudden thrombosis Noisy Higher risk of TE in mitral position If Coumadin must be discontinued, there is increased risk of catastrophic thrombosis	Anticoagulation strongly recommended Potential for sudden thrombosis Some noise Higher risk of TE in mitral position If Coumadin must be discontinued, there is increased risk of catastrophic thrombosis
Special considerations	Sizers and handles specific to prosthesis; must be sterilized Poppet of aortic valve removable to facilitate tying sutures; replaced before aorta closed; mitral poppet not removable Aortic model has three struts; mitral has four	Sizers and handles specific to prosthesis; must be sterilized	Sizers and handles specific to prosthesis; must be sterilized Frequently used in children needing prosthetic valve
Resterilization	Not recommended	Not recommended	Not recommended

*All prostheses should be stored in a cool, dry, contamination-free area.
LV, Left ventricle; *TE,* thromboembolism.
Adapted from Ascione R et al: Mechanical heart valves in septuagenarians, *J Cardiac Surg* 23:8-16, 2007.

FIGURE 24-30 Aortic allograft with aortic valve and arch vessels attached.

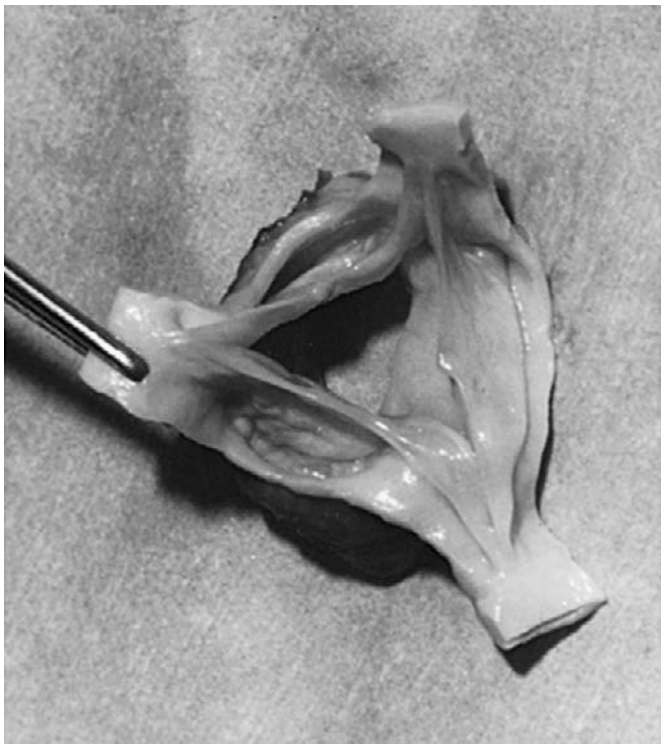


FIGURE 24-31 Aortic valve allograft.

TABLE 24-5

Biologic Valve Prostheses

	Heterograft (Xenograft)		
	Stentless Porcine Bioprostheses	**Stented Porcine Heterograft; Bovine and Equine Pericardial Valve Prostheses**	**Allograft (Homograft)**
Model/description	For use in aortic position Stentless (aortic): no sewing ring; includes porcine aortic root with coronary ostial branches	Pericardial valve used in aortic position Porcine heterograft used in aortic, mitral, and tricuspid positions Porcine heterograft (from excised pig aortic valves; leaflets attached to sewing ring) Aortic bovine and equine pericardium (cut and shaped into trileaflet valve)	Aortic valve allograft (cadaver, organ donor, excised cardiomyopathic heart from transplant recipient; mitral valve allograft also available)
Advantages	Incidence of TE very low; anticoagulation rare after AVR Stentless has excellent flow, especially in small aortic annulus (≤21 mm) No hemolysis Good hemodynamics Use may avoid need for aortic root enlargement Central flow Gradual failure allows elective reoperation Little residual gradient Durability good after age 60 yr Stentless graft has many advantages of allograft valves	Incidence of TE very low; anticoagulation rare after AVR No hemolysis Good hemodynamics in all sizes Central flow Gradual failure allows elective reoperation Residual gradient minimal	Incidence of TE very low; anticoagulation rare; used for AVR and MVR No hemolysis Excellent hemodynamics (especially with stentless technique) Central flow Gradual failure allows elective reoperation No residual gradient
Disadvantages	Durability may be less than 15 yr Accelerated fibrocalcific degeneration in children, patients with hypertension, or patients needing chronic renal dialysis Cross-clamp time and CPB longer than those for insertion of stented valve because of greater complexity of subcoronary insertion	Durability not yet established In small aortic root of large body, may produce prosthesis-patient mismatch Accelerated calcification may be a problem in children, renal patients, or those with hypertension	Limited availability Insertion technique more complex than stented valve Possible immunologic reaction (newer decellularization process strips cells from graft and reduces immune response)
Special considerations	Sizers and handles specific to prosthesis; must be sterilized before insertion; must be rinsed in saline to remove storage solution before insertion; follow manufacturer's instructions for rinsing; frequent irrigation recommended to prevent drying Diets low in calcium recommended for children, renal patients	Sizers and handles specific to prosthesis; must be sterilized before insertion; must be rinsed in saline to remove storage solution before insertion; follow manufacturer's instructions for rinsing; frequent irrigation recommended to prevent drying Diets low in calcium recommended for children, renal patients	No specific sizers; may use sizers for heterografts; cryopreserved allograft must be thawed per protocol; used for aortic or mitral valve replacement; stent can be attached if indicated for use in other positions
Resterilization	Not recommended	Not recommended	Not recommended

AVR, Aortic valve replacement; *CPB,* cardiopulmonary bypass; *MVR,* mitral valve replacement; *TE,* thromboembolism.

Modified from Oakley RE et al: Choice of prosthetic heart valve in today's practice, *Circulation* 117:253-256, 2008; Kumar AS: *Techniques in valvular heart surgery,* New Delhi, India, 2008, CBS Publishers and Distributors; Pepper J et al: Stentless versus stented bioprosthetic aortic valves. A Consensus Statement of the International Society of Minimally Invasive Cardiothoracic Surgery (ISMICS) 2008, *Innovations* 4(2):49-60, 2009; Cheng D: Stentless versus stented bioprosthetic aortic valves: a systematic review and meta-analysis of controlled trials, *Innovations* 4(2):61-73, 2009.

RISK REDUCTION STRATEGIES

Varying Rinsing Procedures for Biologic Heart Valves

Glutaraldehyde storage solution is used for many bioprostheses, and rinsing procedures for its removal vary among bioprosthetic heart valve manufacturers. Both the amount of rinsing solution in each rinsing basin and the time for each rinse (total of three rinsing baths) should be followed according to each manufacturer's instructions. Some manufacturers (see ATS Medical) recommend a *fourth* basin for storing the bioprosthesis until implantation. The following sampling of rinsing processes reflects the differences among manufacturers' recommended rinsing procedures. The person rinsing the valve should collaborate with the circulating nurse when following the instructions for that particular valve.

PERICARDIAL (EQUINE) AORTIC VALVE (ATS MEDICAL 3F)

Prepare *four* rinse basins with a minimum of *500 ml of saline* solution in each basin. Gently agitate the valve for *30 seconds in each of the first three basins* for a total of *1.5 minutes (90 seconds)*. Allow the bioprosthesis to remain in the *fourth basin* until required by the surgeon.

ATS Medical 3f rinse procedure, ATS 3f Aortic Bioprosthesis (Model 1000), Implant Procedure, ATS Medical, Minneapolis, Minn, available at www.atsmedical.com/uploadedFiles/Public_Site/Physicians_International/Biological_Valves/st_broc_3f.pdf. Accessed July 9, 2009.

PERICARDIAL (BOVINE) VALVE (CARBOMEDICS)

Prepare three rinse basins with a minimum of *300 ml of saline solution in each basin*. Gently agitate the valve for *2 minutes in each basin for a total of 6 minutes*. Allow the bioprosthesis to remain in the third basin until required by the surgeon.

CarboMedics rinse procedure, available at www.carbomedics.com/professional_faq.asp?faq=HPBio#27. Accessed July 3, 2009.

PERICARDIAL (BOVINE) VALVE (EDWARDS LIFE SCIENCES PERIMOUNT MAGNA 3000TFX)

Prepare two rinse basins with a minimum of *500 ml of saline solution in each basin*. Gently agitate the valve (keeping it submerged) *for a minimum of 1 minute in each basin for a total of at least 2 minutes*. Allow the bioprosthesis to remain in the third basin until required by the surgeon.

From Edwards Life Sciences: *Instructions for use,* available at http://www.edwards.com/products/heartvalves/mmimplantprep.htm?MagnaMitral=1. Accessed November 25, 2009.

PORCINE VALVE (MEDTRONIC MOSAIC 305)

Prepare three rinse basins with a minimum of *500 ml of saline solution in each basin*. Gently agitate the valve (keeping it submerged) *for 2 minutes in each basin for a total of 6 minutes*. Allow the bioprosthesis to remain in the third basin until required by the surgeon.

Medtronic rinse procedure, available at www.medtronic.ch/cardsurgery/products/pdf/200102908b%20EN.pdf. Accessed July 3, 2009.

PORCINE STENTLESS VALVE (MEDTRONIC STENTLESS FREESTYLE 995)

Prepare three rinse basins with a minimum of *500 ml of saline solution in each basin*. Gently agitate the valve (keeping it submerged) *for 2 minutes in each basin for a total of 6 minutes*. Allow the bioprosthesis to remain in the third basin until required by the surgeon.

From Medtronic: *Instructions for use*. Package insert. Medtronic, Inc., Minneapolis, MN, 2007.

PERICARDIAL VALVE (SORIN *FREEDOM SOLO*)

This is a newer valve detoxified by, but not stored in, glutaraldehyde (other bioprostheses are stored in glutaraldehyde); *eliminates the need for rinsing* (although the prosthesis should be kept moist with saline to prevent drying of the tissue).

Mirzaie M et al: A new storage solution for porcine aortic valves, *Ann Thorac Cardiovasc Surg* 13:102-109, 2007, available at www.atcs.jp/pdf/2007_13_2/102.pdf. Accessed July 3, 2009; see also the review at www.ces.clemson.edu/bio/documents/Publications/Simionescu%20-%20Expert%20Opinion%202004.pdf.

FIGURE 24-32 Valved conduit with Medtronic-Hall tilting disk valve prosthesis.

particularly with mitral and tricuspid valves. Fedak and colleagues (2008) listed more than 30 mitral valve rings and bands commercially available in 2007; the authors also described additional newer prostheses in development for both surgical and interventional percutaneous reparative procedures. When repairing the native valve with an annuloplasty ring, obturators specific to various kinds of annuloplasty rings are used to size the annulus (Figure 24-33, *A* and *B*).

Safety considerations include storing prosthetic materials in a clean, protected environment and using them according to manufacturers' instructions. Before implantation, biologic valves must be rinsed in three saline baths to remove the glutaraldehyde (or other) storage solution (Mirzaie et al, 2007). The prescribed amount of physiologic fluid in each rinsing bath and the recommended rinsing time for each bath vary among bioprosthetic manufacturers. Nurses should adhere to the specific instructions for each prosthesis (Risk Reduction Strategies). It should be noted that some bioprostheses do not require rinsing because they are stored in a physiologically neutral solution (i.e., not glutaraldehyde). However, before and during insertion, all bioprostheses should be kept moist with saline. Mechanical valves should be protected from scratching and other injury.

Preinduction Care. The patient is transferred to the OR suite, where a focused preoperative assessment is performed and the

perioperative nurse reviews the chart for completion and documentation of informed consent, advance directives, laboratory results, diagnostic data, and other pertinent information. The nurse confirms the identity of the patient and the intended operation, including identification and confirmation of the site and side, and the required position as applicable. Verification of which leg (i.e., right or left) will be used for vein harvest in bypass patients may not be necessary if this decision depends on the operator's preference rather than a specific clinical indication. However, some institutions may require site marking of bypass harvesting sites, and the nurse should follow institutional policy for guidance.

Preoperatively, cardiac surgical patients may exhibit more stress and anxiety than other types of patients. Perioperative nurses should anticipate and prepare for this reaction because anxiety increases myocardial oxygen consumption. Efforts to reduce the family's anxiety level are also important and result in less emotional stress being transmitted to the patient.

A peripheral arterial pressure line and venous infusion lines are inserted. A local anesthetic may be used at the insertion sites, and a sedative may be injected intravenously. Occasionally, a patient's response to sedation results in impaired respiration as evidenced by shallow respirations, decreased oxygen saturation, and a respiratory rate of 8 breaths (or less) per minute (Mancini and Bubien, 2008). The nurse noticing these respiratory changes can call a rapid response team (RRT) to assess the patient and initiate treatment before the patient develops more serious reactions, such as cardiopulmonary arrest. In this situation the RRT may consist of the anesthesia providers and staff in the immediate preoperative area rather than a specific hospital-wide RRT. For patients awaiting transfer from the preoperative area to the OR for cardiac surgery, the concept of a clinician acting promptly on changes in a patient's status and initiating a "rapid response" is an important aspect of enhancing a culture of patient safety (Rapid Response Team box).

Admission to the OR. Depending on the patient's response to sedative medications received preoperatively, the patient may require assistance onto the OR bed. Warm blankets should be provided for comfort and to reduce shivering; the nurse should ensure that the blanket temperature does not produce thermal injury (Bujdoso, 2009).

After application of the ECG leads and the pulse oximeter finger cot, the hands, elbows, and feet can be padded. The perioperative nurse confirms that the peripheral arterial pressure line is functioning properly and may reposition the arm as necessary in collaboration with the anesthesia provider. Pulse oximetry function is confirmed. The nurse should be aware that skin pigment, especially in darker-skinned individuals, may overestimate arterial oxygen saturation measured by pulse oximetry (Bickler et al, 2005). Additional monitoring devices are listed in Table 24-6. A "time out" is performed to comply with The Joint Commission's *Universal ProtocolTM* (see Chapter 2).

Anesthesia Induction. The choice of anesthetic agent or agents depends on the cardiovascular effects of the anesthetic, the patient's hemodynamic status and general health, and the anticipated length of stay in the surgical intensive care unit (SICU). Newer, fast-acting anesthetic agents are used to "fast-track" patients postoperatively, whereby the patient is extubated in the OR, or very shortly after admission to the SICU, to speed the recuperation process (Camp et al, 2009).

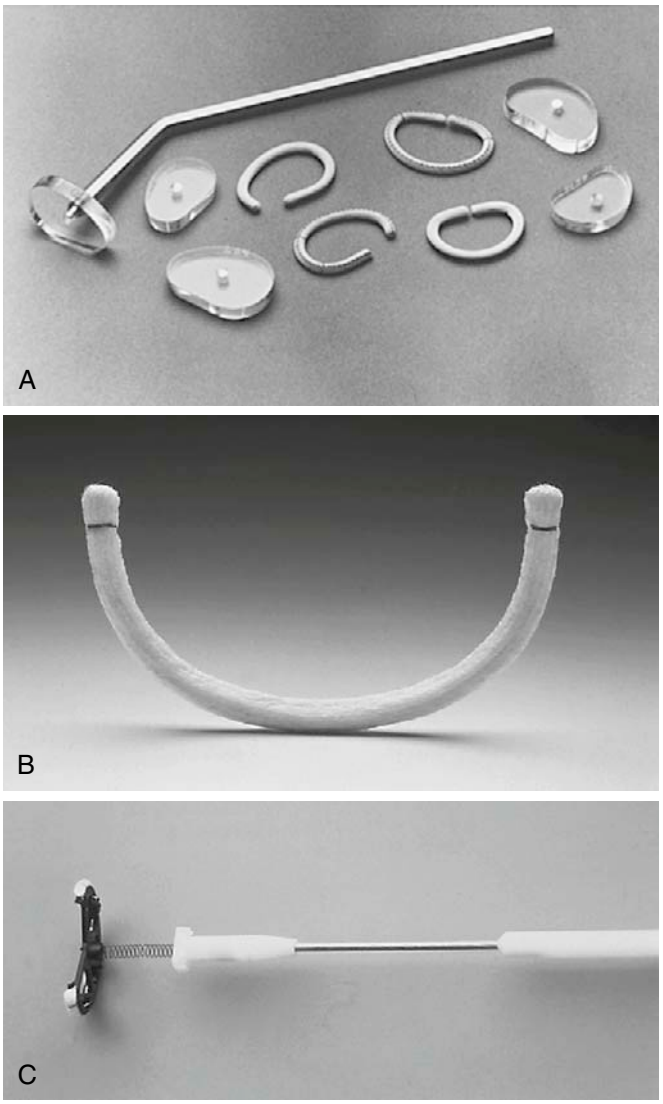


FIGURE 24-33 **A**, Carpentier-Edwards "classic" tricuspid and mitral annuloplasty rings, sizers, and sizer handle. The tricuspid rings are notched in the area corresponding to conduction tissue in the tricuspid annulus to avoid suture injury. **B**, Cosgrove annuloplasty ring. **C**, Ring attached to ring holder and handle.

Because the period of induction is one of the most critical during the procedure, close monitoring of the patient is required, especially for patients with ventricular ischemia from congenital or acquired disease (Moss and Moss, 2009). Anesthetic management focuses on maintaining an adequate cardiac output by keeping myocardial oxygen demand low and the oxygen supply high (DiNardo and Zvara, 2008). (See Chapter 4 for additional considerations related to anesthesia care monitoring.)

Medication Safety. In addition to anesthetic medications, multiple other drugs are employed to cause vasodilation or vasoconstriction, enhance heart rate and contractility, promote anticoagulation, result in diuresis, and provide antibiotic prophylaxis (Surgical Pharmacology). Antibiotic prophylaxis for

RAPID RESPONSE TEAM

Patients' responses to preoperative sedative medication administration can vary, even when the same dose and drug are administered. Some patients may display a reduced respiratory rate, shallow breathing, and decreased oxygen saturation; in more severe cases there may be hemodynamic instability.

In anticipation of changes in respiratory function, circulating nurses (and/or the preoperative nursing caregivers) should routinely ensure that patients in the preoperative area are connected to an ECG monitor, have a pulse oximeter finger cot attached to measure oxygen saturation, and have supplemental oxygen available. Additionally, the patient transport vehicle should be able to be placed into Trendelenburg's position.

When impaired breathing is noticed, the nurse can initiate a *rapid response* by contacting the anesthesia provider(s) caring for the patient. In the cardiac surgery suite, anesthesia personnel are usually immediately available to intercede. An official, institutional *rapid response team* may not be required even if anesthesia personnel have momentarily stepped away from the patient. Anesthesia staff will assess the patient and intervene to improve respiratory function by increasing oxygen flow and possibly treating the patient with small doses of ephedrine or phenylephrine to stimulate the respiratory center. The patient should not be left alone and will be transported to the OR and intubated promptly.

TABLE 24-6

Perioperative Patient Monitoring

Monitoring Device	Location	Measures
Electrocardiogram (ECG)	Lateral, posterior electrode placement	Electrical activity of heart
Arterial line	Peripheral radial artery	Arterial blood pressure (direct)
	Central femoral artery	
	Aorta (with needle attached to pressure tubing, or with sensor in bypass circuit)	
Blood pressure (BP) cuff	Upper arm	Arterial BP (indirect)
Central venous pressure (CVP)	Right atrium (RA)	RA pressure (e.g., CVP)
Pulmonary artery (PA) catheter (Swan-Ganz)	RA (proximal port)	RA pressure (e.g., CVP)
	Right ventricle (RV) (midline port)	RV pressure
	Distal PA (distal port)	PA and pulmonary artery wedge pressure (PAWP)
		Indirect measure of left atrial and left ventricular (LV) pressure
		Cardiac output
Left atrial (LA) line	Left atrium	LA, LV pressure
Pulse oximeter	Finger, earlobe	Oxygen saturation of arterial hemoglobin
Urinary drainage catheter	Urinary bladder	Urine output, renal perfusion/function, temperature
Temperature probes	Esophagus	Temperature (core and peripheral)
	Nasopharyngeal	
	Urinary bladder	
	Rectum	
	Ventricular septum	
	Bypass circuit	
	Tympanic	
	Face/forehead (adhesive patch)	
Neurologic monitoring		
Electroencephalogram (EEG)	Head	Electrical activity of brain; awareness
Transcranial Doppler		Detects cerebral arterial emboli
Bispectral index (BIS)		Detects anesthesia awareness
Cerebral oximetry		Measures cerebral tissue oxygen saturation with sensors placed bilaterally on patient's forehead
Transesophageal echocardiogram (TEE)	Esophagus	Cardiac function, presence of air, integrity of valve repair

Adapted from DiNardo JA, Zvara DA: *Anesthesia for cardiac surgery,* ed 3, Malden, Mass, 2008, Blackwell Publishing; Savino JS, Cheung AT: Cardiac anesthesia. In Cohn LH, editor: *Cardiac surgery in the adult,* ed 3, New York, 2007, McGraw Hill; Moss CJ, Moss R: Assist the anesthesia provider. In Phippen ML et al, editors: *Competency for safe patient care during operative and invasive procedures,* Denver, 2009, Competency & Credentialing Institute.

infection prevention in the cardiac patient is an important consideration and the nurse should confirm that the antibiotic has been infused before the surgical incision is made (Simmonds et al, 2008). According to Engelman and colleagues (2007), *Staphylococcus aureus* is the most frequently cultured organism in cardiac surgical site infection (SSI). The recommended primary prophylactic antibiotic for adult cardiac surgery is a first-generation cephalosporin (usually cefazolin); vancomycin (one preoperative dose and an additional dose) may be a reasonable adjunct to cephalosporin. In patients allergic to penicillin, vancomycin may be considered the primary prophylactic antibiotic with additional gram-negative coverage.

SURGICAL PHARMACOLOGY

Medications Used in Adults During Cardiac Surgery

Medication	Purpose/Description/Delivery
ANALGESICS AND ANESTHETICS	
Thiopental	Induction, ultra–short-acting barbiturate, intravenous bolus
Fentanyl (Sublimaze)	Synthetic narcotic, intravenous bolus and/or infusion
Sufentanil (Sufenta)	Synthetic narcotic, intravenous bolus and/or infusion
Alfentanil (Alfenta)	Synthetic narcotic, intravenous bolus and/or infusion
Remifentanil (Ultiva)	Synthetic narcotic, intravenous bolus and/or infusion
Morphine sulfate	Narcotic, intravenous bolus
Halothane (Fluothane)	Inhalation anesthetic, maintenance
Enflurane (Ethrane)	Inhalation anesthetic, maintenance
Isoflurane (Forane)	Inhalation anesthetic, maintenance
Methohexital (Brevital)	Three times more potent and faster clearance than thiopental
Remifentanil (Ultiva)	Synthetic narcotic, intravenous bolus and/or infusion
Propofol (Diprivan)	Intravenous anesthetic; bolus and/or infusion; very fast acting
Sevoflurane (Ultane)	Inhalation anesthetic, maintenance
Desflurane (Suprane)	Inhalation anesthetic, maintenance
MUSCLE RELAXANTS	
Vecuronium (Norcuron)	Intubation, maintenance of muscle relaxation
Atracurium	Maintenance of muscle relaxation; relatively free of circulatory effects
Doxacurium	Maintenance of muscle relaxation; relatively free of circulatory effects
Pancuronium (Pavulon)	Maintenance of muscle relaxation
Pipecuronium	Maintenance of muscle relaxation; relatively free of circulatory effects
Rocuronium (Zemuron)	Fast-acting muscle relaxant; allows hemodynamic stability
Succinylcholine	Fast-acting muscle relaxant, 0% renal elimination
AMNESIACS	
Midazolam (Versed)	Hypnotic; anxiety-reducing sedative
Scopolamine	Sedative; amnesic
Lorazepam (Ativan)	Hypnotic sedative; premedication
CARDIOVASCULAR AGENTS	
Anticholinergics	
Atropine	Decreases vagal tone; treats sinus bradycardia
Glycopyrrolate (Robinul)	Similar to atropine but has less incidence of dysrhythmias than atropine with slower onset
Vasopressors	
Norepinephrine (Levophed)	Increases force and velocity of contraction; increases systemic and pulmonary vascular resistance
Phenylephrine (Neo-Synephrine)	Arteriolar and venous vasoconstriction; increases blood pressure and systemic vascular resistance
Vasodilators	
Nitroglycerin (Tridil)	Dilates coronary arteries; reduces preload
Phentolamine (Regitine)	Decreases systemic and pulmonary resistance
Prostaglandin E_1 (Prostin VR)	Vascular smooth muscle dilator, potent pulmonary vascular dilator; used to maintain patency of ductus arteriosus in cyanotic neonates, patients with severe pulmonary hypertension
Nitroprusside (Nipride)	Arteriolar and venous vasodilation; reduces preload and afterload
Inotropic Agents	
Amrinone (Inocor)	Increases cardiac output, force and velocity of contraction
Calcium chloride	In iodized form, increases cardiac output, blood pressure (BP), and contractility
Dopamine (Intropin)	In low doses, increases renal and mesenteric perfusion; with moderate doses, increases heart rate, contractility, and cardiac output; in higher doses, increases systemic and pulmonary vascular resistance
Dobutamine (Dobutrex)	Increases contractility with less increase in heart rate than occurs with dopamine; has vasodilation effect on vascular bed
Ephedrine	Increases contractility, cardiac output, BP
Epinephrine (Adrenalin)	Increases rate and strength of contraction, BP (effective bronchodilator)
Isoproterenol (Isuprel)	Increases heart rate, contractility, cardiac output; decreases systemic vascular resistance
Milrinone (Primacor)	Increases cardiac output, force and velocity of contraction

SURGICAL PHARMACOLOGY

Medications Used in Adults During Cardiac Surgery—cont'd

Medication	Purpose/Description/Delivery
Antidysrhythmics	
Lidocaine (Xylocaine)	Acts on ventricles; decreases automaticity of ischemic ventricular tissue
Bretylium (Bretylol)	Prolongs duration of action potential and refractory period; useful for ventricular dysrhythmias refractory to therapy
Digoxin (Lanoxin)	Decreases ventricular rate in atrial fibrillation or flutter and other supraventricular dysrhythmias; avoid in patients with Wolff-Parkinson-White syndrome and other accessory atrioventricular pathways
Nifedipine (Procardia)	Calcium channel blocker; reduces coronary artery spasm; produces coronary vasodilation; extremely light-sensitive; must be given orally or by way of nasal or oral mucosa; antihypertensive
Procainamide (Pronestyl)	Decreases automaticity and conduction in all cardiac tissue (normal and ischemic); stabilizes cellular membranes
Quinidine	Similar to procainamide; atrial and ventricular dysrhythmias
Verapamil (Calan, Isoptin)	Calcium channel blocker; used to treat atrial dysrhythmias; slows ventricular rate in atrial fibrillation or flutter; can be given intravenously
Adenosine	Supraventricular dysrhythmias
DIURETICS	
Furosemide (Lasix)	Decreases renal absorption of sodium and chloride; increases excretion of water and electrolytes, especially potassium, sodium, chloride, magnesium, and calcium
Mannitol	Osmotic diuretic; pulls free water out of organs (reducing cerebral edema); protects kidneys
ANTICOAGULANTS/COAGULANTS	
Heparin	Systemic anticoagulation during CPB; blocks activation of thrombin (and intrinsic clotting cascade)
Protamine sulfate	Heparin antagonist
Bivalirudin	Short-acting direct thrombin inhibitor
ANTIBIOTICS	
Cephalosporins (Mandol, Ancef, Keflex, Keflin, Cefadyl)	Broad-spectrum prophylaxis
Tobramycin (Nebcin)	Aerobic gram-negative and gram-positive bacteria
Vancomycin	Severe endocarditis
Bacitracin	Topical irrigation
MISCELLANEOUS	
Diazepam (Valium)	Sedative, induction of anesthesia
Nitric oxide (NO)	Vascular (especially pulmonary) relaxation; inhaled; reduces pulmonary hypertension
Lidocaine 1% (plain)	Local anesthetic for insertion of invasive monitoring
Naloxone	Opioid antagonist; reverses narcotic-induced respiratory depression
Papaverine	Reduces arterial spasm (e.g., mammary artery)
Potassium	Replaces electrolyte loss
Sodium bicarbonate	Corrects acidosis
Insulin (e.g., NPH)	Corrects hyperglycemia in diabetic patients
Topical hemostatic agents	Intraoperative control of bleeding
Desmopressin (DDAVP)	Pharmacologic hemostatic agent

Adapted from Savino JS, Cheung AT: Cardiac anesthesia. In Cohn LH, editor: *Cardiac surgery in the adult,* ed 3, New York, 2007, McGraw Hill Medical; Simmonds PK et al: Cardiovascular pharmacologic agents. In Conte JV et al, editors: *The Johns Hopkins manual of cardiac surgical care,* ed 2, St Louis, 2008, Mosby; Seifert PC, Collins J: Cardiac surgery. In Phippen ML et al, editors: *Competency for safe patient care during operative and invasive procedures,* Denver, 2009, Competency & Credentialing Institute.

Additional safety precautions include labeling all medications on the field (including irrigating fluids and H_2O). Of particular importance are heparinized solutions, papaverine (to reduce spasm in IMA and radial artery conduits), and saphenous vein infusions. Containers and syringes are labeled and the circulating nurse and the scrub person visually and verbally confirm drug name, dose, route, strength, and outdate of every medication passed onto the field.

Monitoring. Extensive monitoring of hemodynamic and other variables is indicated during cardiac surgery (see Table 24-6). After intubation (or before, depending on the anesthesia provider's preference), additional pressure lines may be inserted to measure central venous pressure (CVP) and pulmonary artery pressures (PAPs). Maximal sterile barriers should be used for insertion of central lines (Clancy, 2009; Hu et al, 2004) (Evidence for Practice). Peripheral and central arterial

EVIDENCE FOR PRACTICE

Optimal Draping for Central Venous Catheters

Central venous catheters are associated with bacterial colonization of the catheter, local infection at the site of insertion, and bloodstream infection. According to Clancy (2009), 250,000 central line–associated bloodstream infections (CLABSIs) occur in U.S. hospitals each year, and add $36,000 in additional cost per patient. In addition to the use of maximal barriers, infection prevention measures include handwashing, skin cleansing with chlorhexidine gluconate, avoiding the femoral site, and removing catheters as soon as possible.

The use of maximal barriers—although time-consuming, more expensive, and more cumbersome than other techniques employing minimal draping—has been shown to reduce the number of CLABSIs. Hu and colleagues (2004) calculated the total direct medical costs and the incidence of CLABSIs, bacterial colonization of the catheter, and death. When compared to minimal barriers, the researchers determined that the use of maximal barriers resulted in the following: lower costs (from $621 to $369 per patient), decreased bloodstream infections (from 5.3% to 2.8%), decreased catheter colonization with local infection (from 5.5% to 2.9%), and decreased death rates (from 0.8% to 0.4%). The authors calculated that $68,000 would be saved with maximal barrier application for every 270 catheter placements, 7 episodes of catheter-related infections would be avoided, and 1 death would be prevented. The results of this study support routine maximal draping for the insertion of central lines.

Modified from Clancy CM: Reducing central line-related bloodstream infections, *AORN J* 89(6):1123-1125, 2009; Hu KK et al: Use of maximal sterile barriers during central venous catheter insertion: clinical and economic outcomes, *Clin Infect Dis* 39, November 15, 2004.

and venous pressures are usually monitored directly by means of a transducer and oscilloscope. Perioperative nurses may be required to collaborate in the preparation and placement of central lines; they should observe the ECG monitors for signs of ventricular irritability, such as ectopy or tachycardia, and be prepared to assist with defibrillation of the patient if necessary. If the patient cannot be resuscitated, the chest is opened rapidly and internal cardiac massage is performed to perfuse the circulatory system.

An indwelling urinary catheter is inserted for measuring urine output and monitoring renal function, especially during and after CPB. The urinary catheter may contain a thermistor temperature probe. Other temperature probes may be placed, usually in the esophagus, nasopharynx, or rectum, or on the forehead. Temperatures can also be recorded from the pulmonary artery catheters and the arterial infusion line of the bypass circuit. Ventricular septal temperatures can be recorded by insertion of a needle probe while the patient's heart is arrested. Monitoring of cerebral oxygenation and the level of anesthesia awareness is frequently employed.

The skin is carefully inspected before ECG and ESU dispersive pads are placed. Bony prominences, such as the coccyx and the back of the head, are padded to prevent pressure necrosis resulting from hypoperfusion and hypothermia during bypass. Because elderly patients are especially vulnerable to skin breakdown, additional precautions to avoid pressure injuries are recommended (Walton-Geer, 2009). Monitoring aseptic practice is an important infection control strategy.

Positioning. The supine position provides optimal exposure for the institution of CPB and the surgical repair of the heart and great vessels. In addition, respiratory impairment and discomfort are reduced with this approach (Bishop, 2009). When the supine position is used, the hands and arms are tucked along either side of the body. The legs may be slightly "frog-legged" to provide access to the femoral arteries for insertion of pressure lines and IABP lines or to excise the saphenous vein. Measures to avoid pressure injury (especially in the elderly, debilitated, or obese patient) include padding the coccyx and applying heel protectors. Measures to protect the occipital area from pressure ulcers include placing pillows under the head and repositioning the head during surgery. Significant factors associated with the development of pressure ulcers include preexisting diabetes mellitus; lower preoperative hemoglobin, hematocrit, and serum albumin levels (Walton-Geer, 2009); and the presence of intra-aortic balloon pumps.

A semilateral position may be employed for thoracoabdominal aneurysms in order to expose both the descending thoracic aorta and the abdominal aorta. A thoracotomy position may be used for some minimally invasive procedures including surgery on the descending thoracic aorta. For minimally invasive surgery, the right or left side of the chest may be elevated with a roll or other positioning device to provide adequate exposure for one or more small thoracotomy incisions. The presence of severe mediastinal adhesions may also necessitate this approach in some repeat valve operations. Thoracotomy positioning aids should be available to position arms and legs per the surgeon's protocol (see Chapter 5 for a discussion of positioning).

Prepping and Draping. For procedures requiring excision of the saphenous vein, the prep extends from the jaw to the toes and includes the anterior (or lateral) area of the chest, abdomen, groin, and legs. The legs and feet are prepped circumferentially and the chest and abdomen from bedline to bedline.

In procedures not requiring saphenous vein excision, the prep extends to a level below the knees to give the surgeon access to the femoral artery or saphenous vein in the thigh area. (Some surgeons prefer to have both legs prepped circumferentially for all cardiac procedures.) Femoral artery access may be required for arterial pressure monitoring or insertion of an intra-aortic balloon. Saphenous vein exposure facilitates access if a bypass conduit is required. In the lateral position, the patient is prepped bedline to bedline anteriorly and posteriorly at least to the knees.

After the prep, the patient is draped so that the anterior areas of the chest, abdomen, and inguinal area are accessible. The perineum is covered, and a towel folded lengthwise (to create a "belt") may be placed across the umbilicus to connect the side drapes. When the saphenous vein is to be excised, both legs remain exposed, with only the feet covered. When draping, the perioperative nurse should consider the placement of bypass lines so that they remain securely attached and do not become contaminated. A small drape or towel may be placed over the groin area when access to it is not immediately necessary. If the femoral artery needs to be accessed, the drape can be discarded. Similarly, towels may be placed over the legs after saphenous vein excision to reduce inadvertent cooling.

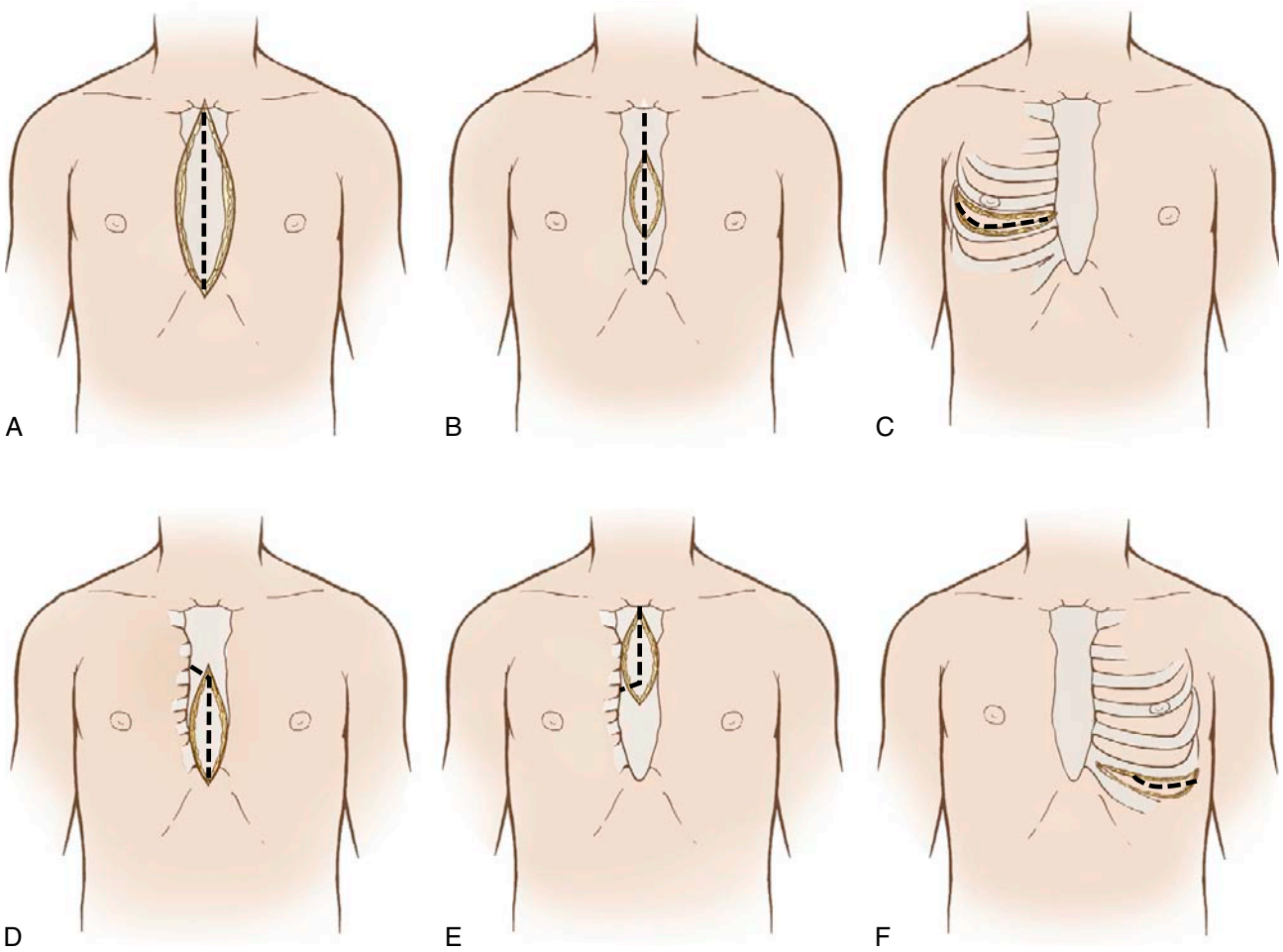


FIGURE 24-34 Schematic representation of traditional incision and sternotomy, **A**, compared with a variety of less-invasive incisions (*dotted lines* represent chest wall incisions). Limited skin incision/full sternotomy, **B**, is gaining popularity because of improved cosmesis and reduced trauma from the limited chest wall retraction. The parasternal approach, **C**, is used less frequently because of the residual chest wall defect. Partial lower or upper sternotomy, **D** and **E**, respectively, has been used predominantly in valve procedures. Right anterior thoracotomy, **F**, is a useful approach, particularly in mitral valve reoperations.

Incisions. A variety of incisions can be used. The standard median sternotomy is most common but mini-sternotomy, mini-thoracotomy, or full thoracotomy incisions are used according to the surgeon's preference and type of procedure (Figure 24-34).

MEDIAN STERNOTOMY. The skin incision for full sternotomy extends from the sternal notch to the linea alba below the xiphoid process (Figure 24-35). Nurses should realize that some women may be unprepared for a sternal scar (Research Highlight). For mini-sternotomy, the sternum is partially divided starting from either the sternal notch or the xiphoid process (depending on the cardiac structures to be exposed). The sternum is divided with a saw, and a sternal retractor is inserted. If the IMA or the saphenous vein will be used, it is made available at this time. The pericardium is incised and the pericardial edges are retracted with (six to eight) sutures sewn to the subcutaneous tissue; this technique enhances exposure by elevating the heart and creates a well to contain irrigation solutions.

In repeat sternotomy, adhesions from a previous cardiac operation must be dissected. The sternum may be divided with an oscillating saw and the retrosternal tissue dissected free. Increased risk of fibrillation from manipulation of the heart and bleeding and laceration of the right ventricle should alert the perioperative nurse to the possibility of instituting femoral vein–femoral artery bypass (discussed later). In addition, disposable defibrillation patches are applied preoperatively to the left lateral chest and the right upper posterior chest; these patches can be activated for defibrillation if the heart has not been exposed. Sterile external paddles may also be available.

Anteroposterior and lateral chest radiographs are useful to determine the extent of retrosternal adhesions and to count the number of chest wires for removal. On occasion, a patient presents for repeat mitral valve surgery. If the initial operation was performed through a thoracotomy incision, sternal adhesions may be minimal or nonexistent and the special precautions associated with repeat sternotomy may not be necessary. Conversely, if the primary chest incision was a sternotomy, a

RESEARCH HIGHLIGHT

Perceptions of Sternal Scars in Women after Cardiac Surgery

The subjective perception of a sternal scar is important to women. The Women's Recovery from Sternotomy Trial (WREST) was undertaken to interview women who had undergone cardiac surgery via median sternotomy. The study aims were to examine the qualitative impact of the cosmetic result of sternotomy and the quantitative association between subjective satisfaction and objective ratings of the sternal scar. Researchers from the nursing faculty at the University of Calgary (Alberta, Canada) undertook a small descriptive exploratory study of women (n = 13) who participated in semistructured audio-taped interviews.

Although participants realized that the scar represented the "cost" of benefits of cardiac surgery, they were not prepared to live with the scar. Significantly more women than men (35% versus 14%, respectively) verbalized that they "did not like" or "hated" their scar. According to the researchers, the scar represented a personal reminder to the participants that they had a health problem and that they had undergone serious surgery, and they felt less attractive because of the scar. Moreover, the visual reminder produced by the scar was perceived by the participants as causing a judgment from members of the public.

Little association was found between the participants' subjective satisfaction (rated on a Likert-type scale) and the objective scar rating using the Beausang clinical scar assessment (r = 0.348, p = 0.294). Many of the participants were "angry," "shocked," and/or "amazed" by their scar, and evidently did not know what would happen during the cardiac procedure. The researchers recommend appropriate preprocedure preparation and postoperative counseling and support regarding the sternal scar in three areas:

1. Initiate a discussion about the potential impact of the sternal scar during consultation about cardiac surgery (i.e., preoperatively).
2. Enable patients to talk with health caregivers about their life in the early recuperative period.
3. Clinicians should clearly differentiate between the patient's objective rating of the surgery and subjective perceptions related to the scar.

Perioperative nurses should be aware of potential alterations to body image and be sensitive to (or initiate) discussions related to body image or what the patient thinks will be the physical and psychologic result of the surgery. Nurses also should be prepared for clinical questions from women about the scarring process itself. It is important to remember also that men may be sensitive to cosmetic results and issues of self-image and self-esteem.

Adapted from King KM et al: A descriptive examination of the impact of sternal scar formation in women, *Eur J Cardiovasc Nurs* 8(2):112-118, 2009.

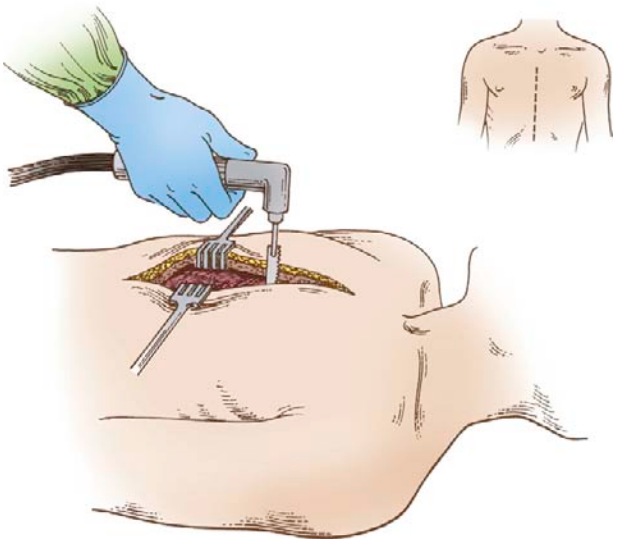


FIGURE 24-35 Median sternotomy with sternal saw.

right or left lateral thoracic incision may provide better exposure because of the presence of fewer adhesions.

MINI-THORACOTOMY. For minimally invasive cardiac procedures, a variety of smaller (up to approximately 4 to 8 cm) incisions and/or ports can be used. These include anterolateral chest incisions small enough for the insertion of specially designed instruments (see Figure 24-14), including video cameras and robotic arms. Minimally invasive cardiac procedures using smaller incisions may be performed under direct visualization or, increasingly, by means of video assistance.

CARDIOPULMONARY BYPASS. The temporary substitution of a pump oxygenator for the heart and lungs allows the surgeon to stop the heart to perform cardiac procedures under direct vision in a relatively dry, motionless field. It also allows the surgeon to manipulate the heart without the attendant risk of producing ventricular fibrillation and reduced cardiac output that jeopardize perfusion to the myocardial, peripheral, and cerebral tissues.

Under some circumstances, access to the anteroapical portion of the heart can be achieved without excess manipulation of the heart. Special retraction/stabilization devices (see Figure 24-17) allow the surgeon to create coronary artery bypass grafts (CABGs) to the anterolateral coronary arteries without the use of CPB and induced cardiac arrest. This enables surgery to be performed on a beating heart (discussed later).

In traditional CPB circuits, systemic venous return to the heart flows by gravity drainage through cannulae (Figure 24-36) placed in the superior and inferior venae cavae (Figure 24-37) or through a single two-stage cannula in the right atrium (Figure 24-38) into tubing connected to the bypass machine. Blood is oxygenated, filtered, warmed or cooled, and pumped back into the systemic circulation through a cannula placed in the ascending aorta or occasionally in the femoral artery (Figure 24-39) or the axillary artery (Khonsari et al, 2008). Because the CPB machine (Figure 24-40) oxygenates blood, the lungs do not need to function and can be deflated to provide better exposure of the mediastinal structures.

A percutaneous method of instituting femoral vein–femoral artery CPB can be used for minimally invasive (or conventional open) procedures (Figure 24-41) and in emergency situations where the environment is not conducive to traditional CPB methods (e.g., in the cardiac catheterization laboratory,

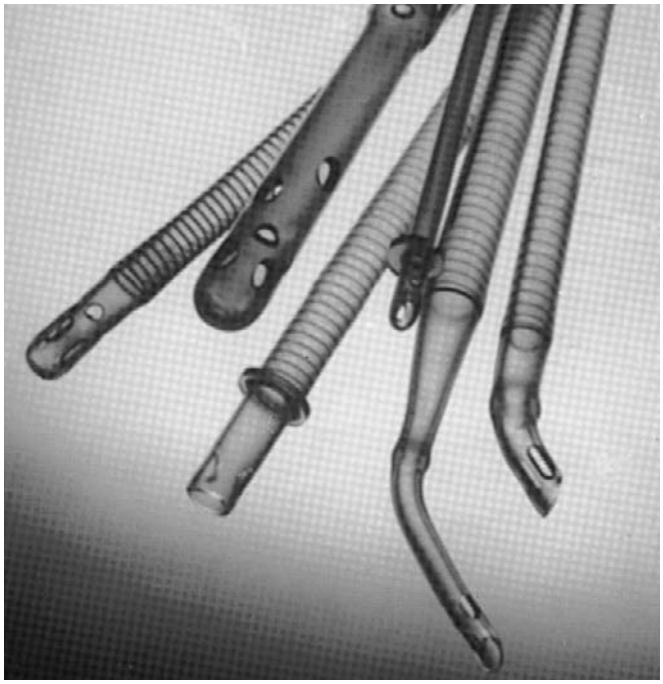


FIGURE 24-36 Arterial and venous perfusion cannulae.

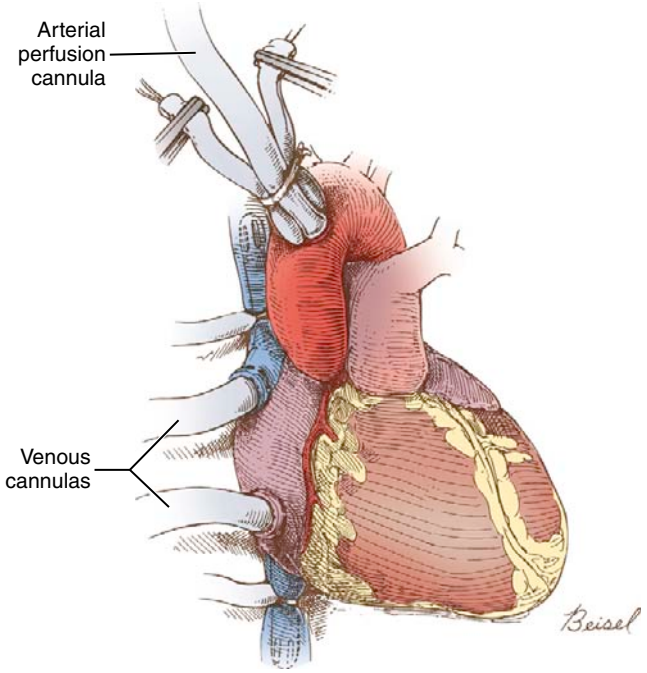


FIGURE 24-37 Bicaval cannulation of the superior and inferior venae cavae; aortic cannulation.

the intensive care unit, and the emergency department). The system employs thin-walled, wire-reinforced catheters inserted into the femoral vein or artery, or both. The resistance of the small-bore cannula used in the femoral vein can impede gravity drainage; to overcome this, a centrifugal pump may be used to actively siphon blood to the pump oxygenator. Other advances include the use of heparin-bonded bypass circuits and tubing; this reduces (but does not obviate altogether) the amount of heparin required to achieve systemic anticoagulation and can reduce bleeding and the associated need for blood products. Efforts to reduce platelet destruction and the inflammatory response by coating components of the CPB circuits with phosphorylcholine and other newer materials have shown some encouraging results (Schulze et al, 2009).

By diverting blood away from the heart, CPB also decompresses the ventricles, thereby reducing myocardial wall tension, which is a significant determinant of myocardial oxygen demand. This principle is evident when CPB or other means of ventricular support are employed to "rest" the heart. Further decompression is achieved by venting the left ventricle to remove air and accumulated thebesian and bronchial venous return as well as systemic return flowing around the venous cannulae (Figure 24-42). The venting catheter is inserted into the left ventricle by way of the right superior pulmonary vein or, less commonly, through the left ventricular apex. The venting line is connected to the suction lines of the bypass machine. A small venting catheter may also be inserted into the ascending aorta to remove air. Occasionally a vent is inserted into the pulmonary artery. Venting can reduce the incidence of gaseous microemboli. Ambient air removal can also be accomplished in cases when the heart is opened (e.g., valve surgery) with the insertion of a CO_2 gas diffuser; the gas is insufflated into the pericardial well. The CO_2 gas dissolves in blood approximately 25 times faster than room air; CO_2 retained within the cardiac chambers is better tolerated than ambient air and less harmful to tissue (Svenarud et al, 2004).

Improved bypass technology has also reduced the incidence of bypass-related microemboli and cellular injury with the use of finer filters for air and particulate emboli and moderation of the strength of siphoning pressures (Groom et al, 2009). Membrane oxygenators incorporated into the bypass circuit (see Figure 24-39) perform gas exchange (removing CO_2 and adding oxygen to the blood) more efficiently and less traumatically. Gases diffuse through a semipermeable membrane that separates the oxygenating gas and the venous blood. Although membrane oxygenators preserve platelet and red blood cell function better than the older "bubble" oxygenators, there does remain considerable morbidity associated with the use of CPB. Extracorporeal circulation causes fluid retention and intercompartmental fluid shifts, multiple organ dysfunction, showers of microemboli, inflammatory responses, and unique bleeding complications (Gourlay and Qureshi, 2008; Groom et al, 2009; Seifert, 2009). The mechanism of injury is believed to be related to the exposure of the blood to the abnormal surfaces of the bypass circuit, hypothermia, shear forces, and altered blood flow. These can initiate a systemic inflammatory response (complement activation), which releases vasoactive substances. Attempts to minimize the inflammatory reaction have focused on modifying the activation of platelets and blood factors that play a major role in initiating the response (Sniecinski and Levy, 2008). To avoid the complications associated with CPB, clinicians have stimulated greater use of "beating heart" ("off-pump") techniques for myocardial revascularization. It should be noted that "off-pump" techniques are not indicated for procedures requiring the heart to be opened (e.g., mitral valve surgery, left ventricular aneurysm repair) because air within the opened chamber would embolize to the brain. CPB enables the heart to be isolated from the systemic

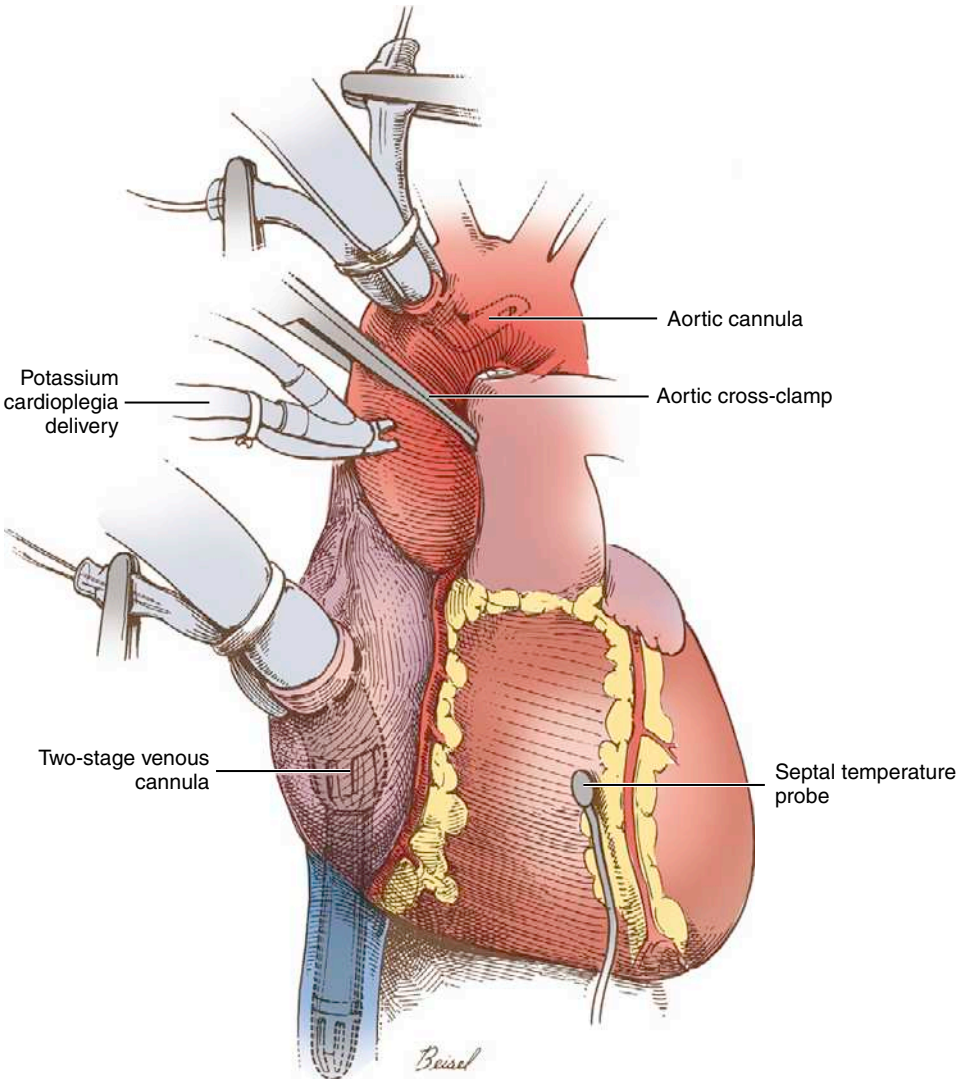


FIGURE 24-38 Diagram showing aortic and venous cannulae during aortic cross-clamping. Also shown is antegrade cardioplegic solution delivery catheter in the aorta proximal to the cross-clamp and a temperature probe. The single (two-stage) venous cannula has openings in the distal end of the cannula to drain the inferior vena cava; the openings in the midportion (right atrial area) of the cannula drain the superior vena cava and the coronary sinus venous return.

circulation so that after the repair is completed (and before the cross-clamp is removed) residual air can be removed through various venting techniques.

Two types of pumps are available: roller pumps and centrifugal pumps. Roller pumps have roller heads that propel blood forward by compressing blood-filled tubing against a smooth, metal housing. Centrifugal pumps use cones or blades that rotate at high speed to produce forward flow. All pumps produce some hemolysis from turbulence and shear forces, but careful calibration and minimal use of connectors can provide relatively atraumatic flow for short periods (e.g., less than 6 hours). Arterial blood flow on bypass is largely nonpulsatile, although modifications to the pump can simulate phasic (systolic/nonsystolic) flow (Gourlay and Qureshi, 2008); the arterial blood pressure is usually manifested by a mean arterial waveform on the oscilloscope during CPB.

Suction lines are ordinarily used during CPB to return shed blood to the venous reservoir and the oxygenator. These lines may combine conventional handheld suction tubes and ventricular decompression lines or sumps (see Figure 24-42). Before the initiation of CPB, the entire extracorporeal circuit must be primed and rendered free of air to prevent air emboli.

The priming solution is usually a combination of colloid and crystalloid fluids with a balanced electrolyte component. Priming volumes (i.e., within the CPB circuit) are generally between 1400 and 2000 ml (Frumento and Bennett-Guerrero, 2008). When the patient's blood volume mixes with the prime, there is some hemodilution and a subsequent reduction of the hematocrit (Hct) level. Advantages of hemodilution include reducing the number of homologous serum reactions and the incidence of hepatitis and human immunodeficiency virus (HIV) as well as providing better perfusion of the capillary beds because of reduced blood viscosity. Hct levels as low as 25% may be adequate during CPB, but once CPB is terminated, transfusion of red blood cells may be required to enhance the blood's oxygen-carrying capacity. In low-weight, low-hematocrit

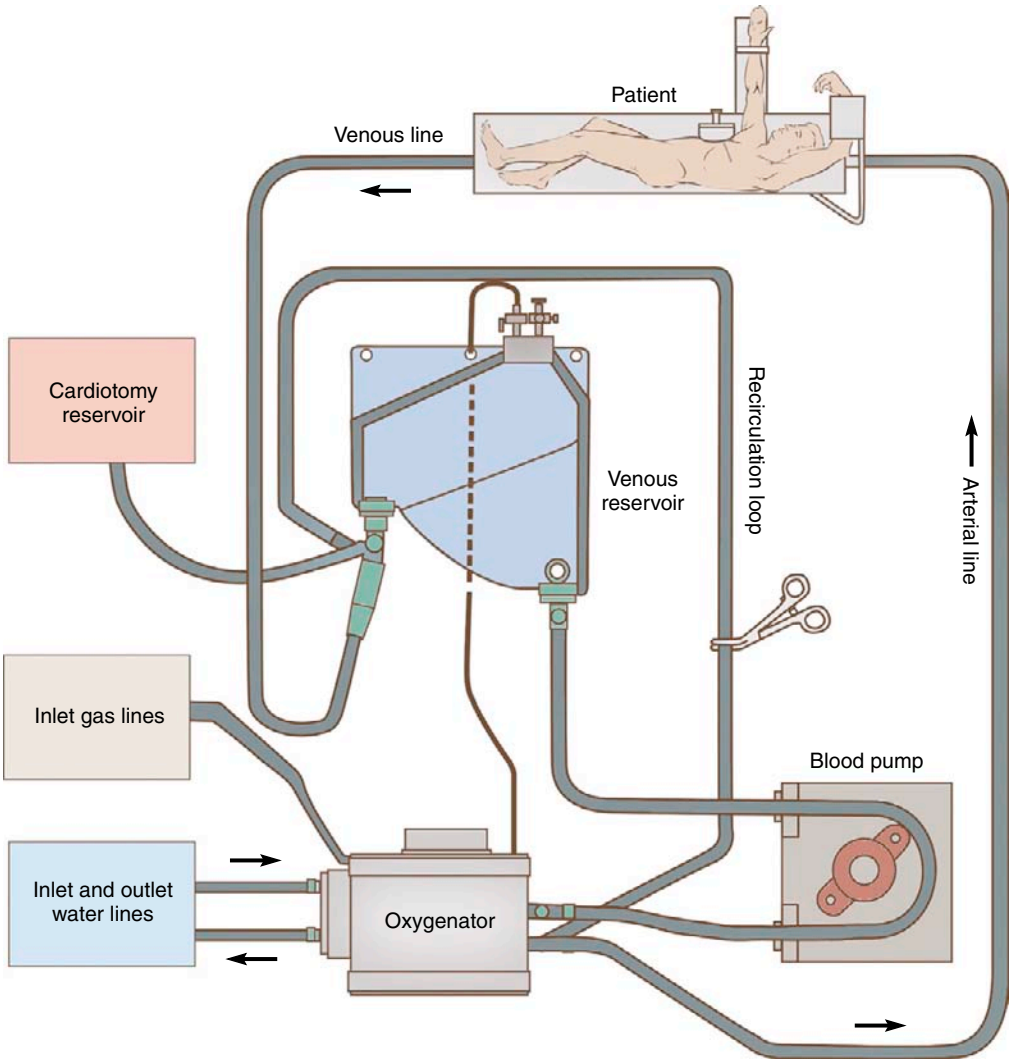


FIGURE 24-39 Cardiopulmonary bypass circuit. Venous blood is drained by gravity from the right atrium or venae cavae into an oxygenator that incorporates a blood reservoir and a heat exchanger, which warms or cools the blood as needed. The ventilating gas flowing into the oxygenator removes carbon dioxide and adds oxygen to the blood. Saturated blood leaves the oxygenator and is pumped from the reservoir into the arterial system by the use of a roller pump. Filters and monitors are incorporated into the circuit. Additional roller pumps are used to suction shed blood from the pericardial well and the intracardiac chambers (cardiotomy suckers); the blood is returned to the cardiotomy reservoir. Another roller pump is used to vent air and blood through a right superior pulmonary venous catheter that is inserted into the left ventricle.

patients, hemodilution may not be tolerated. One method to decrease hemodilution is to employ the technique of *rapid-autologous-prime* (RAP). First, the perfusionist shortens the length of bypass tubing (thereby reducing the volume of prime solution in the CPB circuit). After the surgeon inserts the arterial cannula into the aorta and connects it to the arterial tubing leading to the bypass machine (but before initiation of bypass), the perfusionist allows a predetermined amount of the patient's arterial blood to drain from the line and fill part of the bypass circuit; the perfusionist then clamps the circuit. The clamps are removed at the initiation of bypass (Frumento and Bennett-Guerrero, 2008).

The amount and kind of drugs used in the priming solution vary among institutions, but heparin is routinely added to block clot formation in the bypass circuit. Anticoagulation is routinely monitored during bypass, and more heparin is given as needed to maintain an activated clotting time (ACT) exceeding 600 seconds. Other ingredients are added to maintain normal pH and electrolyte status (Frumento and Bennett-Guerrero, 2008).

Arterial blood flow rates are estimated according to the patient's height, weight, and body surface area. Depending on the arterial and venous pressure values and the results of blood gas determinations, the flow is adjusted.

Myocardial Protection. Improvement in the results of cardiac surgery is attributable in great part to progress made in the protection of the myocardium. Coronary circulatory interruptions, ischemia, and hypoperfusion accompanying induced cardiac arrest are often necessary to permit the surgeon

sufficient time to repair cardiac lesions under direct vision. Unless measures are taken to protect the myocardium during these periods, irreversible damage can result. The main protective strategies are cooling the heart (and the rest of the body) to reduce metabolic demand, rapidly arresting the heart so that myocardial energy resources are preserved, and restoring intracellular homeostasis (e.g., by correcting pH, oxygen, and electrolyte imbalances) to avoid postischemic reperfusion injury (Mentzer et al, 2007).

FIGURE 24-40 Cardiopulmonary bypass pump. Modular system with integrated centrifugal pump driver.

HYPOTHERMIA. Hypothermia in cardiac surgery is the deliberate reduction of body temperature for therapeutic purposes. A moderate degree of hypothermia, to 28° C (82.4° F), permits reduction of oxygen consumption by 50%. At 20° C (68° F) there is a further reduction of about 25%. Systemic circulatory cooling is achieved with the heat exchanger of the heart-lung machine. When very cold temperatures (less than 20° C [68° F]) are desired for myocardial protection in prolonged, complex cases, additional surface cooling of the heart with topical application of cold saline/slush or continuous irrigation of the pericardial wall can be used. Large ice chips in pericardial irrigating fluids should be avoided to prevent injury to the phrenic nerve within the right and left lateral pericardium and other cardiac tissue. Insulation pads placed behind the heart can reduce heat conduction from relatively warmer organs. Transmural cooling of the heart is achieved with cardioplegia (discussed later).

Ventricular fibrillation can occur during the cooling process although it is less likely at temperatures greater than 32° C (89.6° F). Other complications are related to the adverse effects that hypothermia has on coagulation and wound healing; this may delay hemostasis after heparin reversal and have an impact on recuperation (Edmunds, 2004; Mentzer et al, 2007).

CARDIOPLEGIC ARREST. Rapidly arresting the heart during diastole is beneficial because an arrested heart uses less energy than a fibrillating or beating heart. Cardioplegia with hypothermia can reduce energy requirements even further

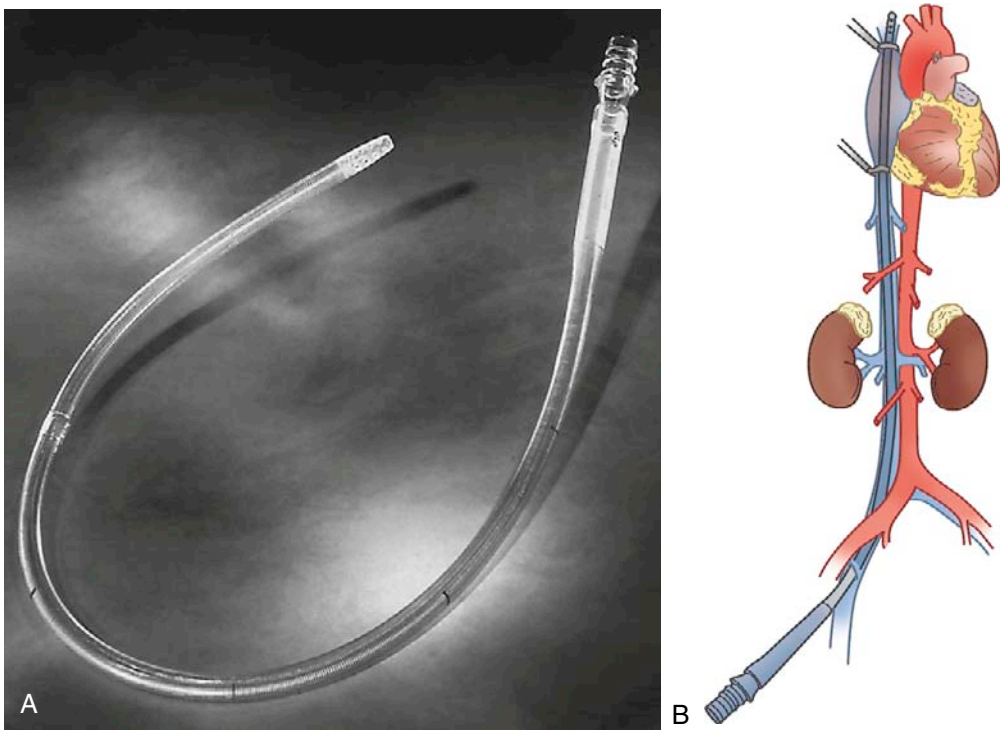


FIGURE 24-41 **A**, Venous endovascular cannula. **B**, The catheter tip is inserted into the femoral vein and threaded to the right atrium; the distal tip is positioned in the superior vena cava (SVC) to drain the upper body.

(Mentzer et al, 2007). Both "warm" and "cold" heart surgery proponents concur that infusing a warm initial bolus of cardioplegia acts as a form of active resuscitation in energy-depleted hearts. There is also concurrence that providing a warm terminal bolus of cardioplegia helps to avoid reperfusion injury (caused by oxygen free radicals and lactic acid buildup) by providing oxygen and other nutrients to the heart. The controversy lies in the use of normothermic ("warm") cardioplegia during the period of arrest when the actual surgical repair or bypass construction occurs. Proponents of warm arrest techniques seek to avoid the complications associated with hypothermia; warm cardioplegia is delivered continuously while the surgical repair is performed (Salerno, 2007). Opponents of continuous warm cardioplegia cite the technical difficulty associated with a constant flow of cardioplegia obscuring the surgical site. Some authors favor intermittent cold cardioplegia infusions because if cardioplegia infusions are even momentarily interrupted to enhance visualization, myocardial protection is jeopardized (Mentzer et al, 2007; Khonsari et al, 2008).

CARDIOPLEGIA DELIVERY. Cardioplegic arrest is accomplished by infusing the coronary arteries with a 4° to 10° C (39.2° to 50° F) solution containing potassium (2 to 50 mEq/L) and buffering agents to counteract ischemic acidosis. Potassium acts by depolarizing the myocardial cell membrane and arresting the heart in diastole.

Delivery of the solution may be by the antegrade or the retrograde route (Figure 24-43). With antegrade delivery, a needle is inserted into the aortic root proximal to the aortic cross-clamp; the cardioplegic solution is infused under pressure that closes the aortic valve leaflets. The only remaining route for the solution is into the right and left coronary arteries and the coronary circulation (see Figure 24-38). If the aortic valve does not close properly, the cardioplegic solution will flow preferentially into the left ventricular chamber, causing distention; in these cases direct cannulation of the coronary ostia is performed. Direct infusion into vein grafts protects the myocardium distal to coronary lesions and enhances transmural cooling. Retrograde infusion is achieved with a catheter placed transatrially into the coronary sinus; the perfusate enters the coronary venous system and flows through the myocardial circulation, leaving through the coronary ostia. The retrograde route is especially useful in the presence of coronary artery obstructions and left ventricular hypertrophy.

When the heart is sufficiently arrested, the ECG reflects a straight line; when electrical activity is noted on the monitor (fine fibrillation), the cardioplegic solution is reinfused when continued cooling is desired (approximately every 15 to 20 minutes).

Minimally invasive techniques for myocardial protection have also been developed (described under Cardioplegic Delivery). Percutaneously inserted catheters can infuse antegrade cardioplegic solution through a catheter threaded into the aortic root; retrograde cardioplegic solution is infused through a catheter inserted into the internal jugular vein and then passed into the SVC, the right atrium, and the coronary sinus.

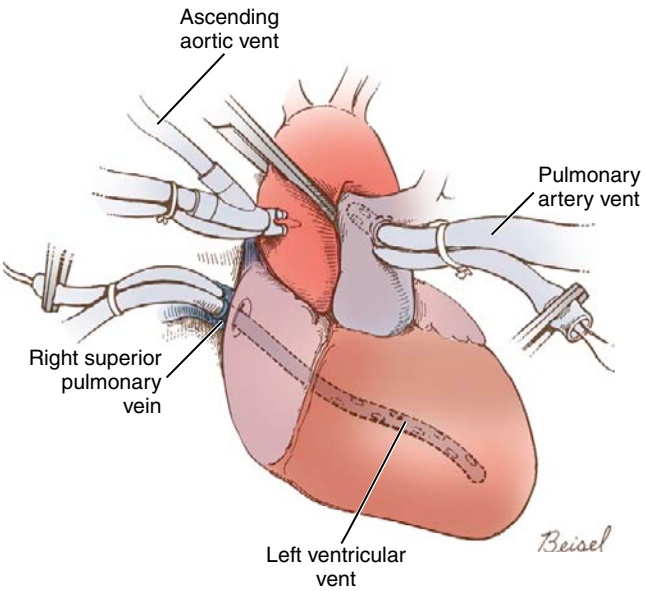


FIGURE 24-42 Types of venting catheters.

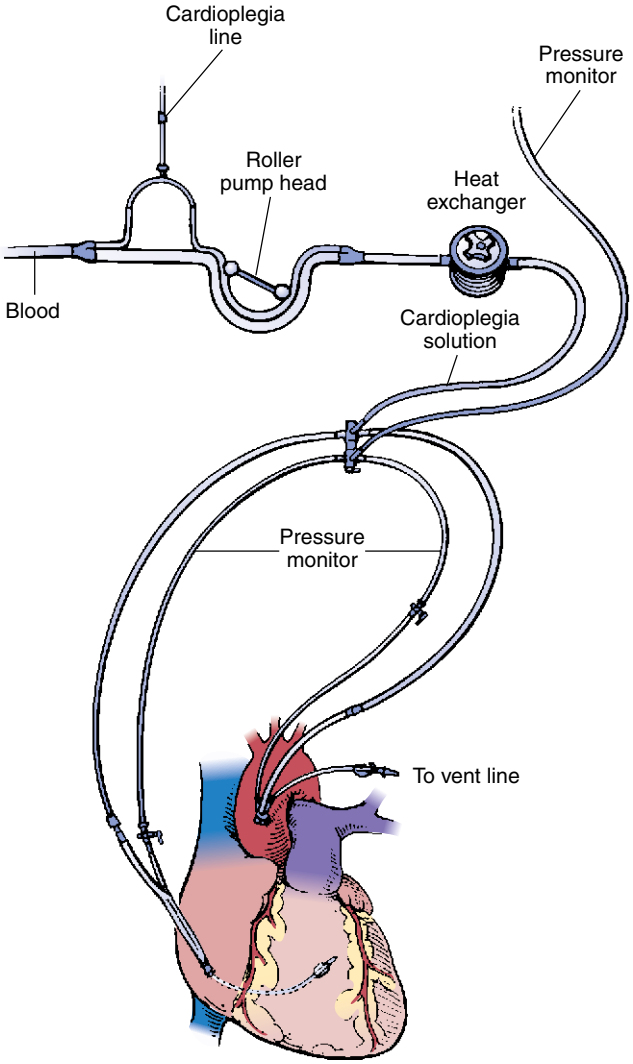


FIGURE 24-43 Antegrade-retrograde cardioplegia system. The antegrade cardioplegia catheter is inserted into the aorta proximally to the cross-clamp; the catheter is Y-ed into a vent line and into the retrograde cardioplegia catheter, which is inserted transatrially into the coronary sinus. The coronary sinus pressure is monitored; its pressure should remain less than 50 mm Hg.

CIRCULATORY ARREST. In some highly complex procedures, such as those involving the aortic arch, it may be impossible to place an occluding clamp across the aorta. In these cases, circulatory arrest may be used to maintain a dry operative site. Because all blood flow will be interrupted, additional protection is required to protect myocardial, cerebral, and other tissue from ischemia.

The patient is cooled with the heat exchanger to approximately 18° C (65° F), at which point the bypass pump is turned off (Pretre and Turina, 2007). The incision is made, and the repair is performed. The small amount of collateral drainage entering the field can be removed with a suction catheter. When the repair is completed, air is removed and CPB is slowly reinstituted. Rewarming is performed at a rate of approximately 1° C every 3 minutes.

CEREBROPLEGIA. Circulatory arrest poses additional risk to the brain. Cerebral protection, cerebroplegia, is provided by the infusion of oxygenated blood to the brain. *Antegrade* cerebral perfusion is achieved with the insertion of cannulae directly into the innominate artery, the right common carotid artery, or another branch of the aortic arch. *Retrograde* cerebral perfusion is accomplished using a cannula that has been Y-ed to the superior vena cava drainage cannula that connects to the arterial infusion line. When blood flow is stopped (during circulatory arrest), the venous line is clamped, the connection to the arterial line is opened, and the retrograde cerebral perfusion line is used to infuse cerebroplegia into the head vessels (Pretre and Turina, 2007). Blood returning from the head (through the carotid or vertebral arteries) is suctioned from the field.

Termination of Cardiopulmonary Bypass. Near the end of the repair, the heart is allowed to rewarm while the perfusionist rewarms the patient systemically with the oxygenator's heat exchanger. Air is evacuated from the left ventricle and the proximal portion of the aorta. The cross-clamp is removed. The heart often converts spontaneously to sinus rhythm, but internal (or external) defibrillation may be necessary. Temporary epicardial pacing wires may be sutured to the right atrial appendage or the right ventricle; these are used postoperatively if the patient has transient bradycardia, supraventricular tachycardia, or other dysrhythmias. Atrial fibrillation (AF) is a common postoperative complication that is associated with a greater risk of embolic events and increases the patient's length of stay (Sethares et al, 2008).

When the heart is contracting, the patient is gradually weaned from CPB. Ventilation of the lungs is restarted. Venous flow is gradually reduced by clamping the venous line or lines, and a commensurate reduction in arterial flow is made by the perfusionist. When heart action is sufficient and systemic and pulmonary blood pressures are stabilized, the bypass is terminated and the cannulae are removed.

Measures to actively promote body heat retention are implemented to enhance clotting mechanisms, immune function, and oxygenation. Maintenance of normothermia after the termination of CPB has also been recommended to reduce the risk of postoperative infection (Savino and Cheung, 2007).

Closing. After hemostasis is achieved, catheters are inserted into the pericardium for mediastinal drainage of shed blood. If either or both pleurae have been entered, chest tubes are inserted to drain shed blood entering from the pericardium and to create negative intrapleural pressure to facilitate lung expansion. The tubes are connected to a water-seal drainage system or an autotransfusion drainage system by using straight or Y connectors. Chest tube drainage of greater than 100 ml/hr requires investigation of possible causes (Sethares et al, 2008). The clinician anticipates possible blood studies to determine whether clotting factors require replacement, hemostasis of anastomoses is present, or bypass conduits require exploration. Reopening the chest may be necessary to control bleeding.

Chest closure in median sternotomy is achieved with wire sutures (see Figure 24-19). The wire sutures are twisted, excess wire is cut, and the wire ends are buried into the sternal periosteum. Some surgeons use small metal crimpers to approximate and hold the wires (rather than twisting and burying the wire ends). In a frail sternum, a long sternal closing wire may be threaded longitudinally along the right and left lateral margins of the sternum; the crossed sternal wires are inserted through the longitudinal wires and then approximated to close the sternum. This reinforces the sternal closure and reduces the possibility of sternal dehiscence. In some thin patients with little subcutaneous tissue over the sternum, one (or more) of the sternal wires may continue to cause discomfort after the sternum has fully healed. In these patients the surgeon may elect to remove the wire as an ambulatory (outpatient) procedure (Ambulatory Surgery Considerations).

The linea alba is closed with suture. A layer of sutures is placed to approximate the fascia over the sternum; the subcutaneous tissue and skin are closed. If metal staples are used on the skin, a staple remover should accompany the patient to the recovery area. Thoracotomy incisions are closed in standard fashion.

Before transferring the patient, the perioperative nurse telephones a report to the recovery area, usually the cardiovascular SICU. Figure 24-44 lists information commonly supplied. The patient's special concerns and fears as well as significant physiologic alterations should be communicated.

Perioperative documentation follows the standard protocol and includes a description of the procedure performed and identification of medications and all implanted material (with lot and serial numbers). Hospital policy should be followed to ensure compliance with the Safe Medical Devices Act.

AMBULATORY SURGERY CONSIDERATIONS

Removal of Sternal Wire

Ambulatory surgery patients undergoing removal of one or more sternal wires are placed in the supine position. Monitoring generally consists of an electrocardiogram and pulse oximetry. Anesthesia may be "straight local" or monitored anesthesia care. The anterior chest is prepped and draped, and the surgeon may inject a local anesthetic over the skin covering the sternal wire. A small incision is made over the wire and the tissue and adjacent adhesions are divided. The wire is cut with a wire cutter and the wire is removed with a heavy needle holder. Hemostasis is achieved, the incision is closed, and dressings are applied. After a short period in the PACU or other recovery area, the patient is discharged.

Patient Transfer Report

PROCEDURE (include source of autogenous grafts) on pump _____ off pump _____

Endoscopic vein harvest yes ___ no ___ N/A ___

MONITORING DEVICES (LOCATION)

CVP _____ Arterial Line_____ SWAN _____ Peripheral _____

LA _____ Other_____

HEMODYNAMICS

BP _____ PAP _____ PAD _____ PAWP _____ CO _____ CI _____ CVP _____ Svo_2 _____

INTRAOPERATIVE OCCURRENCES

BLOOD LOSS _____ URINE _____ DYSRHYTHMIAS _____ BYPASS

PROBLEMS _____ DEFIB X's _____ LO TEMP _____ HI TEMP_____

CROSS-CLAMP TIME _____ PUMP TIME _____

BLOOD: GIVEN _____ AVAILABLE _____ AUTOTRANSFUSION TOTALS: _____ ml _____ Units

COMPONENTS: FFP _____ PLATELETS _____ CRYO _____

ADDITIONAL ORDERED (TYPE) _____

MEDICATIONS

NEO _____ DOPAMINE _____ DOBUTAMINE _____ LIDOCAINE _____ NITRO _____

LEVOPHED _____ EPINEPHRINE _____ NITROPRUSSIDE _____ INOCOR _____

DDAVP _____ OTHER _____

TUBES/DRAINS: MEDIASTINAL _____ PLEURAL (Rt/Lt) _____

EPICARDIAL LEADS: ATRIAL _____ VENTRICULAR _____

PACING: YES/NO RATE_____

LABS:

K+ _____ Na+ _____ Glu _____ Hgb _____ Hct _____

PATIENT CONCERNS _____

ADDITIONAL INFORMATION _____

ICU BED # _____ ETA _____

REPORTED BY _____

To _____ TIME _____

BP, Blood pressure; *CI*, cardiac index; *CO*, cardiac output; *CRYO*, cryoprecipitate; *CVP*, central venous pressure; *DDAVP*, 1-deamino-8-*D*-arginine vasopressin (e.g., Desmopressin); *ETA*, estimated time of arrival; *FFP*, fresh frozen plasma; *Glu*, glucose; *Hct*, hematocrit; *Hgb*, hemoglobin; *K+*, potassium; *LA*, left atrial; *Na+*, sodium; *NEO*, Neo-Synephrine; *NITRO*, nitroglycerine; *PAD*, pulmonary artery diastolic pressure; *PAP*, pulmonary artery pressure; *PAWP*, pulmonary artery wedge pressure; *Svo_2*, percent saturation of mixed venous blood; *SWAN*, Swan-Ganz (pulmonary artery) catheter.

FIGURE 24-44 Patient transfer report.

Postoperatively, complications associated with cardiac surgery are outlined in Table 24-7. Excessive or sudden hemorrhage producing cardiac tamponade may initiate the need for a rapid response team to control the hemorrhage and achieve hemostasis.

Evaluation

Evaluation of perioperative care includes the determination of whether the patient met the outcomes identified in the plan of care. Such evaluation assists perioperative nurses to determine whether the nursing interventions designed for a specific patient were successful. This type of data collection becomes the basis of the development of future plans of care for similar patients. Evaluation should be documented in the perioperative record. For the nursing diagnoses and the subsequent plan of care presented in this chapter for the cardiac surgery patient, outcome statements might be as follows:

- The patient's cardiac function was consistent with or improved from baseline levels established preoperatively as evidenced by blood pressure within expected range; warm, dry skin; and urine output more than 30 ml/hr.
- The patient will be free from signs and symptoms of infection at the surgical site or sites as evidenced by absence of redness, edema, purulent incisional drainage, or untoward elevation of temperature postoperatively.
- The patient was free from signs and symptoms of injury related to surgical position as evidenced by the absence of acquired neuromuscular impairment and tissue necrosis.

TABLE 24-7

Complications of Cardiac Surgery

Body System	Complication	Treatment Measures
Cardiovascular	Bleeding	Transfusion Replacement of clotting factors Control of hypertension Maintenance of normothermia Possible return to OR for exploration and hemostasis
	Cardiac tamponade	Release of constricting blood via chest tube insertion or operative exploration
	Myocardial ischemia/infarction	Monitor ECG for ischemic changes Measure serum enzymes Minimize oxygen demand Administer medications to reduce cardiac workload and dysrhythmias Insertion of an IABP
	Dysrhythmias	Administer antidysrhythmic drugs Correct electrolyte imbalances Correct acid-base, hypovolemia Employ pacemaker therapy Cardiovert or defibrillate as necessary Maintain adequate CO
Pulmonary	Hemothorax/pneumothorax	Maintain chest tube patency Check chest tubes for air leaks Insert additional chest tube (pleural or mediastinal)
	Atelectasis/pneumonia	Check ventilator settings and endotracheal tube Suction endotracheal tube Monitor breath sounds Monitor pulse oximetry Obtain chest x-ray film Elevate head of bed Ensure proper function of NG tube After extubation, encourage mobilization and use of incentive spirometry Frequent staff handwashing
	Pulmonary embolus	Frequent patient mouth care Employ compression stockings Assess for acute chest pain and SOB Perform radiologic examination Possible surgical embolectomy
	Failure to wean from ventilator	Maintain aggressive pulmonary toilet Monitor pulse oximetry Frequent mobilization (even while on ventilator) Pain and anxiety management Incentive spirometry once extubated Possible tracheostomy
Kidneys	Renal insufficiency/failure	Promote adequate CO, renal perfusion Monitor urine output Diuretics for oliguria Administer volume (vs. drugs) to increase renal perfusion Possible dialysis
Gastrointestinal (GI)	Ileus	Assess bowel sounds and distention Maintain NG tube function Progress diet slowly
	GI bleeding	Maintain NG tube function to differentiate upper and lower GI bleeding Stress ulcer prophylaxis Monitor complaints of nausea Use extra caution with anticoagulants
Neurologic	Stroke	Avoid hypotension Assess neurologic function Restart preoperative antidepressant drugs
	Neurocognitive dysfunction/ postcardiotomy delirium	Avoid hypoperfusion Correct metabolic derangements Avoid hypoxemia Orient frequently to time and place Discontinue medications that may promote delirium Ensure a safe environment

TABLE 24-7

Complications of Cardiac Surgery—cont'd

Body System	Complication	Treatment Measures
Immune	Nosocomial infection	Frequent staff hand cleansing Strict aseptic technique Dressing care, urinary catheter care Early removal of central lines, urinary catheters, chest tubes Administer antibiotics
	Mediastinitis	Strict aseptic technique Administration of antibiotics
Metabolic	Hyper/hypoglycemia	Limited blood transfusion Glucose (hyperglycemic) control Possible return to OR for debridement and muscle flap repair Avoid hyperglycemia (maintain glucose at less than 200 mg/dl) Avoid hypoglycemia Monitor for potential rebound from insulin administered during surgery

CO, Cardiac output; *ECG,* electrocardiogram; *IABP,* intra-aortic balloon pump; *NG,* nasogastric; *OR,* operating room; *SOB,* shortness of breath.
Modified from Sethares K et al: Care of patients undergoing cardiac surgery. In Moser DK, Riegel B, editors: *Cardiac nursing: a companion to Braunwald's heart disease,* St Louis, 2008, Saunders; Gray RJ, Sethna DH: Medical management of the patient undergoing cardiac surgery. In Libby P et al, editors: *Braunwald's heart disease,* ed 8, Philadelphia, 2008, Saunders; Babb M: Clinical risk assessment: identifying patients at high risk for heart failure, *AORN J* 89(2):273-288, 2009.

- The patient was free from excessive bleeding as evidenced by chest tube drainage less than 100 ml/hr, dressings dry and intact, normal coagulation function studies (or undergoing replacement treatment for deficient clotting factors), and normal body temperature.
- The patient demonstrated knowledge of the physiologic responses to the cardiac disorder (at his or her level of understanding), the proposed surgical treatment, and the immediate perioperative events as evidenced by verbalization of disease state, purpose of surgery, sequence of events, anticipated outcomes, and recovery process.
- The patient's myocardial, peripheral, and cerebral tissue integrity was adequate: there were no new electrocardiographic manifestations of infarction, peripheral pulses were palpable, and his/her sensorium was improving after extubation in the OR.

Patient and Family Education and Discharge Planning

Many patients are admitted to the cardiac service on the day of surgery; teaching sessions can be scheduled before admission along with preoperative laboratory testing. Perioperative nurses should include details about the surgical procedure, sights and sounds that the patient may sense, and anesthesia care. With hospital length of stay shortened from 1 week or more to 3 to 5 days, patient education and preparation for home care maintenance has become even more critical for enhancing positive patient outcomes. The perioperative nurse acts to reinforce, review, clarify, and add to important information and instructions the patient and family or significant others need in planning for surgery, recovery, and discharge. Although patients undergoing repeat operations have had experience with cardiac surgery, they still have significant learning needs because changes in their own disease, alterations in surgical techniques, and the introduction of newer devices alter the expectations of patients (Setheres et al, 2008). Published articles about innovative endovascular thoracic repairs (Thompson and Bertling, 2009) as well as procedures becoming increasingly common, such as endoscopic vein harvesting (Pear and Williamson, 2009), are valuable resources. The *AORN Journal* initiated a "Patient Education" page to accompany many clinical articles in order to assist perioperative nurses in their cardiovascular patient teaching activities (see Thompson and Bertling, 2009; Tinkham, 2009; Cherry et al, 2009). The *Journal of the American Medical Association* (JAMA, 2009) offers a patient education page. Another area of intense patient interest is minimally invasive surgery and comparisons of "on-pump" and "off-pump" techniques (Patient and Family Education).

Additional resources (electronic, peer support) can supplement traditional education strategies. An expanding array of internet sites developed by professional organizations can be accessed for examples of patient information. The American College of Surgeons (ACS, 2009a,b), the American Heart Association (AHA, 2009b,c), the American Society of Anesthesiologists (ASA, 2009), and the Society of Thoracic Surgeons (STS, 2009) all have cardiac-related information for consumers as well as staff. Support groups such as The Mended Hearts (www.mendedhearts.org/) provide education, support, and social networking among cardiac surgical patients. Electronic mail (e-mail) is an increasingly popular form of communication between patients and caregivers and some cardiac surgical practice groups as well as healthcare institutions have interactive web sites.

In addition to specific information about the perioperative period, the cardiac patient's preoperative state of mind may be a significant factor. Depression and anxiety are associated with major adverse cardiac events (MACE) such as myocardial infarction, cardiac arrest, or cardiac death (Frasure-Smith and Lesperance, 2008). Halpin and Barnett (2005) showed that a negative (i.e., pessimistic) state of mind (compared with an optimistic state) may be predictive of an increased length of stay, increased possibility of stroke, and prolonged ventilation time. Having the patient complete a preoperative mental health status questionnaire, or being aware of the results of a previously completed questionnaire, can provide insight into the patient's frame of mind and serve as an opportunity to alter

PATIENT AND FAMILY EDUCATION

Patient Teaching Considerations for Minimally Invasive Surgery (On/Off Pump)

	Beating Heart/Off-Pump	Arrested Heart/On-Pump
Definition	CABG without CPB or induced cardiac arrest; HR and contractile force may be pharmacologically reduced; stabilizer used at anastomotic site; apical retractor used to expose lateral and posterior coronary arteries	CABG with CPB and endovascular technique for CPB and induced cardiac arrest
Indications	Multiple-vessel disease, angioplasty contraindicated, medical problems, poor anatomy, accessible target arteries, previous CABG with blocked grafts	Multiple-vessel disease, angioplasty contraindicated, need to stop heart to enhance technical precision, accessible target arteries, valve or other cardiac disease requiring entry into a heart chamber
Contraindications	Intramyocardial lesions, hemodynamic instability	Highly complex lesions, posterior targets
Incisions	Sternotomy or mini-sternotomy (cephalad or caudad); 1-3 small right or left rib or submammary incisions	1-4 small rib incisions, 1 or 2 groin incisions, 1 or 2 neck incisions
CPB	No, available on standby	Yes
Cardioplegia	No	Yes
Procedure time	2 hr or more	2 hr or more
Hospital LOS	2-5 days (vs 4-6 for sternotomy)	3-5 days (vs 4-6 for sternotomy)
Advantages	Avoids CPB, ischemic arrest, and hypothermia; may enable more complete revascularization with postoperative insertion of intracoronary stents into posterolateral coronary arteries in cardiac catheterization laboratory ("hybrid" procedure); may reduce MACE in patients with LMD	Allows repair of more complex lesions without technical challenge of a moving heart; better able to produce more complete revascularization; significantly reduces air embolism as a result of opening cardiac chambers
Potential complications and disadvantages	Learning curve technically more challenging; may cause VF; may have to revert to standard sternotomy with CPB and induced arrest	Learning curve technically more challenging; may have to revert to standard sternotomy; potential for endovascular injury to cannulated blood vessels
Discharge planning	Anticipated faster recovery of 1-2 wk (vs 4-12 wk for sternotomy), earlier ambulation, need to identify reportable signs and symptoms (angina, difficulty breathing, infection)	Anticipated faster recovery of 1-2 wk (vs 4-12 wk for sternotomy), earlier ambulation, need to identify reportable signs and symptoms (angina, difficulty breathing, infection)

CABG, Coronary artery bypass grafting; *CPB,* cardiopulmonary bypass; *HR,* heart rate; *LMD,* left main coronary artery disease; *LOS,* length of stay; *MACE,* major adverse cardiac events; *VF,* ventricular fibrillation.

Modified from Sarin EL et al: Off-pump coronary bypass grafting is associated with reduced operative mortality and in-hospital adverse events in patients with left main coronary artery disease, *Innovations* 4(2):80-85, 2009; Verma S et al: Off-pump coronary artery bypass surgery, *Circulation* 109:1206-1211, 2004.

pessimistic attitudes amenable to conversion to a more positive state of mind. Patient attitudes also may be affected by the anticipation of pain and the hesitation to complain of pain or request pain medication. Perioperative nurses can anticipate those fears and encourage patients to ask for pain medications in order to facilitate early postoperative ambulation, deep breathing and coughing, and other activities that promote recovery.

Specific information may be required. Patients undergoing prosthetic (i.e., mechanical) valve replacement can expect to require long-term anticoagulation therapy. Important information includes drug dosage, reportable signs and symptoms of complications and side effects (e.g., bleeding, poor healing), and a follow-up protocol for monitoring bleeding times.

The patient's ability to cough and breathe deeply should be determined; the patient should be instructed to use a cough pillow or splinting techniques. Required lifestyle changes should be reviewed and the patient's feelings about these modifications elicited. The perioperative nurse should verify that the patient knows reportable signs and symptoms associated with the specific procedure and understands prescribed medications, including medication dosages, potential side effects, and signs and symptoms of complications (see Table 24-7). Any misconceptions should be clarified or referred to an appropriate source. The family or significant others' ability and willingness to assist the patient in home care maintenance should be queried; referrals to an agency for assistance at home may be required.

Quality of life is an important goal for patients. Although objective measures are often used by clinicians to determine the patient's level of satisfaction with the quality of care received, measuring the patient's quality of life experienced after surgery has been largely limited to evaluating angina relief and return to work. However, other important variables may reflect quality of life, and nurses can assist patients with recovery and recuperation by incorporating these variables into the discharge plan. Quality of life for family caregivers also needs to be considered because with shortened lengths of stay, patients increasingly depend on others to assist them in the recuperative process. Support for caregivers is an important adjunct

RESEARCH HIGHLIGHT

Perioperative Nurse Postoperative Visits

Since 2001 perioperative cardiac nurses at a hospital in Orebro, Sweden, have made postoperative visits to cardiac surgical patients. A prospective exploratory study (N = 74 patients) was designed to evaluate the quality of the postoperative follow-up and to determine if the quality of the visit was related to gender or type of admission. The measurement instrument contained 16 items designed to elicit patients' perception of quality. There were statistically significant higher scores measuring quality in patients who had undergone emergency surgery compared with patients having elective surgery (e.g., coronary artery bypass grafting, valve surgery, aortic dissection repair). The postoperative follow-up visit by the perioperative nurse was perceived to be valuable by patients, especially by those who had undergone emergency surgery.

Compared to men, women rated a significantly higher quality score in two items:

1. "I had [the] possibility to see and feel material used during a heart operation, as an example, sternum suture, mechanical valve, and graft suture" (p. 108).
2. "I had satisfactory information about the technical equipment used at the operation, as an example, the heart-lung machine" (p. 108).

Both men and women assigned high scores to experiencing respect and seriousness and having a meaningful postoperative follow-up visit by the theatre (i.e., perioperative) nurse.

The study authors suggest that a caring relationship is established during the follow-up visit as a result of meeting the patient as an individual with his/her own experience, and meeting patients' desire for information about the pre-, intra- and postoperative periods of the surgery. Perioperative nurses should employ drawings and "props" (such as mechanical heart valves, suture, and short sections of bypass tubing) to supplement their teaching. This study reinforces the value of postoperative visits to cardiac surgical patients by perioperative nurses.

Adapted from Falk-Brynhildsen K, Nilsson U: Cardiac surgery patients' evaluation of the quality of theatre nurse postoperative follow-up visit, *Eur J Cardiovasc Nurs* 8(2):105-111, 2009.

in the patient's recovery. Nurses can help patients set realistic postoperative goals and develop strategies for appropriate lifestyle changes. The subjective perceptions of patients usually accurately reflect the patient's quality of life. At times when the quality of life is perceived as suboptimal (e.g., during a difficult recuperative period), the nurse can reassure patients that physical, emotional, and psychologic improvement is a progressive process (Dickson and McMahon, 2008; Seifert, 2008).

A patient's perception and the clinical indications for treatment may not be congruent but clinicians should recognize that the patient's definition of "quality of life" should be investigated and addressed whenever feasible. Postoperative visits can elicit patient needs (Falk-Brynhildsen and Nilsson, 2009) (Research Highlight). In some individuals who have little tissue covering the sternum, one or more chest wires may become a significant irritation following complete sternal healing. Patients may constantly rub the tissue over the wire, increasing risk for injury to the skin and subcutaneous tissue. As previously noted, removal of the irritating chest wire can be performed on an ambulatory basis (see Ambulatory Surgery Considerations). Although there are relatively few ambulatory procedures related to cardiac surgery, nurses should be as sensitive to relatively "minor" patient concerns as they are to the more serious problems jeopardizing hemodynamic stability.

Surgical Interventions

The following section describes operations for acquired forms of heart disease. Both traditional "open" procedures and minimally invasive techniques are described. Traditional procedures are performed through a median sternotomy incision using aortocaval CPB (see Figures 24-37 and 24-38) and antegrade-retrograde cardioplegia (see Figure 24-43) with routine chest drainage and closure. Minimally invasive procedures are described for CPB, saphenous vein harvesting, coronary artery bypass grafting, atrial fibrillation, and MVR. These procedures may be performed through a median sternotomy or an anterior left or right thoracotomy; some lesions may be approached through a cephalad or caudal mini-sternotomy.

EXTRACORPOREAL CIRCULATION PROCEDURES

Operative Procedures

Aortic-Caval Cannulation by Way of Sternotomy

1. A longitudinal pericardial incision is made, and the pericardial edges are retracted by suture to the chest wall.
2. If the aorta is to be cannulated for arterial blood return to the patient, it is partially dissected from the pulmonary artery.
3. Purse-string sutures are placed in the aorta (twice) and right atrium (or both venae cavae) for the eventual placement of the perfusion cannulae. Tourniquets are placed over the suture ends and held with a hemostat.
4. For ascending aortic cannulation, the aorta is incised inside the purse-string sutures with a knife (the surgeon places a finger over the aortotomy); the cannula is inserted, and the purse-string sutures are firmly secured with the tourniquet. It is important to have the distal end of the cannula clamped before it is inserted into the aorta to prevent backbleeding from the aorta. To prevent air emboli, the arterial connection is made under a saline drip, or by having the perfusionist slowly pump priming solution out of the arterial line. Arterial cannulation is generally performed before caval cannulation so that direct access for blood replacement is available if needed.
5. Venous cannulation is performed in one of the following ways:
   a. Single, two-stage cannulation for venous return to the pump-oxygenator: An incision is made into the right atrial appendage and the two-stage cannula (see Figure 24-38) is inserted into the atrium. The distal end of the

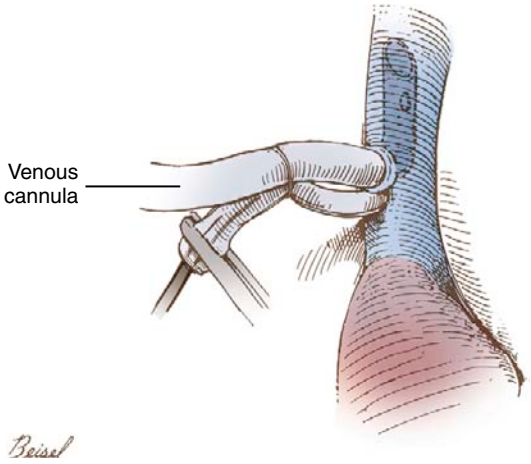


FIGURE 24-45 Right-angle cannula in superior vena cava.

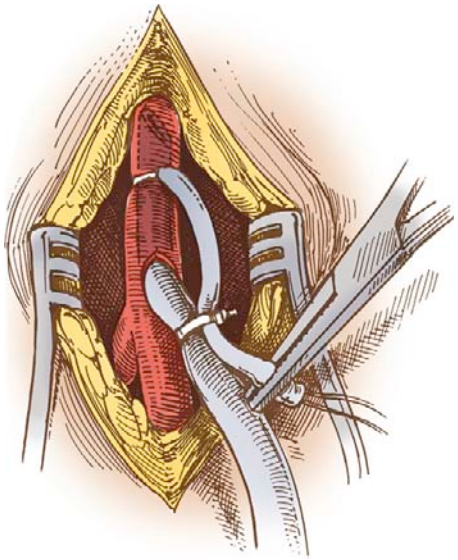


FIGURE 24-46 Cannulation of femoral artery.

cannula is placed into the inferior vena cava (IVC). The purse-string suture is secured with a tourniquet, and the catheter is permitted to fill partially with blood before being connected to the venous line.

b. Double cannulation: For double cannulation, a second incision is made into the atrial wall within the purse-string suture and the cannulae are placed in the inferior and superior venae cavae (see Figure 24-37). To force all venous return into the cannulae, umbilical tapes with tourniquets may be placed around each cava and then tightened. This forces systemic venous return to enter the cannulae, producing total CPB (see Figure 24-42).

6. In procedures where greater exposure of the right atrium is required (e.g., tricuspid valve surgery, closure of atrial septal defects in adults), a right-angle cannula may be inserted into the SVC (Figure 24-45).

Femoral Vein–Femoral Artery Cannulation

1. A vertical or oblique incision is made into the femoral triangle, and the femoral vein and artery are exposed. Umbilical compression tapes are passed around the vessels above and below the proposed venotomy and arteriotomy. Vascular clamps may be applied above and below the incision into each vessel.
2. A purse-string suture is placed in the femoral artery. A needle is inserted into the artery, followed by a guidewire. The needle is removed, and dilators are threaded over the guidewire to enlarge the artery. The dilators are removed, and the perfusion catheter (occluded distally with a tubing clamp) is inserted retrograde into the arteriotomy as the proximal clamp or tourniquet is released. The proximal tourniquet is tightened (Figure 24-46). The cannula is connected to the arterial line.
3. An incision is made into the femoral vein, and the venous catheter is inserted into the vein as the proximal clamp or tourniquet is released. After the cannula is in place, the proximal tourniquet is tightened to prevent bleeding from the venotomy. The cannula is occluded at the distal end with a tubing clamp to prevent bleeding from the cannula. The cannula is connected to the venous line, and the tubing clamp is removed.

MINIMALLY INVASIVE CANNULATION. Femoral cannulation techniques are employed. Femoral arterial cannulation is as just described. Venous drainage is achieved with an extended catheter inserted into the exposed femoral vein, and the distal tip is advanced to the SVC to the inferior portion of the RA (see Figure 24-41). Side ports along the distal portion of the cannula allow drainage of blood from the SVC, the right atrium, and the IVC. Because of the higher resistance to drainage flow compared with right atrial cannulation, a centrifugal pump or vacuum-assisted drainage incorporated in the CPB circuit is used to augment venous drainage.

PUMP-OXYGENATOR PREPARATION. After the arterial and venous connections are completed and the lines secured, bypass is slowly begun and the desired flow rate is gradually achieved. Arterial infusion is calibrated to match venous outflow in order to maintain a consistent cardiac output and blood volume. Perfusion flow is adjusted as necessary during the operation (Mongero and Beck, 2008).

Axillary Artery Cannulation. Although infrequently used for arterial perfusion, the right axillary artery (AA) is a useful cannulation site when circulatory arrest is necessary for surgery on the aorta. Another indication for its use occurs in the presence of acute or chronic aortic dissection when retrograde flow through the femoral artery may produce femoral artery dissection and malperfusion of the central organs (e.g., the kidneys). The AA is usually free of atherosclerosis and has excellent collateral flow from the thyrocervical trunk to the suprascapular and transverse cervical arteries, which helps to avoid upper extremity ischemia during cross-clamping (Kokotsakis et al, 2005). Use of the AA also facilitates antegrade cerebral perfusion during hypothermic arrest. The artery can be cannulated directly, but the risk of dissection favors indirect cannulation via an 8-mm to 10-mm Dacron tube graft anastomosed to the artery (Khonsari et al, 2008; Kokotsakis et al, 2005).

The patient is positioned supine with a roll under the shoulders to enhance access to the artery; the OR bed may be tilted

PATIENT SAFETY

Patient Safety Considerations for Axillary Artery Cannulation

During high-risk, low-volume procedures, such as axillary artery (AA) cannulation, less frequently encountered patient safety factors should be scrutinized with care. These factors include understanding the purpose and plan for the procedure, having the necessary supplies, anticipating possible complications, and preparing for alternate techniques. The considerations listed are pertinent to the use of the axillary artery.

BLOOD PRESSURE (BP) MONITORING

- Use bilateral radial artery BP lines to compare right- and left-sided pressures and to confirm the absence of a pressure gradient.
- Use a right radial artery line to monitor antegrade cerebral perfusion during hypothermic arrest.
- Cerebral perfusion pressure should be kept at 50 mm Hg (or less).

PREVENTION OF INJURY TO BRACHIAL PLEXUS

- Traction and manipulation should be avoided.
- Do not use electrosurgical energy in area of brachial plexus.

CANNULATION

- Ensure absence of preexisting dissection in *axillary* artery when *aortic* dissection is present.
- There is increased risk of dissection with *direct* cannulation of axillary artery; attachment of tube graft for *indirect* cannulation is often performed.
- During cardiopulmonary bypass (CPB) the BP tends to be higher on the side of the arterial (axillary) cannulation; contralateral BP line should be used for monitoring.
- Known, severe atherosclerosis of the axillary artery is a contraindication to its use.

AVOIDANCE OF VASCULAR INJURY

- Closing the artery after completion of CPB should avoid narrowing the arterial lumen; the graft can be cut in a way that does not impinge on the vessel lumen and also does not leave residual graft material, which can allow stasis of blood and increase the risk for thromboembolus.

HEMOSTASIS

- If metal ligating clips are used to close the graft, ensure proper function of the clip applier.

Adapted from Khonsari S et al: *Cardiac surgery: safeguards and pitfalls in operative technique,* ed 4, Philadelphia, 2008, Lippincott Williams & Wilkins; Kokotsakis J et al: Right axillary artery cannulation: surgical management of the hostile ascending aorta, *Texas Heart Inst J* 32(2):189-193, 2005.

to the left for better exposure of the artery during cannulation. The right arm may be positioned next to the body with the elbow flexed slightly; the arm may be extended in some procedures, depending on surgeon preference. Additional patient safety considerations are listed in the Patient Safety box.

CANNULATION PROCEDURE

1. The right axillary (or subclavian) artery is exposed via a small incision below and parallel to the midportion of the right clavicle. The tissue is dissected toward the insertion of the pectoralis minor muscle and the deltopectoral groove; the pectoralis major muscle is dissected and divided, and the axillary vein and underlying artery are exposed and gently mobilized for about 2 cm.
2. The brachial plexus is located (cephalad to the vessels); manipulation is avoided to protect the plexus during cannulation and the operative procedure.
3. A partial occlusion clamp is applied to the artery and an 8-mm to 10-mm Dacron tube graft is anastomosed end-to-side to the artery with 4-0 or 5-0 polypropylene suture.
4. A straight arterial cannula is inserted through the graft and a heavy silk tie or umbilical tape is tied around the graft over the cannula to prevent bleeding.
5. Arterial flow is slowly initiated. Blood pressures via both the right and left radial arteries are compared to confirm the absence of a pressure gradient; after confirmation, arterial flow is increased to the initial desired rate of 2.2 to 2.8 L/min/m^2.
6. Completion of bypass and removal of the AA cannula: After CPB has been discontinued, the arterial cannula is gradually withdrawn and the AA graft is clamped (or ligated with two large metal clips); the graft is cut a few millimeters above the artery and oversewn with polypropylene suture. The surgeon is careful to avoid narrowing the AA or leaving a graft "stump" (which could become a source of emboli) during closure (Khonsari et al, 2008; Kokotsakis et al, 2005).

Cardioplegic Delivery

ANTEGRADE CARDIOPLEGIA. A purse-string suture and tourniquet are placed into the anterior ascending aorta proximal to the aortic cross-clamp, and a needle-tipped catheter is inserted. Both the catheter and the cardioplegic tubing are flushed to remove residual air. The catheter tubing is Y-ed into a vent line so that alternatively the needle can be used to infuse the cardioplegic solution into the aortic root or vent air and blood from the aorta and left ventricle. Individual lines incorporated into the antegrade infusion system can be used to selectively infuse the coronary bypass graft or grafts. Handheld cardioplegic cannulae may be used to infuse cardioplegic solution directly into the coronary ostia, but the risk of injuring ostial tissue usually favors this technique when retrograde delivery cannot be achieved.

RETROGRADE CARDIOPLEGIA. A purse-string suture is placed into the lateral wall of the right atrium, and a tourniquet is applied to the suture. A stab wound is made into the atrium, and the retrograde catheter is inserted and palpated into the coronary sinus. Blood is aspirated from the catheter, and the catheter is connected to the flushed retrograde infusion line and to a pressure line. Infusion pressure should be between 20 and 45 mm Hg (Khonsari et al, 2008). Because a full right atrium facilitates insertion of the catheter, insertion is performed before the initiation of CPB when possible. If the patient is already on CPB, the surgeon can fill the atrium by clamping the venous drainage line momentarily, thereby diverting blood into the heart.

MINIMALLY INVASIVE ENDOVASCULAR ANTEGRADE-RETROGRADE CARDIOPLEGIA. A system of endovascular multilumen catheters designed to infuse solutions, vent air and blood, measure intravascular pressures, and occlude the aorta may be used (Figure 24-47). Fluoroscopy or TEE can be employed to confirm proper catheter placement.

The intravascular aortic catheter has three lumens. The first lumen has an inflatable balloon at the tip that, when inflated inside the vessel, occludes the aorta and serves as an internal "cross-clamp." The second lumen can be used either to infuse antegrade cardioplegic solution or to vent the ventricle. The third lumen is used to measure aortic root pressure. The catheter is introduced into the femoral artery and advanced into the ascending aorta. Either the femoral artery used for arterial inflow or the contralateral femoral artery is used.

A triple-lumen coronary sinus retrograde cardioplegic catheter is inserted percutaneously through the jugular vein into the SVC. The catheter is guided into the coronary sinus under fluoroscopy. One lumen allows manual catheter balloon inflation; another lumen is used to infuse retroplegic solution; and the third lumen measures coronary sinus pressure.

A third catheter is used as a venting-and-decompression device. It is inserted into the jugular vein (through a separate sheath from the retrograde catheter) and advanced into the main pulmonary artery.

These catheter systems allow surgeons to use minimally invasive techniques to treat lesions, such as mitral valve stenosis, that cannot be performed safely with a beating heart.

Termination of Cardiopulmonary Bypass

1. After the intracardiac procedure has been completed, all air is evacuated from the left ventricle. A warm dose of cardioplegic solution may be given, after which the cross-clamp is removed. The warm solution dilates the coronary vascular bed and enhances coronary perfusion once the cross-clamp is removed.
2. Defibrillation is often spontaneous with removal of the aortic cross-clamp and the entry of warm blood into the coronary circulation. If not, internal defibrillation is necessary. Endovascular, minimally invasive procedures will require external defibrillation with sterile external paddles or patches. Temporary epicardial pacing wires attached to the atrium and to the ventricle are used to adjust the heart rate and optimize cardiac output.
3. Venous flow to the pump is reduced. Arterial flow is also reduced to equal the reduced venous return. When heart action is sufficient and systemic arterial blood pressure is stabilized, venous return is further reduced and the patient is taken off bypass by clamping all lines and stopping the pump.
4. As the cannulation catheters are removed, the purse-string sutures are tightened and tied. Additional sutures may be required for hemostasis.
5. Chest tubes are inserted into the pericardium (and the pleural cavity if the pleura has been opened).
6. Protamine sulfate, a heparin antagonist, is administered.
7. The pericardium is usually left open so that accumulating drainage does not produce cardiac tamponade.

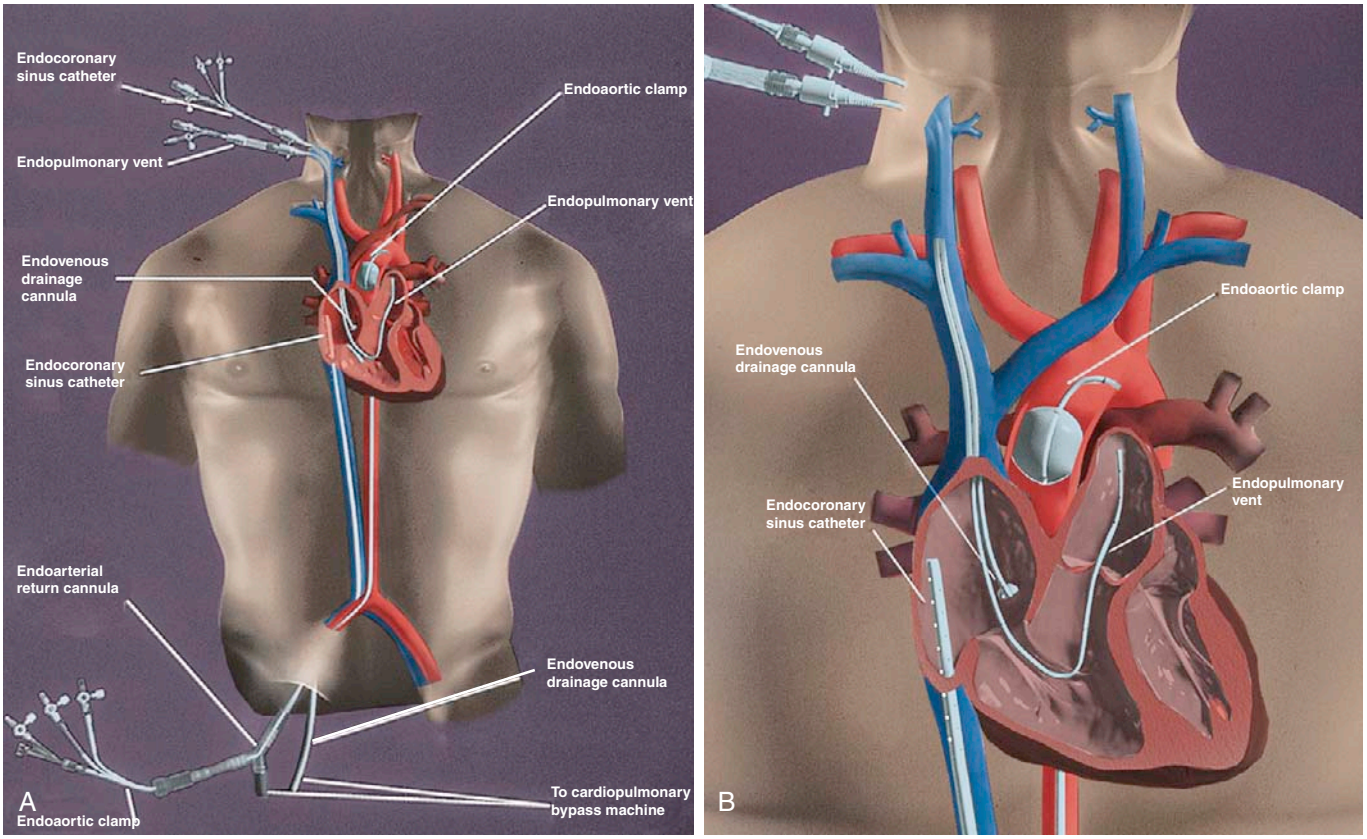


FIGURE 24-47 **A**, Endovascular cardiopulmonary bypass and myocardial protection system (see text). **B**, Intracardiac placement of catheters.

Closure of Femoral Incisions

1. The femoral catheters are removed, and the arteriotomies are closed with nonabsorbable cardiovascular suture. Compression tapes and bulldog clamps, if used, are removed.
2. The incision is closed with absorbable sutures, and the skin is closed with interrupted or continuous sutures.
3. Dressings are applied to all incisions.

PERICARDIECTOMY

Pericardiectomy is the partial excision of the adhered, thickened fibrotic pericardium to relieve constriction of compressed heart and large blood vessels. The adhered portions of the scarred, thickened pericardium restrict diastolic filling and myocardial contractility. As the pericardial space is obliterated and calcification of the pericardium occurs, the heart is further compressed. Ascites, elevated venous pressure, decreased arterial pressure, edema, and hepatic enlargement result. In most patients the etiology is unknown although there are documented cases caused by chronic pericarditis, which may be of tubercular, rheumatic, viral, or neoplastic origin. Either the supine position or the left lateral position may be used for a left anterolateral thoracotomy (Lachman et al, 2009; Kouchoukos et al, 2003).

Procedural Considerations

The use of CPB is rare, but it may be requested on a standby basis. The supplies and instruments for bypass should be available.

Operative Procedure

1. The lungs are hypoinflated to enhance exposure of the heart. The right and left phrenic nerves are identified and carefully protected. The pericardium is incised.
2. The outer, thickened pericardium is removed as indicated. Cartilage scissors may be required. The fibrous portions adhering to the atria and ventricles are carefully dissected with dry dissectors and scissors. Caution is exercised to prevent perforation of the atria and right ventricle; thus small islands of adherent pericardium may be retained.
3. Dissection is continued, and the large blood vessels are exposed and freed as indicated.
4. Drainage catheters are placed near the heart or through the pleural spaces, and connections to the water-seal drainage system are established.

SURGERY FOR CORONARY ARTERY DISEASE

The growth of minimally invasive surgical techniques (including off-pump CABGs) and percutaneous coronary interventions (PCIs) is most evident in the treatment of CAD. PCIs with bare metal or drug-eluting stents are performed in more than 2 million patients annually. Although there is some evidence that drug-eluting stents have a higher rate of thrombotic occlusion than bare metal stents, Kirtane and colleagues (2009) found comparable results with either type of stent.

When compared to PCI with stent insertion, CABG remains the standard of care for patients with left main or three-vessel CAD (Serruys et al, 2009; Patel et al, 2009; Li et al, 2009) although there is ongoing controversy about the preference for PCI or CABG among subsets of patients with CAD (Smith, 2009). Hybrid rooms facilitate a combination of both traditional surgical techniques and fluoroscopically-guided PCI.

In addition to PCI, revascularization procedures for the ischemic myocardium include an expanding array of options such as port-access, robotic, endoscopic, and video-assisted procedures using smaller thoracic or sternal incisions (Table 24-8). Other forms of revascularization include left ventricular aneurysmectomy and transmyocardial laser revascularization. Endoscopic saphenous vein and radial artery excision is performed frequently.

Off-pump coronary artery bypass (OPCAB) is popular, and procedures employing CPB can be performed with minimally invasive systems (Sarin et al, 2009; Sellke et al, 2005). Table 24-9 lists revascularization procedures that can be performed using a variety of on- or off-pump techniques. Advantages of the minimally invasive techniques, with or without CPB, include more cosmetic incisions, less perioperative bleeding, fewer surgical wound infections, and earlier postoperative ambulation. Previous disadvantages attributed to OPCAB (e.g., more technically challenging, prolonged operative time, and less complete revascularization) have been overcome, as depicted in a review of two randomized, controlled trials that showed similar outcomes, including health-related quality of life (Angelini et al, 2009). Procoagulant activity in the first 24 hours after OPCAB increases the risk of graft thrombosis. Therefore perioperative anticoagulation therapy should be "more aggressive" than that for conventional CABG, according to Shimokawa and colleagues (2009, p. 1419). In patients with myocardial infarction (MI), off-pump CABG surgery performed within 6 hours of the onset of symptoms showed better results than CABG with CPB (Fattouch et al, 2009).

Distal and proximal anastomotic devices have the potential to make it easier to perform bypass procedures in confined spaces on a beating heart, but many of these devices require further refinement. These new vascular connectors employ a variety of designs: grasping hooks that attach the vein to the aorta, magnets, U clips, and other coupling systems (Nasso et al, 2009). Another innovative proximal anastomotic technique consists of a clampless device that reduces the risk of disrupting aortic atherosclerotic plaque, which may be dislodged and embolize after the application of a partial occlusion clamp (Shimokawa et al, 2009).

Standard surgical treatment of CAD includes myocardial revascularization with CABG by use of the internal (thoracic) mammary artery (IMA), greater saphenous vein, radial artery, and other autogenous arterial and venous conduits. CABG often alleviates angina pectoris and prolongs life in patients with CAD of the left main and left anterior descending coronary arteries (Serruys et al, 2009; Patel et al, 2009; Li et al, 2009). The IMA demonstrates excellent long-term patency (Morrow and Gersh, 2008), and this has promoted the use of arterial conduits such as the radial artery (Collins et al, 2008), especially in diabetic patients (Singh et al, 2008); the gastroepiploic artery (Sasaki, 2008); and the inferior epigastric artery (Tavilla et al, 2004). The saphenous vein remains an effective conduit when multiple grafts are needed (Ozcan et al, 2008). Although the majority of saphenous vein grafts currently are harvested via the endoscopic technique (see #3 in the outline on p. 1054), a large study of approximately 2900 patients (Lopes et al, 2009) has shown less optimal outcomes with the endovascular technique. The increasing number of reoperations for CAD has also stimulated the use of alternative conduits (Box 24-6).

TABLE 24-8

Thoracic Incisions

Incision	Position	Possible Indications	Special Patient Needs
Median sternotomy: Incision along center of sternum	Supine	Most adult cardiac procedures except those on branch pulmonary arteries, distal transverse aortic arch, and descending thoracic aorta; OPCAB	Padding for hands, elbows, feet/heels, back of head, dependent bony prominences
Mini-sternotomy: Partial upper or lower sternal incision starting either from sternal notch or from xiphoid process and extending to midportion of sternum; lower-end sternal splitting (LESS)	Supine	MAS, or OPCAB procedures	Same as median sternotomy
Parasternotomy: Resection of right or left costal cartilages (from second to fifth cartilage, depending on surgical target)	Supine; small roll may be placed under affected side	Left: MAS CABG Right: MAS CABG, valve procedures	Same as median sternotomy; risk of postoperative chest wall instability
Anterolateral thoracotomy: Curvilinear incision along subpectoral groove to axillary line	Supine with pad or pillow under operative site; arm supported in sling or overarm board; arm on unaffected side may be tucked along side	MAS, MIDCAB, trauma to anterior pericardium and left ventricle; repeat sternotomy	Padding for extremities; pillow or other device to elevate affected side; armboard or sling for arm on affected side
Left anterior mini-thoracotomy; right anterior mini-thoracotomy: One or more small incisions (or ports) on left or right side	Supine with small roll under affected side	Left: MAS, MIDCAB, port-access for robotic surgery Right: MAS valve procedures, surgery for atrial fibrillation ("mini-MAZE"); port-access for robotic surgery	Same as anterolateral thoracotomy
Lateral thoracotomy: Curvilinear incision along costochondral junction anteriorly to posterior border of scapula	Placed on side with arms extended and axilla and head supported; knees and legs protected	Lung biopsies; first-rib resection; lobectomy	Armboard, overarm board, axillary roll, padding for extremities, pillow between legs; sandbags, straps, wide tape, or other devices to support torso
Posterolateral thoracotomy: Curvilinear incision from subpectoral crease below nipple, extended laterally and posteriorly along ribs almost to posterior midline below scapula (location of intercostal incision depends on surgical site); used less frequently with availability of VATS techniques	Lateral with arms extended and axilla and head supported; knees and legs protected	First-rib resection; lobectomy	Similar to needs for lateral thoracotomy
Transsternal bilateral anterior thoracotomy ("clamshell"): Submammary incision extending from one anterior axillary line to other across sternum at fourth interspace	Supine	Bilateral lung transplant; emergency access to heart when sternal saw not available	Same as median sternotomy; requires transection of left and right IMA
Subxiphoid incision: Vertical midline incision from over xiphoid process to about 10 cm inferiorly (may divide lower portion of sternum to enhance exposure)	Supine	Pericardial drainage, pericardial biopsy, attachment of pacemaker electrodes, MAS	Same as median sternotomy

TABLE 24-8

Thoracic Incisions—cont'd

Incision	Position	Possible Indications	Special Patient Needs
Thoracoabdominal incision: Low curvilinear incision on left side extended to anterior midline, continued vertically down abdomen	Anterior thoracotomy with chest at 45-degree angle to table; abdomen supine	Thoracoabdominal aneurysm	Same as anterolateral thoracotomy

CABG, Coronary artery bypass graft; *IMA,* internal mammary artery; *MAS,* minimal access surgery; *MIDCAB,* minimal access direct coronary artery bypass; *OPCAB,* off-pump coronary artery bypass; *VATS,* video-assisted thoracoscopic surgery.
Adapted from Bishop P: Position the patient. In Phippen ML et al, editors: *Competency for safe patient care during operative and invasive procedures,* Denver, 2009, Competency & Credentialing Institute; Walton-Geer PS: Prevention of pressure ulcers in the surgical patient, *AORN J* 89(3):538-548, 2009.

TABLE 24-9

Types of Myocardial Revascularization

Acronym	Procedure Name	Incision	Indication
MIDCAB	Minimally invasive direct coronary artery bypass (infrequent)	Left anterolateral thoracotomy	Single left anterior descending (LAD) and/or diagonal coronary artery anastomosis with left internal mammary artery (LIMA)
LATCAB	Lateral anterior thoracotomy coronary artery bypass	Anterolateral thoracotomy	Saphenous vein or radial artery from descending aorta to circumflex coronary artery system
OPCAB	Off-pump coronary artery bypass	Median sternotomy with full or limited skin incision	Multiple anastomoses
TECAB (also called ECABG)	Totally endoscopic coronary artery bypass; endoscopic coronary artery bypass graft (CABG)	Thoracic ports	Multiple anastomoses; on or off bypass
PACAB (also called port-access CAB)	Port-access coronary artery bypass	Thoracic ports	Multiple anastomoses; robot may or may not be used
Robotic CAB	Minimally invasive surgery (MIS) employing robotic assistance	Thoracic ports, small incisions	Multiple anastomoses
Robotic or nonrobotic LTMR	Laser transmyocardial revascularization	Thoracic ports, small incisions	Multiple anastomoses
Hybrid	Combined surgery and percutaneous coronary intervention (PCI)	Sternotomy (usually)	CABG: LAD and/or diagonal coronary artery; PCI: lateral and/or posterior coronary arteries

Modified from McCarthy P: Surgical management of heart failure. In Libby P et al, editors: *Braunwald's heart disease,* ed 8, Philadelphia, 2008, Saunders; Bridges CR et al: The Society of Thoracic Surgeons practice guideline series: transmyocardial laser revascularization, *Ann Thorac Surg* 77:1494-1502, 2004; Yuh DD et al: Totally endoscopic robot-assisted transmyocardial revascularization, *J Thorac Cardiovasc Surg* 130(1):120-124, 2005.

Dysrhythmias, and AF in particular, are common after CABG and can lead to hemodynamic compromise, systemic embolism, the need for extended anticoagulation therapy (with its attendant risk of bleeding complications), cardiac pacing, patient discomfort and anxiety, and increased cost and length of stay. Preoperative, intraoperative, or early postoperative administration of amiodarone is effective in reducing the incidence of postoperative AF (Gray and Sethna, 2008).

Increasing controversy over gender differences and their effect on outcomes after CABG has stimulated perioperative practice guidelines for CABG in women (Babb, 2009; Edwards et al, 2005; Puskas et al, 2007; Toumpoulis et al, 2006) (Evidence for Practice, p. 1009). In particular, the guidelines focus on use of the IMA, glycemic control, avoidance of anemia and hypothyroid states, the questionable value of hormone replacement therapy, and off-pump CABG.

Other ischemia-related disorders (including heart failure) that can benefit from surgery include postinfarction ventricular septal defect (VSD), mitral regurgitation (MR), and certain ventricular (e.g., tachycardia) and supraventricular (e.g., AF) dysrhythmias.

BOX 24-6

Alternative Conduits for Use as Coronary Bypass Grafts

- Splenic artery
- Lesser saphenous vein
- Cephalic vein
- Basilic vein
- Greater saphenous vein allografts (homografts)
- Synthetic grafts (e.g., Dacron, PTFE)

PTFE, Polytetrafluoroethylene
Modified from Hsia TY et al: Coronary artery disease. In Conte JV et al, editors: *The Johns Hopkins manual of cardiac surgical care,* ed 2, St Louis, 2008, Mosby.

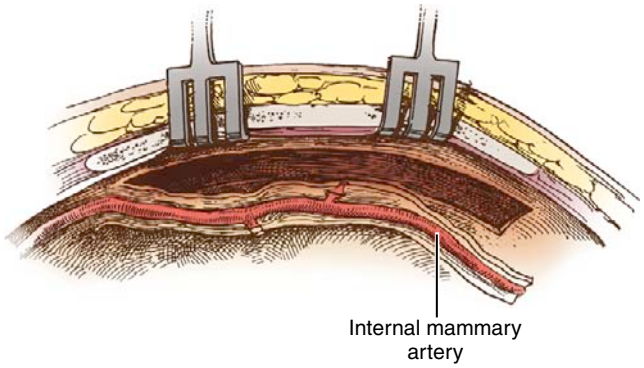


FIGURE 24-48 Dissection of internal mammary artery (IMA). Bleeding from side branches is controlled by vascular clips on the IMA side and electrocoagulation on the sternal side. Dilute solution of papaverine is sprayed onto or into the lumen of the IMA to dilate the artery and reduce muscular spasm. The IMA pedicle is placed in the pleural cavity until needed for anastomosis.

Coronary Artery Bypass Grafts with Arterial and Venous Conduits

Operative Procedure

Coronary artery instruments are added to the basic setup for cardiac surgery.

1. A median sternotomy is performed as described.
2. Conduit preparation:
   a. *IMA.* A special retractor, such as the one shown in Figure 24-15, elevates the sternum to expose the IMA. The surgeon dissects the IMA from its retrosternal bed until the necessary length is obtained (Figure 24-48). The surgeon clamps the exposed artery, cuts the IMA caudal to the clamp, and confirms that blood flow through the IMA is adequate. The surgeon may inject papaverine (or another antispasmodic drug) into the IMA lumen with a blunt-tip needle and then occlude the tip of the IMA with a small bulldog clamp. The surgeon may wrap the pedicle with a papaverine-soaked sponge and store the vessel in the left (or right) pleural space until needed. The remaining clamped portion of the distal IMA is ligated with a tie to prevent backbleeding. Occasionally, both right and left IMAs are used. Heparin is given before arterial grafts are clamped and cut to prevent intraluminal thrombosis.
   b. Endoscopic IMA dissection can be performed through thoracic ports (see Table 24-9) inserted into the left anterior thorax at the level of the fourth intercostal space. Ligation of arterial branches and venous tributaries is performed with hemostatic clips and electrocoagulation.
   c. *Radial artery.* Generally the artery is taken from the patient's nondominant arm; adequate blood flow through the ulnar artery must be confirmed (commonly by Doppler). The artery may be removed endoscopically or through a longitudinal incision beginning 3 cm distal to the elbow crease lateral to the biceps tendon and ending 1 cm before the wrist crease (Figure 24-49). The artery is exposed and mobilized with a vessel loop and harvested as a free graft with adjacent veins and fatty tissue. The artery is ligated proximally and distally after systemic heparinization. Papaverine may be injected into the lumen to reduce spasm. The arm incision is closed and may be dressed and repositioned along the patient's side; additional drapes may be applied to maintain sterility of the field.
   d. *Gastroepiploic artery.* When an additional arterial conduit is needed, the gastroepiploic artery may be used, although the required entry into the peritoneum to dissect the artery increases the risk of postoperative complications (Figure 24-50).
   e. *Saphenous vein.* The necessary length of saphenous vein is harvested from one or both legs either with video-assisted endoscopic techniques or (less commonly) by a traditional open incision (Figure 24-51). Tributaries on the leg side are ligated, electrocoagulated, or clipped. After the saphenous vein is dissected free, it is removed and tributaries on the vein side are ligated. The distal end of the vein is identified to place the vein in a reversed position so that the semilunar valves do not interfere with the flow of blood. The vein is flushed with heparinized blood or saline and kept moist until needed.
3. With the endoscopic technique, saphenous vein harvesting is performed through one to three incisions over the vein at the knee and at the ankle and the groin if necessary. The vein is located under direct vision; the remaining length of vein is excised using a 5-mm angled endoscope and endoscopic scissors. An endoscopic clip applier and bipolar electrocoagulation can be used to seal tributaries on the leg side. Once the vein is removed, the vein tributaries are ligated with silk ties. To reduce postoperative tunnel dead space and minimize fluid accumulation, the leg is wrapped with a pressure bandage.
4. CPB with mild hypothermia is instituted. (If CABG is performed without CPB, the patient is not cooled. CPB standby is usually available.) Antegrade-retrograde cardioplegic solution is infused after the aorta is cross-clamped.
5. Coronary anastomoses using the saphenous vein, free arterial grafts, and in situ arterial grafts (e.g., IMA and gastroepiploic artery) are performed.
   a. The affected coronary artery is identified, and a small incision is made into the artery. The graft conduit is beveled to approximate the incision (side-to-side jump grafts may be performed as well).

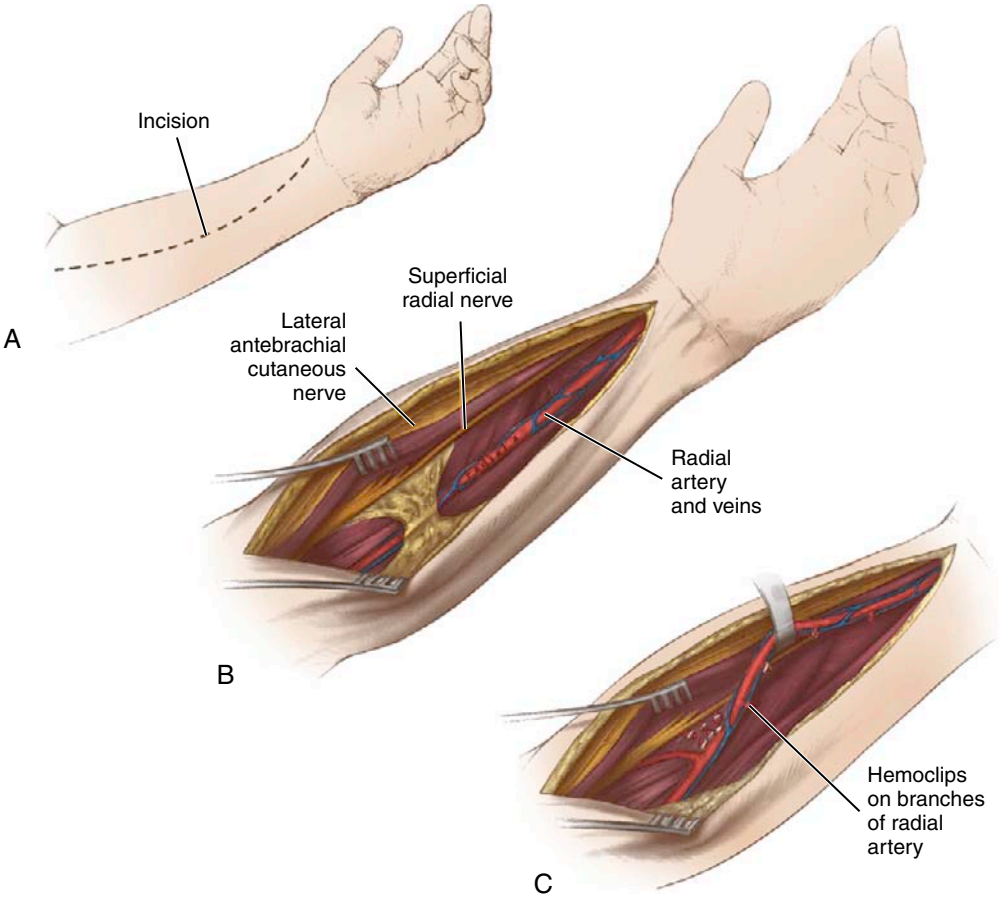


FIGURE 24-49 Dissection of radial artery. Before removal of the radial artery, Allen's test is performed to ensure that the ulnar artery will provide sufficient blood flow to the hand if the radial artery is excised: the radial and ulnar arteries are compressed to produce blanching of the hand. The ulnar artery is released while compression is maintained on the radial artery. The skin on the palm of the hand should immediately become red as blood flow is restored through the ulnar artery to the hand. **A**, Incision line. **B**, Deep forearm dissection exposes the radial artery and vein pedicle. **C**, Radial artery pedicle is mobilized, and the multiple side branches are clipped. The artery is removed and may be irrigated with a vasodilator. A continuous intravenous infusion of diltiazem helps to prevent vasoconstriction of the artery.

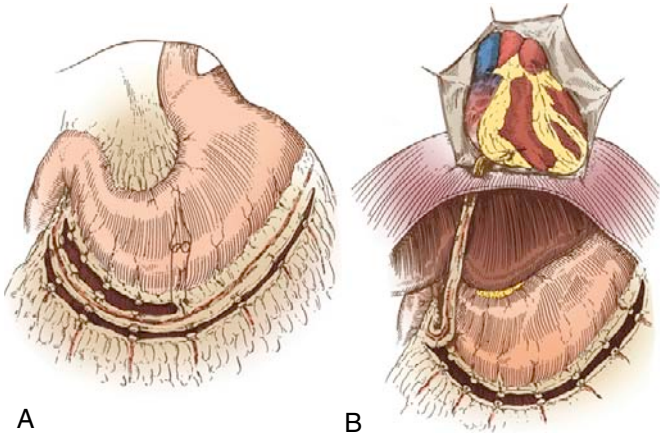


FIGURE 24-50 Right gastroepiploic artery mobilization. **A**, Branches to the stomach are divided with clamps and ties; omental branches may be divided with a staple gun. The gastroepiploic pedicle is isolated proximally to its origin from the gastroduodenal artery. **B**, The pedicle is brought up into the pericardium and anastomosed to the right coronary artery (shown here). The artery can also be grafted to the distal right and left anterior descending coronary arteries.

b. The anastomoses are made with fine cardiovascular sutures (Figure 24-52). Before each anastomosis is completed, the distal coronary artery may be probed to ensure patency.

6. Steps 5a and 5b are repeated for each subsequent anastomosis.
7. The distal anastomosis of the IMA to the coronary artery is done as described for the anastomosis of the saphenous vein graft to the coronary artery. No aortic (proximal) anastomosis is required because the IMA remains attached proximally to the subclavian artery. Because the IMA has demonstrated superior long-term patency—and the left anterior descending (LAD) coronary artery is a critical source of blood to the left ventricle—the IMA is commonly attached to the LAD coronary artery.
8. Aortic anastomoses:
   a. Proximal aortic anastomoses may be performed with a partial occlusion clamp but more often the anastomoses are performed during a single aortic cross-clamping to avoid excessive manipulation of the aorta that could lead to intimal injury or dislodgment of atherosclerotic

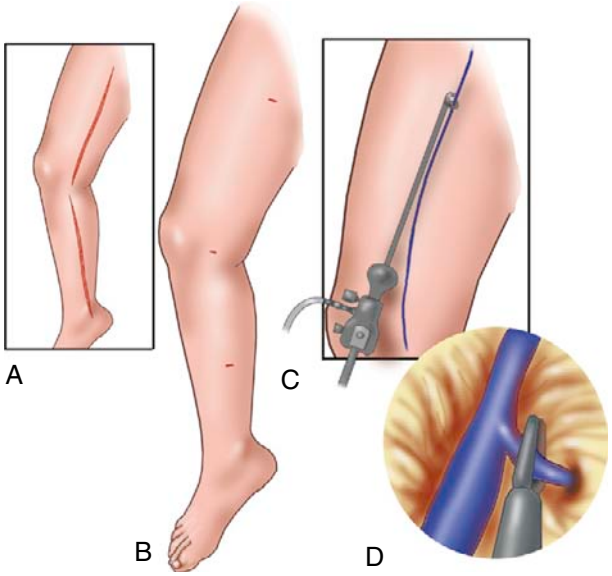


FIGURE 24-51 Excision of greater saphenous vein. **A**, Traditional open incision. **B**, Incision sites (ankle, knee, groin) for video-assisted, endoscopic vein harvesting. **C**, Endoscope inserted into medial knee incision and used to dissect the vein. **D**, Venous tributaries may be divided and electrocoagulated or clipped on the leg side; silk ties are commonly used on the vein side.

material. Increasingly, the aorta is assessed with TEE before the anastomoses are performed to identify proximal anastomotic sites that are relatively free of atherosclerotic plaque. After the proximal anastomoses are completed, the aortic cross-clamp is removed and the heart is defibrillated. Assessment of the aorta is especially helpful during *beating heart surgery* (usually through a median sternotomy) that requires proximal aortic anastomoses (with a saphenous vein or other free graft) to be completed while the heart is contracting. After identification of a suitable site (i.e., relatively free of plaque), the proximal anastomoses may be performed with a partial occlusion clamp. The aorta is partially occluded with an angled vascular clamp, and a small segment is resected (approximately the diameter of the vein graft). The aortotomy is made with a knife blade and the opening is enlarged with a punch (Figure 24-53).

   b. The conduit is anastomosed, end to side, to the aorta with fine vascular sutures (Figure 24-54). The partial occlusion clamp (if used) is removed, so that the proximal portion of the vein graft can fill with blood. Needle aspiration of the vein graft is performed to prevent air from entering the coronary circulation.

   c. When proximal anastomoses are performed during a single period of cross-clamping, air is aspirated from the grafts before the cross-clamp is removed.

9. The aortic anastomoses of the vein grafts may be marked with radiopaque clips or rings for future identification.
10. Cardiopulmonary bypass is discontinued, and the sternum is closed.
11. Minimally invasive procedures:
   a. Minimally invasive direct coronary artery bypass (MIDCAB) may be performed, albeit less frequently, in patients with lesions (e.g., narrowings in the LAD and

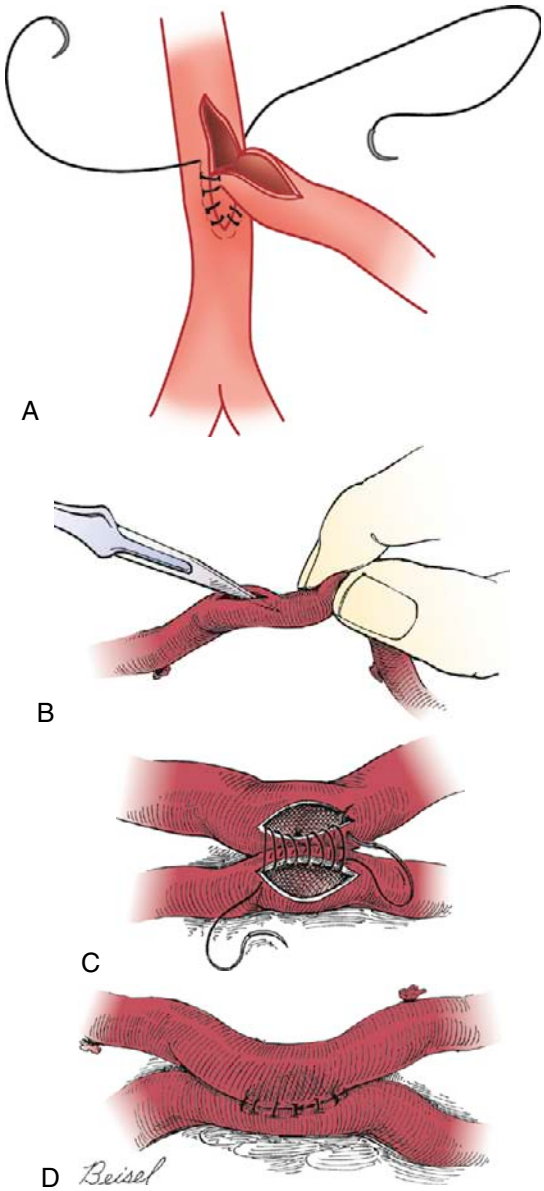


FIGURE 24-52 **A**, End-to-side coronary anastomosis with bypass graft conduit. Side-to-side coronary anastomosis with bypass graft conduit. **B**, Arteriotomy made with #11 blade is shown. **C**, Double-ended suture used to create anastomosis. **D**, Completed anastomosis. Side-to-side anastomoses are used to make more than one attachment of a conduit to an artery, especially when there may be insufficient available conduit material.

diagonal coronary arteries) that are easily accessible through an anterior thoracotomy. Beating heart procedures performed through a median sternotomy allow surgeons to access lateral and posterior arteries. When endovascular CPB and cardioplegic solution are used, more lateral and posterior arteries (e.g., obtuse marginal and right coronary arteries) may be grafted because ventricular fibrillation secondary to stimulation of the heart is obviated with induced cardioplegic arrest. A double-lumen endotracheal tube may be inserted so that the left lung can be hypoventilated to enhance visualization of

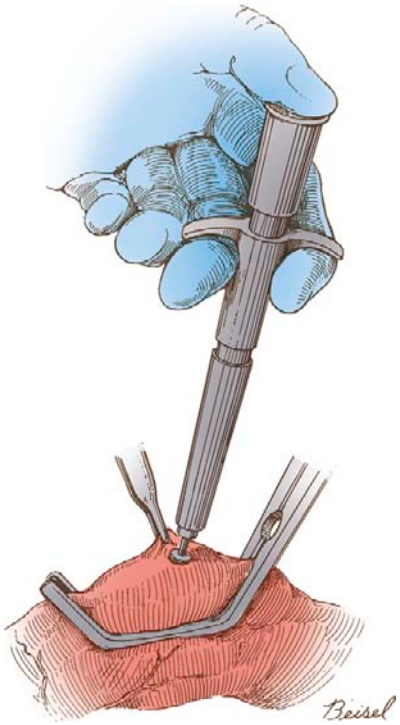


FIGURE 24-53 Proximal anastomosis of bypass graft. A partial occlusion clamp isolates the portion of the ascending aorta where the aortotomy is to be made with the punch.

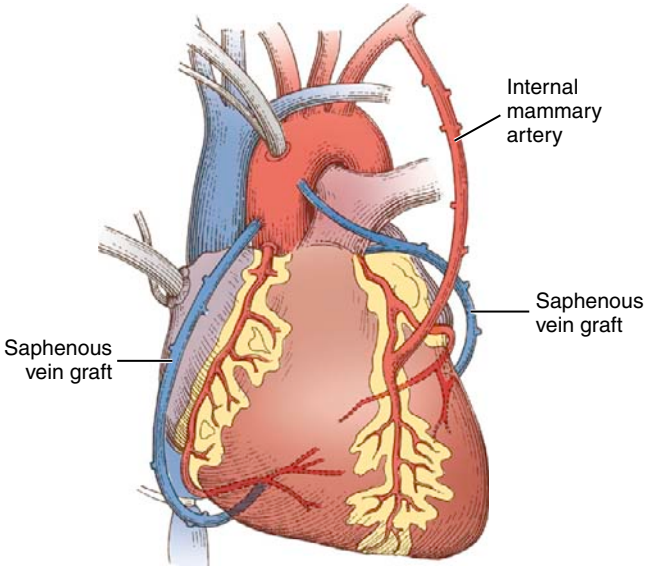


FIGURE 24-54 Coronary artery bypass grafts with reversed saphenous vein and the left internal mammary artery.

the LAD (and the IMA) while the right lung is ventilated sufficiently to oxygenate pulmonary blood flow.

b. With OPCAB, cardiac contraction may pose a technical difficulty for the surgeon in creating a precise anastomosis. Coronary stabilizers are used to reduce the motion of the heart in the vicinity of the anastomosis (Figure 24-55). These attachments fit onto the retractor, thereby freeing the surgeon's hands to suture the anastomosis.

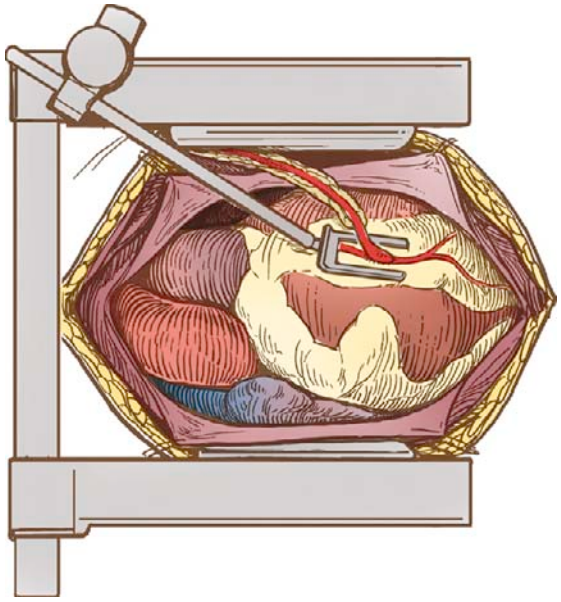


FIGURE 24-55 Coronary anastomotic site stabilizer used during beating heart bypass surgery. The horseshoe-shaped foot has a nonsmooth surface to provide an atraumatic grip on the epicardium, reduce the movement of the beating heart, and isolate the target coronary artery site for anastomosis.

Left ventricular apical suction cups allow the apex to be retracted, thereby exposing lateral and posterior coronary arteries (see Figure 24-17). Pharmacologic cardiac motion reduction has been achieved with beta-blocker drugs and adenosine, but the newer stabilizers have reduced the need for these drugs. Bleeding from the arteriotomy (because of the continued beating of the heart) obscures the field; a fine mist of humidified CO_2 gas sprayed over the anastomotic site and the use of elastic coronary artery tourniquets may be used to control bleeding.

c. Port-access procedures (Figure 24-56) may be performed with a robot and the use of endovascular catheters (see Figure 24-47). Anastomoses are achieved with video-assisted thoracoscopic techniques. If better visualization is desired or required, the surgeon can convert to a median sternotomy.

Laser Transmyocardial Revascularization

Patients with chronic, severe angina who cannot be revascularized with either coronary bypass surgery or PCI may be appropriate candidates for laser transmyocardial revascularization (TMR) (Horvath and Zhou, 2007). Channels are created in the left ventricular wall with laser energy (e.g., CO_2, holmium:yttrium-aluminum-garnet [Ho:YAG]). Endoscopic, laser, robot-assisted TMR can further enhance the role of TMR as a surgical treatment or as an adjunct to PCI. Laser safety precautions should be followed.

Ventricular Aneurysmectomy

Left ventricular aneurysmectomy (LVA) is the excision of an aneurysmal portion of the left ventricle and reinforcement with synthetic patch material. LVA is a form of left ventricular reconstruction undertaken to optimize cardiac function.

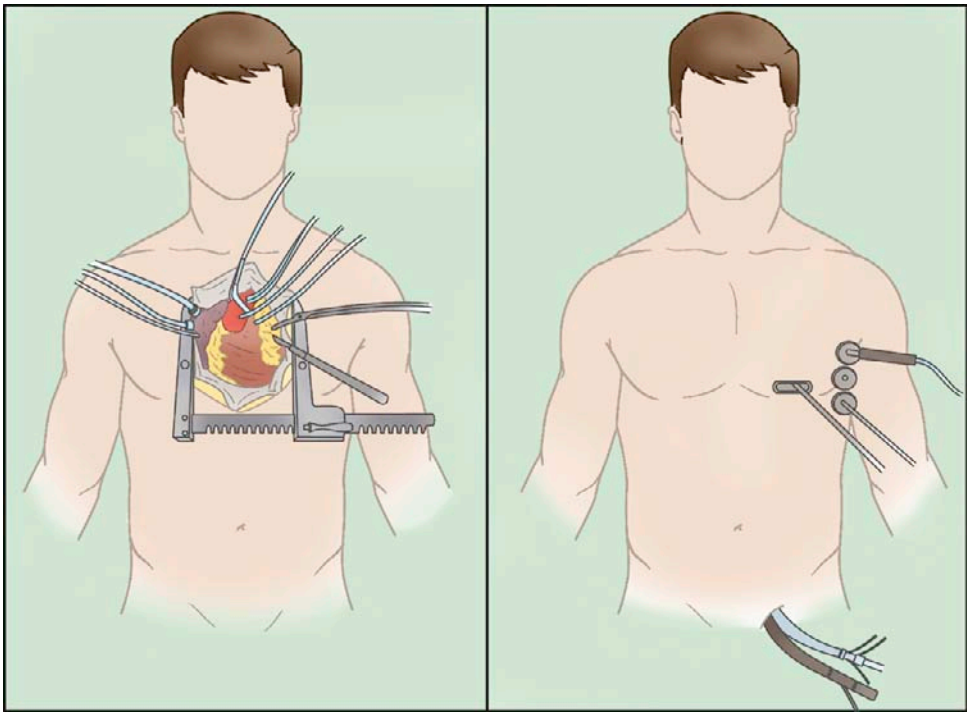


FIGURE 24-56 Traditional sternotomy *(left)* compared with minimally invasive incisions *(right)* that provide access to the heart and to the femoral artery and vein.

An aneurysm of the left ventricle occasionally develops after a severe myocardial infarction in which part of the myocardium is replaced by thin scar tissue that can rupture. The LV undergoes *remodeling* when the scar stretches as a result of the left ventricular pressure and forms an aneurysm (McCarthy, 2008). The aneurysm is usually adherent to the pericardium; it may not be possible to dissect it free until CPB has been established.

Procedural Considerations. The patient is placed in the supine position. The setup is the same as that described for open-heart surgery, with the addition of synthetic patch material, Teflon felt pledgets, and 0, 3-0, and 4-0 cardiovascular sutures. Occasionally, Teflon felt strips are required to bolster the suture lines. Patch closure of the ventriculotomy (endoaneurysmorrhaphy) is performed more often than the traditional excision, plication, and oversewing of the ventricular tissue. Patch closure better preserves the geometry of the left ventricle (McCarthy, 2008; Lundblad et al, 2009).

Operative Procedure

1. A median sternotomy is performed, and CPB is begun as previously described.
2. The scar tissue of the ventricle is excised, and any clot is carefully removed (Figure 24-57, *A* and *B*).
3. A circular cuff of scar tissue is left, through which a purse-string suture with felt pledgets is placed through the rim of the scar (Figure 24-57, *C*).
4. A patch of woven Dacron is sewn to the rim with interrupted sutures (Figure 24-57, *D*). A second (internal) patch of pericardium may be placed for hemostasis.
5. The edge of the patch is reinforced with a running suture (Figure 24-57, *E*).
6. The left ventricle may be vented with a catheter inserted into the right superior pulmonary vein; after the ventricle is deaired, the catheter is removed and closure of the incision completed.

Postinfarction Ventricular Septal Defect. Ventricular septal or free-wall rupture is a catastrophic complication of myocardial infarction, creating an acute left-to-right shunt and cardiac failure requiring early surgical repair. The defect is closed with a prosthetic patch and other materials commonly used for postinfarction ventricular aneurysm. Felt strips and plicating sutures may be used to reinforce the suture line (McCarthy, 2008).

SURGERY FOR HEART FAILURE

Early procedures to reconstruct the left ventricle, introduced by Batista and modified by Dor, were developed for patients with heart failure mainly caused by ischemic coronary disease and hypertension (McCarthy, 2008). The dilated, hypokinetic portions of the ventricle are excised and repaired to produce a more efficient pumping chamber. Techniques for ventricular reconstruction have expanded options for surgical treatment of heart failure. Additional interventions include mitral valve repair (see following section) for ischemic mitral regurgitation (de Varennes et al, 2009), mechanical and biologic support, and cardiac transplantation (described later).

SURGERY FOR THE MITRAL VALVE

Mitral *stenosis* (MS) is a narrowing of the valve orifice such that it causes impedance to forward blood flow. It is often caused by rheumatic fever. The normal orifice area of the valve is about

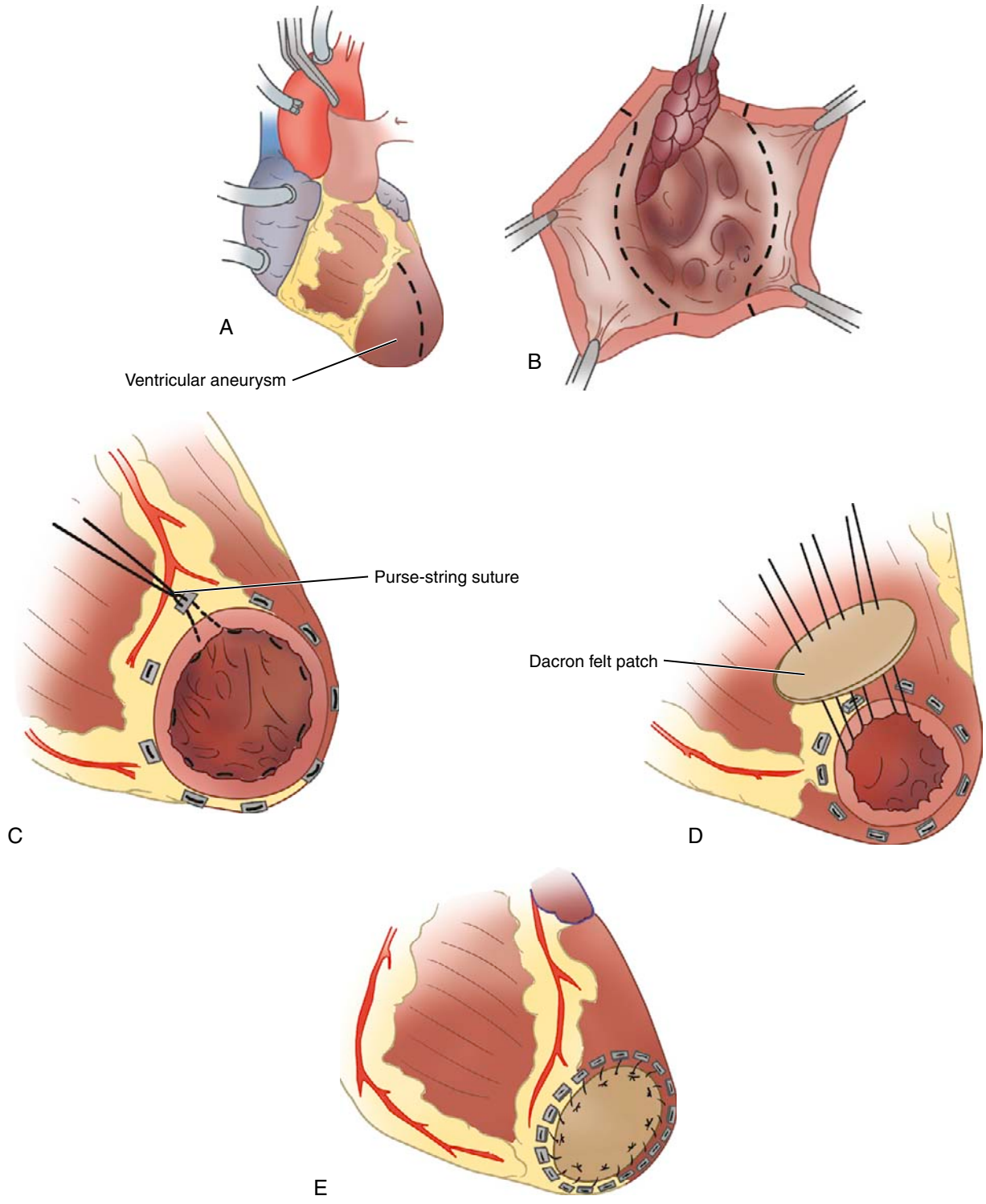


FIGURE 24-57 Repair of left ventricular aneurysm. **A**, Left ventricular apical aneurysm. **B**, Intracavitary clot is removed. **C**, Pledgetted sutures placed around the edge of the excised ventricular tissue. **D**, A patch is inserted. **E**, Completed repair.

5 cm^2. As the disease progresses, the mitral valve becomes a narrow slit in a fibrotic plaque, severely limiting blood flow into the left ventricle. MS causes a rise in pressure and dilation of the left atrium. This pressure is transmitted throughout the pulmonary vascular bed, with subsequent pulmonary hypertension, right ventricular hypertrophy, and possibly tricuspid valve regurgitation (Otto and Bonow, 2008). The major symptoms of MS are dyspnea, fatigue, and orthopnea. Late findings are severe pulmonary congestion and right ventricular failure. A characteristic diastolic murmur is heard, and AF is not unusual. Thromboembolism may result from stasis of blood in the left atrial appendage.

Mitral *regurgitation* (MR) occurs when the valve leaflets do not close properly or when the leaflets are perforated and blood escapes back into the left atrium during ventricular systole (Stout and Verrier, 2009). Common causes of MR are myxomatous degeneration and a secondary result of aortic valve stenosis. Other causes of MR are degenerative, ischemic, and dilated cardiomyopathy. During ventricular diastole, the blood regurgitated into the left atrium augments blood volume entering the left ventricle. MR may accompany MS or be attributable to leaflet tears, annular dilation, or elongated or ruptured chordae. Ischemic heart disease may produce papillary muscle dysfunction, which prevents sufficient anchoring of the leaflets in the closed position. Symptoms are primarily dyspnea on exertion and easy fatigability related to pulmonary congestion.

The surgeon's selection of the procedure (repair or replacement) is determined by the mitral valve anatomy, stage of disease, presence or absence of calcification, history of thromboembolism and dysrhythmia, the patient's ability to tolerate long-term anticoagulation therapy (required after insertion of a mechanical valve prosthesis), the patient's willingness to undergo reoperation if a bioprosthesis deteriorates, and additional associated pathologic defects (Kumar, 2008). Improvements in imaging capabilities with two-dimensional, three-dimensional, and color-flow Doppler echocardiography have enabled surgeons to diagnose more precisely and subsequently to identify the most appropriate reparative procedure (Lee and Bonow, 2008). Improved imaging has also fostered the development of a consistent nomenclature to describe specific segments of the mitral valve leaflet anatomy. Quill and colleagues (2009), building on the studies of Kumar and associates (1995) and the classic work of Carpentier (1983), have suggested dividing each mitral leaflet into an alpha-numeric system: (1) the *anterior* leaflet is divided into three sections that are designated from the lateral to the medial position (left to right): *A1* (lateral), *A2* (middle), and *A3* (medial); (2) the *posterior* leaflet is divided into three sections that are designated (left to right): *P1* (lateral), *P2* (middle), and *P3* (medial) (see mitral valve in Figure 24-6, *B*). The goal of this system is to provide consistent descriptions for planning, performing, and documenting the care for this highly variable, complex, and dynamic structure.

Consistency in description also promotes reproducibility of the reparative procedures performed to preserve the native valve. Mitral valve repair is widely employed because the complications associated with prosthetic replacement and anticoagulation therapy can be avoided. The technique selected must be tailored to the unique pathophysiologic findings; therefore the surgeon carefully evaluates the leaflets and related structures at the time of surgery before deciding which procedure to perform. Because there is a possibility that the valve may have to be replaced, instruments (and prostheses) for replacement as well as repairs should be available. Also included are atrial handheld or self-retaining retractors, obturators for sizing prosthetic rings and valves, sizer or prosthesis handles, and special sutures if requested. Bicaval cannulation often is used to enhance exposure of the operative field and to decompress the heart (see Figure 24-37). TEE is used to establish a cardiac functional baseline and to confirm efficacy of the repair both after the cross-clamp is removed and the heart resumes beating and after bypass is discontinued. TEE is also used intraoperatively to assess left ventricular function and to detect the presence of air (seen as white specks) within the cardiac chambers.

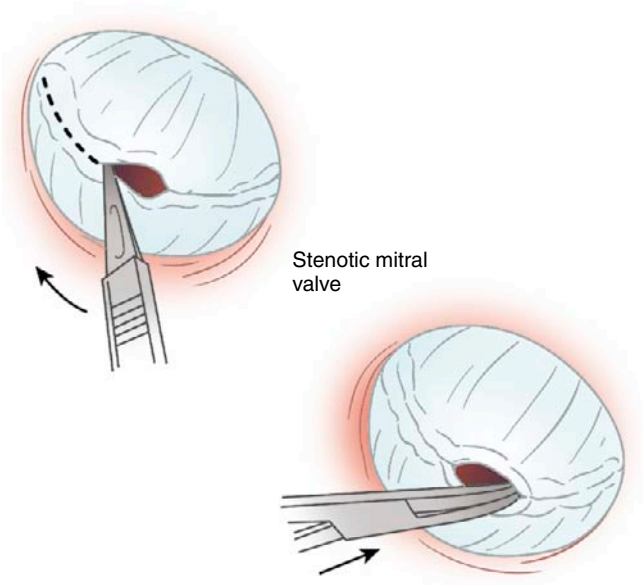


FIGURE 24-58 Mitral commissurotomy (see text).

Mitral Valve Repairs

Open Commissurotomy of the Mitral Valve for Mitral Stenosis. Open commissurotomy is the separation of fused, adherent leaflets of the mitral valve.

PROCEDURAL CONSIDERATIONS. The patient is placed in the supine position for a median sternotomy. The setup is the same as that described for open-heart procedures, with mitral valve instruments.

OPERATIVE PROCEDURE

1. A median sternotomy is performed, and bicaval cannulation is performed for CPB.
2. The left atrium is incised, and the valve is inspected; in some cases, a transseptal approach (right atrium to left atrium) may be used.
3. Fused leaflets are separated with vascular forceps and scissors or a knife (Figure 24-58). A dilator may be used to enlarge the mitral valve orifice.
4. The valve is again inspected for any resultant insufficiency.
5. An annuloplasty ring may be inserted to reinforce the repair.
6. The left atrium is closed with a continuous cardiovascular suture.

Mitral Annuloplasty for Mitral Regurgitation. Mitral annuloplasty is the reduction of a dilated annulus by inserting a prosthetic ring. Although it has been assumed that only the posterior leaflet is subject to annular dilation, it has been demonstrated that the anterior portion can also be affected. Prostheses are available to repair the entire circumference of the annulus (see Figure 24-33, *A*) or only the posterior leaflet (see Figure 24-33, *B*). The techniques (and associated prostheses) introduced by Carpentier (1983) and others continue to expand.

OPERATIVE PROCEDURE

1. The left atrium is incised, and sump suctions are inserted into the atrial cavity to remove blood.
2. The annulus, leaflets, chordae, and the rest of the mitral complex are inspected.

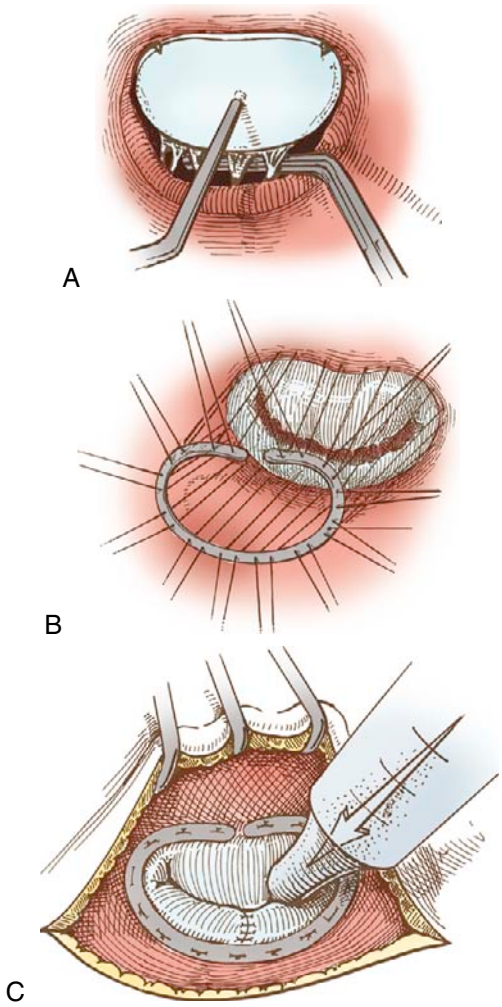


FIGURE 24-59 Mitral valve annuloplasty (see text).

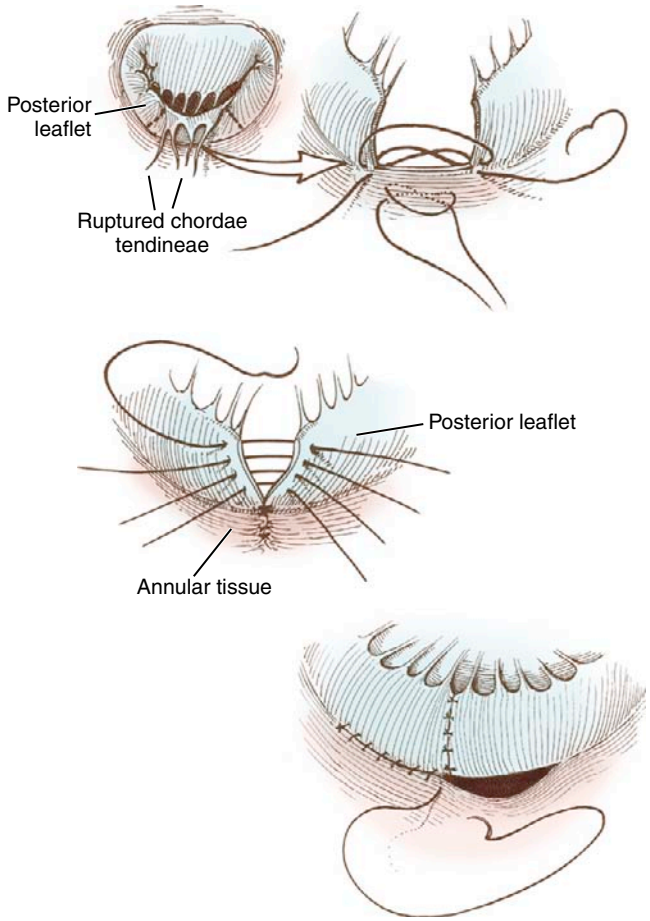


FIGURE 24-60 Quadrangular resection of nonsupported posterior leaflet tissue caused by ruptured chordae tendineae (see text). A similar technique can be used to resect *redundant* tissue causing mitral regurgitation.

3. If generalized annular dilation is present, an annuloplasty ring is inserted; a C-shaped ring may be used for dilation affecting the posterior leaflet (see Figure 24-33). An obturator is used to determine the appropriate-size ring (Figure 24-59, *A*). Interrupted sutures are placed around the circumference of the annulus and then into the ring (Figure 24-59, *B*). When the stitches are tied, the excess annular tissue of the posterior leaflet is evenly drawn up against the prosthesis (Figure 24-59, *C*).
4. The valve is inspected for competency; a bulb syringe filled with saline may be used to distend the ventricle and confirm the competence of the valve leaflets. The left atrium is closed.

Mitral Valvuloplasty Repairs for Mitral Regurgitation. Mitral valvuloplasty is the repair of the valve leaflets or related structures. Selection of the appropriate repair for perforated or redundant valve leaflets or for shortened or elongated chordae tendineae requires careful assessment and evaluation of the abnormalities present. Historically most mitral valve repairs have been performed on the posterior leaflet, but a number of anterior leaflet repairs have been developed (see steps 5 to 8 in the following Operative Procedure).

OPERATIVE PROCEDURE

1. Perforated leaflets can be patched with pericardium.
2. Redundant, prolapsed *posterior* leaflet tissue can be resected (Figure 24-60). The cut edges of the posterior leaflet are sewn together, and the corresponding annular segment is plicated. An annuloplasty ring is inserted to reinforce the leaflet repair and reduce annular dilation.
3. Shortened, fused chordae tendineae can be lengthened and mobilized by their division into secondary chordae or by incising the tip of the papillary muscles.
4. Redundant tissue of elongated chordae may be implanted into the papillary muscle head or folded over itself and secured with a suture (rarely performed).
5. *Anterior* leaflet prolapse is a greater challenge and traditionally has been an indication for valve replacement. A small triangular resection of the anterior leaflet (reinforced with annuloplasty ring insertion) can be performed.
6. Elongated or ruptured chordae may be replaced with polytetrafluoroethylene (PTFE) suture (Figure 24-61).
7. A chordal flip procedure (Figure 24-62) can be used to reestablish chordal attachment to the *anterior* leaflet. A section of the posterior leaflet with attached chordae is cut, swung over to the anterior leaflet, and sewn onto the anterior

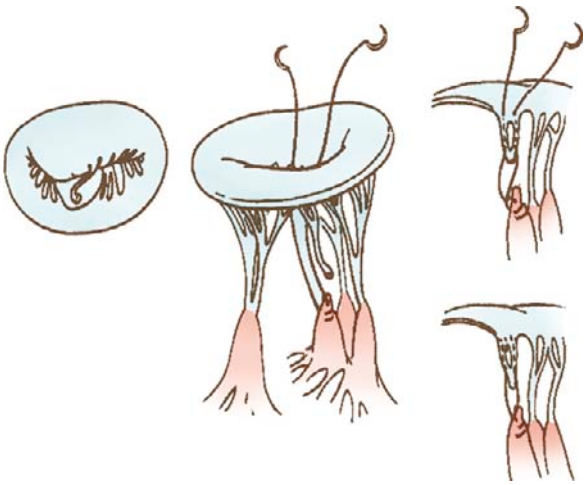


FIGURE 24-61 Chordal replacement with polytetrafluoroethylene (PTFE) (see text).

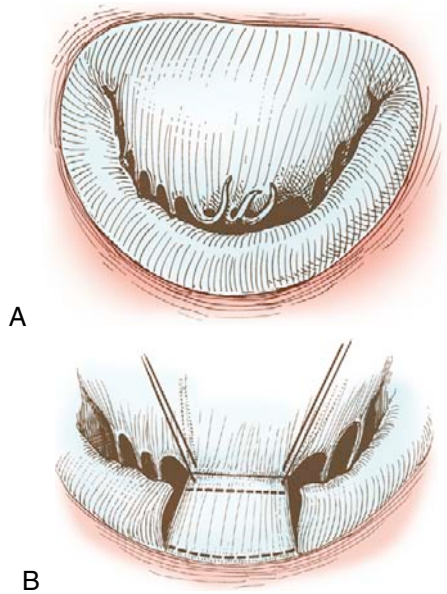


FIGURE 24-62 Chordal flip procedure. Although portions of the posterior leaflet can be resected with success, the same is not true of the anterior leaflet because the shape of the valve and the coaptation margin are altered. **A**, When there are ruptured chordae of the *anterior* leaflet of the mitral valve, the flip procedure can be used to reestablish chordal support for the anterior leaflet. **B**, A portion of normal posterior leaflet tissue with attached chordae is cut, swung over, and sewn onto the flail segment of the anterior leaflet.

leaflet. The remaining posterior leaflet defect is closed with suture (see step 2).

8. The edge-to-edge technique introduced by Alfieri and colleagues (2001) can be used to repair mitral valves with bileaflet prolapse (i.e., both the *anterior* and *posterior* leaflets are incompetent, producing severe MR). The free edges of the mitral leaflets are approximated, and a figure-of-eight suture (or percutaneously-delivered clip) is placed in the central portion of the apposed leaflets. This creates a double-orifice mitral valve that can significantly reduce MR and preserve the native valve (Mascagni et al, 2005). Frequently an annuloplasty ring supplements the Alfieri technique (Fedak et al, 2008).

Percutaneous mitral valve repair employing various devices and delivery methods is under investigation. The complex nature of the mitral valve apparatus poses particular challenges to avoid injury to the valve components or other cardiac structures (Fedak et al, 2008).

Mitral Valve Replacement

Mitral valve replacement (MVR) is the excision of the mitral valve leaflets and replacement with a mechanical or biologic prosthesis. Generally, the mural (posterior) leaflet and associated chordae and papillary muscles are retained to maintain left ventricular configuration (*geometry*), thereby enhancing postoperative ventricular function. If possible, the anterior leaflet is also retained if it does not interfere with prosthetic function and it is not too heavily calcified.

Median sternotomy is performed in most cases, but right thoracotomy incisions are useful in selected cases (e.g., reoperation, especially in patients with CABG IMA and vein grafts to the LV coronary circulation). Minimally invasive (and robotic) procedures on the mitral valve can also use right and left thoracotomy incisions or ports.

Procedural Considerations. Although the surgeon may intend to implant a specific type of prosthesis, patient-related factors (Box 24-7) or prosthetic valve complications (Box 24-8) may modify the plan (Oakley et al, 2008). A complete range of the surgeon's preferred valves should be available, as well as saline to rinse the glutaraldehyde storage solution (see Risk Reduction Strategies box on p. 1029) from biologic prostheses if they are used. Pledgetted sutures of alternating colors are used, and suture holders may be available additionally to keep the stitches in the correct order. Venting catheters and aspirating needles are used to remove air from the heart and ascending aorta. A small dental mirror may be used after a bioprosthesis has been implanted to ensure that sutures are not caught in the struts of the valve.

Operative Procedure. Double venous cannulation is used.

1. The aorta is cross-clamped, and cardioplegic solution is infused through the aortic root and/or retrograde through the coronary sinus.
2. The left atrium is incised along the interatrial groove to expose the mitral valve (Figure 24-63, *A*).
3. The valve is assessed, and the anterior leaflet is excised. The posterior leaflet and occasionally the anterior leaflet are retained to enhance the ventricular configuration and postoperative function. Rongeurs may be used to debride heavy calcification; loose debris is removed. A margin of the valve annulus is retained to insert fixation sutures to the prosthesis (Figure 24-63, *B*).
4. A valve sizer is used to determine the correct size of the prosthesis, which is delivered to the field.
5. Nonabsorbable cardiovascular sutures (15 to 20 or more) are placed in the annulus of the valve and then placed into the sewing ring of the prosthesis.

BOX 24-7

Patient-Related Factors and Risks for Valve Surgery

- Age
- Gender
- Residence
- History of atrial fibrillation
- Endocarditis (preoperative)
- Connective tissue disorders (e.g., myxomatous changes)
- Congenital anomalies (e.g., bicuspid aortic valve)
- Enlarged left atrium
- Left atrial thrombus
- Coronary artery disease
- Left ventricular function (e.g., functional class, myocardial infarction, heart failure)
- Syncope
- Mismatch between native valve orifice and patient body size
- Anticoagulation therapy compliance
- Preexisting medical problems (e.g., diabetes mellitus, hypertension, hepatic or renal disease)
- Valve lesion, anatomic anomalies
- Previous cardiac surgery

Modified from Stout KK, Verrier ED: Acute valvular regurgitation, *Circulation* 119:3232-3241, 2009; Rahimtoola SH: Choice of prosthetic heart valve for adult patients, *J Am Coll Cardiol* 41(6):893-904, 2003; Oakley RE et al: Choice of prosthetic heart valve in today's practice, *Circulation* 117:253-256, 2008; Ascione R et al: Mechanical heart valves in septuagenarians, *J Cardiac Surg* 23:8-16, 2007.

BOX 24-8

Valve-Related Risks and Complications

- Thromboembolism
- Anticoagulation-related hemorrhage
- Prosthetic valve endocarditis
- Mismatch between prosthetic valve orifice and patient body size
- Periprosthetic leak
- Prosthetic failure

Modified from Oakley RE et al: Choice of prosthetic heart valve in today's practice, *Circulation* 117:253-256, 2008; Stout KK, Verrier ED: Acute valvular regurgitation, *Circulation* 119:3232-3241, 2009; Rahimtoola SH: Choice of prosthetic heart valve for adult patients, *J Am Coll Cardiol* 41(6):893-904, 2003; Pepper J et al: Stentless versus stented bioprosthetic aortic valves. A Consensus Statement of the International Society of Minimally Invasive Cardiothoracic Surgery (ISMICS) 2008, *Innovations* 4(2):49-60, 2009; Ascione R et al: Mechanical heart valves in septuagenarians, *J Cardiac Surg* 23:8-16, 2007.

6. The sutures are held taut (and moistened with saline) as the prosthesis is guided into position and secured, and the sutures are tied and cut (Figure 24-63, *C*).
7. Continuous nonabsorbable sutures are used to partially close the atriotomy. The patient is placed in the Trendelenburg position, and the lungs are inflated to remove air from the pulmonary veins and atrium. Air is aspirated from the left ventricle through a hypodermic needle inserted into the LV apex or through the vent catheter, and the atrial closure is completed.

Endoscopic, video-assisted, robotic mitral valve surgery has progressed from a technical curiosity to an acceptable method (albeit with a significant learning curve) of intracardiac, telemanipulated valve repair. Both mitral valve repair and replacement have been performed with these techniques (Figure 24-64), as well as procedures to correct other intracardiac structural lesions (Chitwood, 2005; Chitwood et al, 2008).

SURGERY FOR THE TRICUSPID VALVE

Right-sided valve disease "deserves a little more respect" according to the title of a review by Bruce and Connolly (2009, p. 2726). The authors recommend more aggressive therapy in patients with both tricuspid and pulmonary valve disease before clinical deterioration occurs. Among the treatment options for tricuspid valve disease are suture annuloplasty, ring annuloplasty, and valve replacement with either a biologic or a mechanical prosthesis. Percutaneous approaches have been investigated in the experimental setting (Rogers and Bolling, 2009).

Like the mitral valve, the tricuspid annulus is saddle-shaped and techniques to repair the valve should consider this anatomic configuration for optimal repair (Rogers and Bolling, 2009). Annuloplasty ring insertion may be preferable to suture annuloplasty (Tang et al, 2006; Bruce and Connolly, 2009).

Tricuspid Valve Annuloplasty

Tricuspid valve annuloplasty reduces a dilated annulus with a suture technique (Rabago et al, 1980) or a prosthetic ring. Tricuspid valve regurgitation may be caused by bacterial or viral endocarditis, the presence of a pacemaker or defibrillator lead through the valve annulus, or the functional result of mitral valve disease. After mitral valve correction, tricuspid valve function may return to normal, although this theory has been questioned (Rogers and Bolling, 2009; Bruce and Connolly, 2009). Preoperatively, if the tricuspid annular dilation is diagnosed to be severe, ring repair (similar to mitral annuloplasty) or valve replacement may be performed. Caution is taken to avoid injury to the conduction tissue in the area of the AV node. A pulmonary artery catheter is usually not inserted preoperatively because it can interfere with the surgical field. A catheter may be inserted after the repair is completed.

Patients with significant tricuspid stenosis or regurgitation or failed tricuspid (suture or ring) annuloplasty may require insertion of a prosthetic biologic or mechanical valve (Bruce and Connolly, 2009). There are no specific tricuspid prosthetic valves; rather, a mitral prosthesis would be implanted.

Operative Procedure

1. Double venous cannulae are inserted so that they do not cross one another in the right atrium, and occluding tapes are tightened around the cavae and cannulae to prevent venous return from entering the right atrium and obscuring the surgical site. A right-angled venous cannula may be placed into the superior vena cava to enhance exposure.
2. The right atrium is opened longitudinally to expose the tricuspid valve. Sump suctions are inserted to remove coronary sinus drainage.
3. In the DeVega (Rabago et al, 1980) suture annuloplasty technique (Figure 24-65), a double-armed, felt-pledgetted suture is placed in the valve annulus, beginning at the anteroseptal commissure and continued around to the level

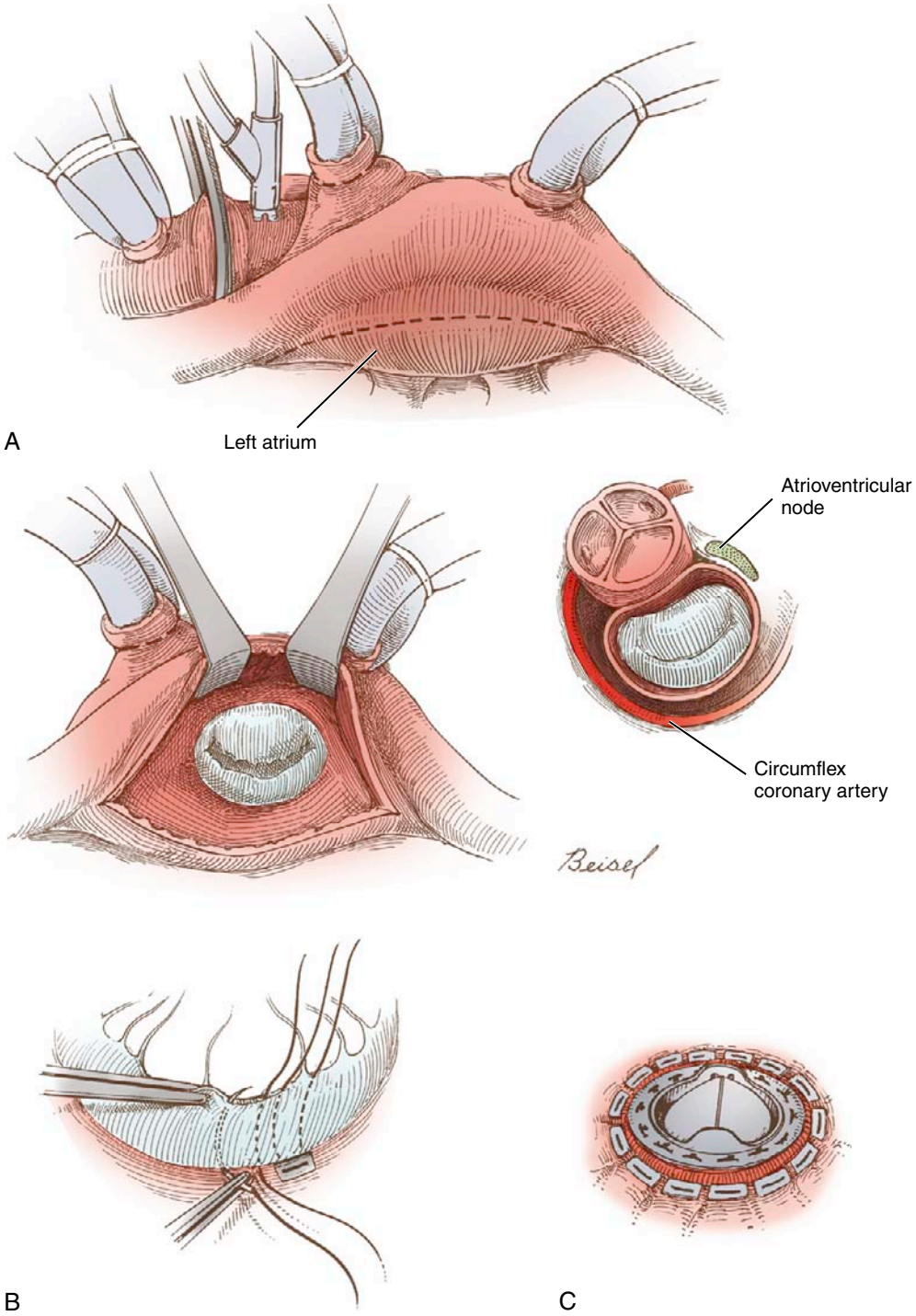


FIGURE 24-63 Mitral valve replacement. **A**, Line of incision and cannulation for bypass, anatomic relationship between mitral and aortic valves with location of conduction node, and exposure of valve. **B**, Placement of pledgetted double-armed sutures in native valve annulus. **C**, Completed valve replacement.

of the coronary sinus orifice. The remaining arm of suture is similarly placed. The suture is tied over a pledget with sufficient tension to reduce the annular area to the size desired.

4. In the ring annuloplasty technique, a prosthetic ring is inserted in a manner similar to that used for mitral valve annuloplasty (see Figure 24-59).
5. For valve replacement, the surgeon selects the desired prosthesis and inserts it in a manner similar to that for mitral valve replacement (see Figure 24-63).
6. Saline may be injected into the ventricle to test the competence of the repair, and TEE is also employed.
7. The right atrium is closed with nonabsorbable suture.

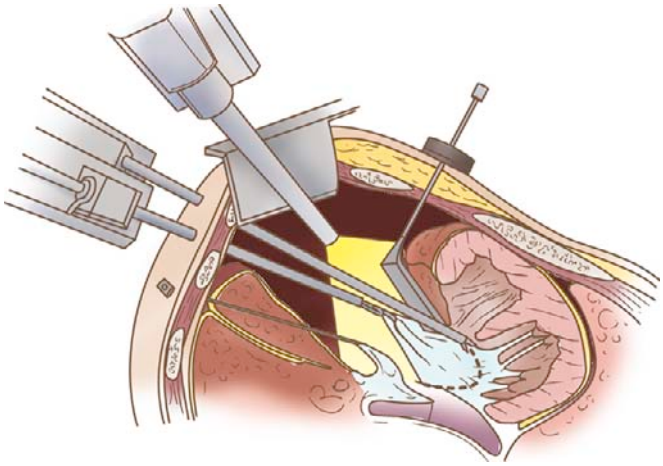


FIGURE 24-64 The 1-cm robotic instrument arms are placed through the chest wall. A transthoracic retractor arm elevates the interatrial septum toward the sternum. The three-dimensional camera is placed through a 4-cm incision, which also serves as a working port for the assistant.

SURGERY FOR THE PULMONARY VALVE

Pulmonary valve surgery in the adult is unusual, although patients with genetic deformities or those who have undergone repair of congenital pulmonary valve or right ventricular outflow tract obstruction (see Chapter 25) may present with significant pulmonary valve disease (Bruce and Connolly, 2009). Generally mild or moderate pulmonary stenosis (PS) produces few symptoms. For patients with severe PS, treatment options include valvulotomy or valve replacement via percutaneous or standard surgical techniques. Generally an aortic bioprosthesis or an allograft is inserted for valve replacement.

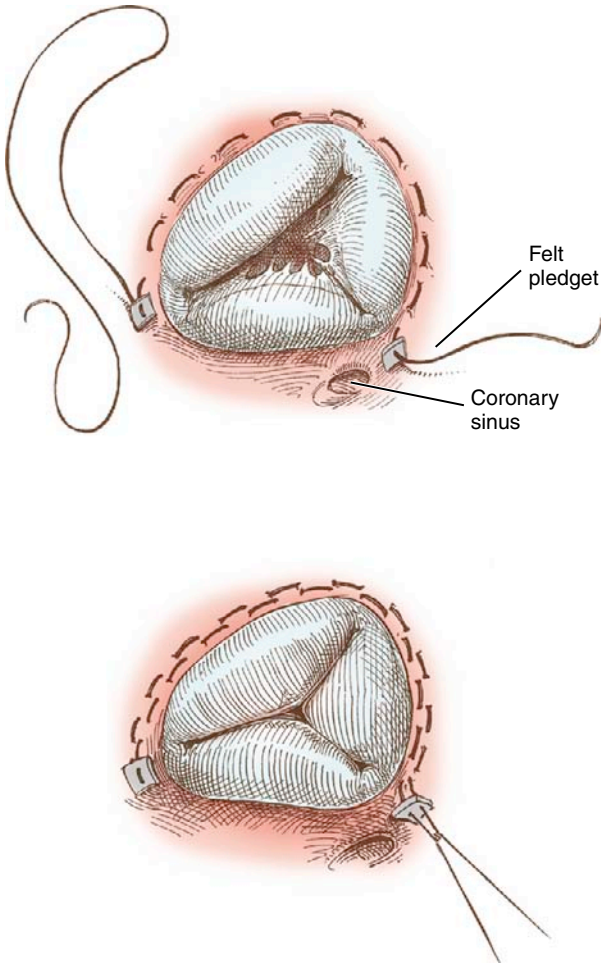


FIGURE 24-65 DeVega tricuspid valve suture annuloplasty.

SURGERY FOR THE AORTIC VALVE

Aortic *stenosis* (AS) produces obstruction to left ventricular outflow. Whether caused by rheumatic fever, a congenital bicuspid valve, or calcification, the fused valve leaflets present an increasing resistance to left ventricular outflow, thus increasing the pressure inside the left ventricle. Recent histopathologic and clinical data suggest that calcified AS is not a "degenerative" passive process but, rather, an active and possibly inflammatory disease process (Otto and Bonow, 2008).

To compensate for the increased pressure load, the ventricle hypertrophies so that it can generate sufficient pressure to eject blood through the narrowed opening. When disease is severe, large pressure gradients are often measured during cardiac catheterization, with differences in systolic pressures between the ventricle and the aorta reaching 50 mm Hg or more. In the early stages of the disease, a systolic ejection murmur may be heard, but patients are rarely symptomatic. Eventually, fatigue, exertional dyspnea, angina pectoris, syncope, and congestive heart failure may develop, presenting a grave prognosis. Although infrequent, sudden death may be the first sign of AS in asymptomatic patients who are not well monitored (Cohanes and Davidoff, 2009; Dal-Bianco et al, 2008).

In developing countries aortic *insufficiency (regurgitation)* is most often caused by rheumatic fever, and in developed countries it is usually caused by congenital anomalies (commonly a bicuspid aortic valve) (Otto and Bonow, 2008). Although *repair* of the aortic valve is challenging because of the precise closing mechanism of the valve leaflets, aortic valve reparative techniques have been employed successfully in selected patients (Otto and Bonow, 2008). Total valve excision and replacement with a prosthesis or an allograft are commonly performed.

Interventional percutaneous and minimally invasive techniques have been developed. Transcatheter aortic valve implantation performed in the cardiac catheterization laboratory is increasingly employed as a treatment option; long-term data are not widely available, but the trend is toward more percutaneous interventions in high-risk patients (Webb et al, 2009). Mini-sternotomy incisions can be employed although objective advantages over conventional sternotomy have not been seen with this technique (Brown et al, 2009).

In addition to selection of access, other challenges include the choice and size of a prosthetic valve. Selection is based on achieving appropriate hemodynamic function in relation to body size. The small aortic root (e.g., less than 21 mm) presents challenges to provide an adequate cardiac output. In patients with a small aortic annulus and large body mass (referred to as *patient/prosthesis mismatch*), the surgeon selects a prosthesis that will provide flow adequate to meet the body's needs. The stentless aortic valve (see Figure 24-27, *B*) is frequently used

because of the excellent hemodynamics (Cheng et al, 2009). Patch enlargement of the small aortic root is another option (Feindel, 2006; Sellke and Ruel, 2009) (described in the following Operative Procedure), and the patient's own pulmonary valve can be used as an autograft to replace the aortic valve; the pulmonary valve is then replaced with an allograft. Allografts may be used to replace the aortic valve as well.

Aortic Valve Replacement

The aortic valve is excised and replaced with a mechanical or biologic prosthesis or an aortic valve allograft or autograft.

Procedural Considerations

To the basic setup the following may be added:

- Aortic valve instruments
- Aortic valves, sizers, and holders
- Coronary sinus retrograde-infusion cannula and venting catheters
- Saline and three basins to rinse the glutaraldehyde storage solution from bioprostheses
- Saline bath to thaw frozen allografts

Operative Procedure

1. After the institution of CPB, a left ventricular vent is inserted through a stab wound into the right superior pulmonary vein and the tip is advanced into the left ventricle. A retrograde cardioplegia catheter is inserted into the coronary sinus (Figure 24-66, *A*).
2. The aorta is cross-clamped. If aortic insufficiency is present, the initial bolus of cardioplegic solution is infused retrogradely; subsequent cardioplegic infusions are also given retrogradely. Occasionally, direct coronary perfusion (Figure 24-66, *B*) is given if a retrograde catheter cannot be inserted; however, direct perfusion is avoided when possible (because of the risk of injuring the coronary endothelium). If aortic stenosis is present, the initial bolus of cardioplegic solution may be infused by needle through the aorta into the aortic root. Once the heart is arrested, the aorta is opened.
3. The native valve is inspected. The valve is carefully excised to avoid injury to the annulus and underlying structures (Figure 24-66, *C*). Calcium is debrided from the annulus with scissors or rongeurs, or both. Narrow packing may be used in the left ventricle to confine small, loose, calcified fragments that could subsequently embolize. Instruments should frequently be wiped clean with a moist sponge.
4. The annulus is sized, the proper prosthesis is selected, and a prosthesis holder is attached.
5. a. If a biologic valve is selected, it is delivered to the field and rinsed in three saline baths according to the manufacturer's instructions (see Risk Reduction Strategies box on p. 1029). Biologic valves should be kept moist with frequent saline rinsing; they should *not* be immersed in antibiotic solution.
   b. If an allograft is used, it is delivered to the field and thawed in saline baths according to protocol.
   c. If a mechanical valve is chosen, it should be protected from scratches or other injury.
6. a. The new valve is implanted (Figure 24-66, *D* and *E*) by use of a technique similar to that previously described for MVR.
   b. If the aortic annulus is too small to accept a prosthesis of adequate size, the annulus and proximal portion of the ascending aorta can be enlarged. A patch of bovine pericardium or Dacron graft can be placed longitudinally in the proximal anterior ascending aorta where the aortic annulus has been incised (Figure 24-67, *A* and *B*). The valve prosthesis is sutured to the natural annulus and then to the patch (Figure 24-67, *C*). The patch is sutured to the remaining edges of the aortotomy (Figure 24-67, *D*).
7. The aorta is closed with nonabsorbable sutures, and the cross-clamp is removed.
8. The left side of the heart is deaired (by vent, by moving the OR bed side to side, or by other maneuvers chosen by the surgeon). The patient is placed in the Trendelenburg's position, and the lungs are inflated. The heart is not allowed to eject blood until the surgeon is satisfied that no air remains within the left ventricle. TEE is used to identify residual air. The heart is defibrillated if it does not resume beating spontaneously.
9. Rewarming of the heart continues, the venting catheter or catheters are removed, and the chest is closed in the routine manner.

Combined Surgery

When CABG is to be performed with aortic valve replacement, the procedure usually is done in the following order:

1. The diseased valve is excised, the annulus is sized, and the prosthesis is selected.
2. Distal coronary anastomoses are performed.
3. The prosthetic valve is inserted.
4. The aorta (or left atrium in MVR) is closed.
5. The proximal coronary anastomoses are inserted into the aorta, after which the aortic cross-clamp is removed.

Double Valve Replacement

When the *aortic and mitral valves are both replaced,* the valves are first excised and the annuli sized. Then the mitral valve prosthesis is first implanted, followed by the aortic valve. (If the aortic prosthesis is inserted first, the firm prosthetic aortic annular ring could cause cardiac injury and make insertion of a mitral prosthesis difficult.) The aorta is closed, and after sufficient deairing of the left ventricle, the left atrium is closed.

SURGERY FOR THE THORACIC AORTA

Thoracic aortic aneurysmectomy is excision of an aneurysmal portion of the ascending aorta, aortic arch, or descending thoracic aorta and replacement with a prosthetic graft, valve-graft conduit, or intra-aortic prosthesis. Collagen-impregnated grafts have significantly reduced interstitial bleeding and obviated the need for preclotting techniques.

Aneurysms may be caused by atherosclerosis, trauma, infection, or cystic medial degeneration (Isselbacher, 2008). *Atherosclerosis* affects large and medium arteries with tunica intima deposits of plaques containing cholesterol, lipoid material, and lipophages. Atherosclerosis generally affects the smaller arteries rather than the aorta. *Arteriosclerosis* is a condition characterized by loss of elasticity and by thickening and hardening of the arteries. Both conditions may lead to aneurysm formation within an artery.

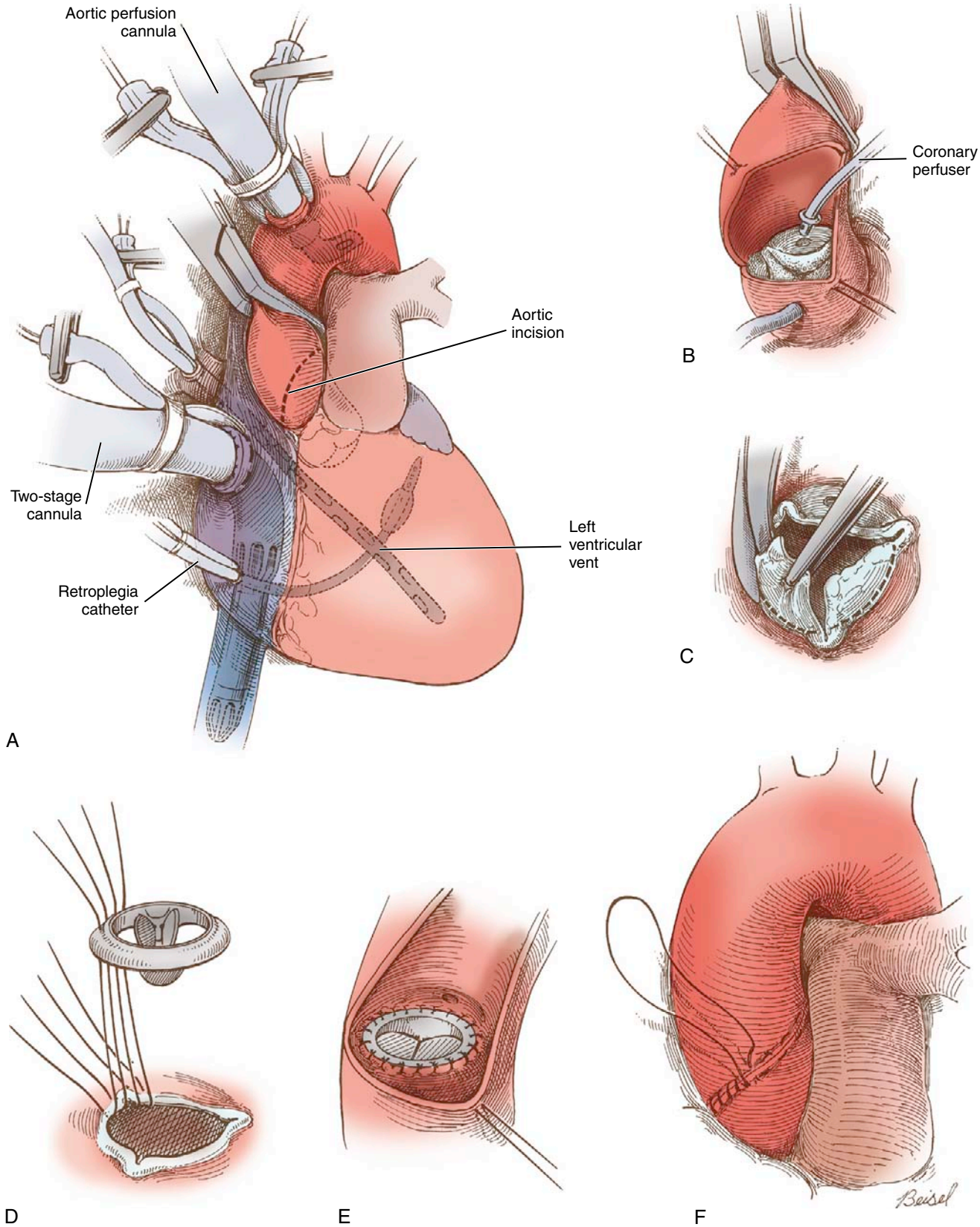


FIGURE 24-66 **A**, Cannulation, retrograde cardioplegia, and vent sites for aortic valve procedures. Note incision line. **B**, If retrograde cardioplegia is not used, handheld coronary ostial catheters can deliver antegrade cardioplegic solution. **C**, Diseased valve is completely excised. **D**, Sutures are placed in the valve annulus and the prosthetic sewing ring. **E**, Stitches are tied and cut. **F**, Closure of the aortic suture line.

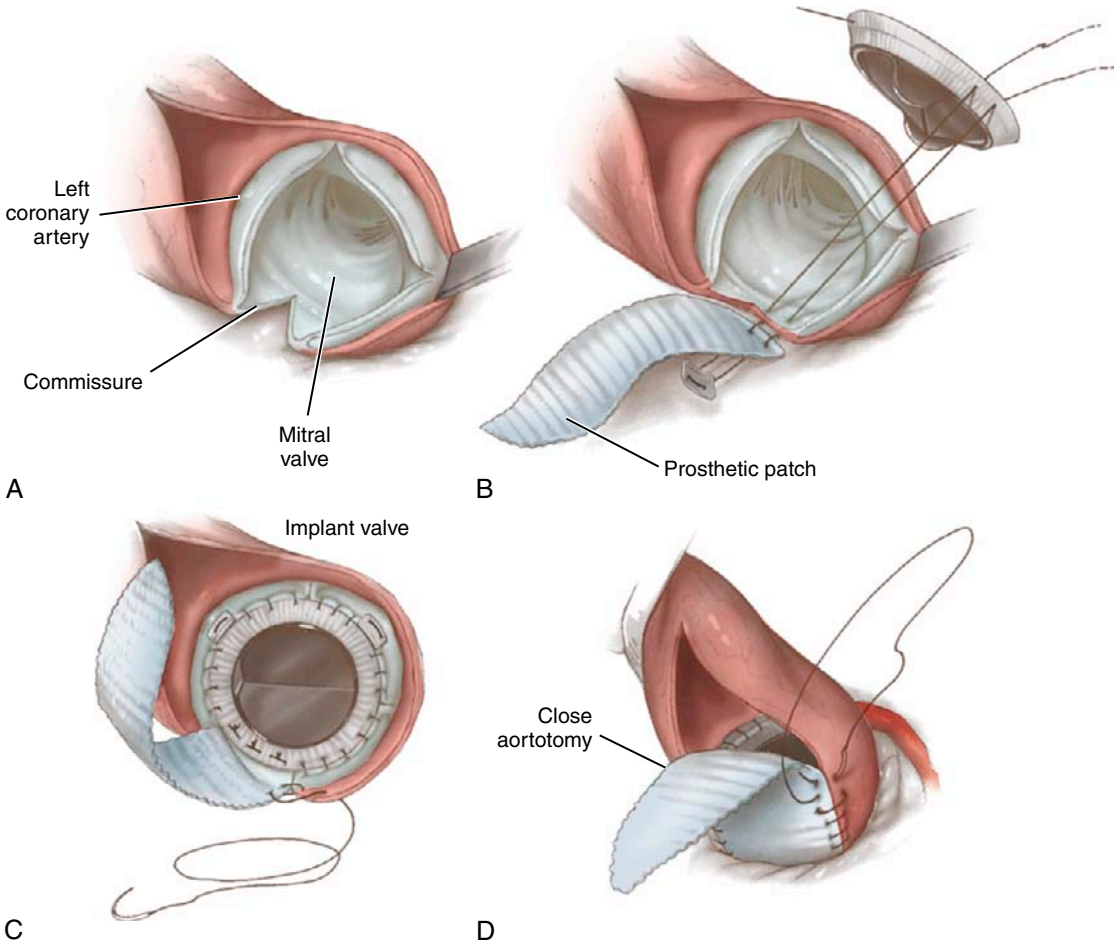


FIGURE 24-67 Technique for aortic enlargement (Nicks-Nuñez operation). **A**, The aortotomy is extended through the commissure separating the left and noncoronary cusps. **B**, A prosthetic patch is sewn into the cut portion of the aorta and into the prosthetic valve. **C**, The prosthetic valve is seated, and the stitches are tied and cut. **D**, The patch is incorporated into the aortotomy closure.

Aortic *dissection* is a unique entity and is related to a tear in the tunica intima of the aorta that exposes underlying degenerative changes in the tunica media layer of the artery. Intraluminal blood flow penetrates and flows through the tear, resulting in subsequent dissection of the tunica media (Isselbacher, 2008). As blood passes between the layers of the wall, it forms a false channel; as the channel extends and enlarges, the blood flow can be obstructed through the aorta and its branches, or the aorta can rupture, causing severe hemorrhage (Figure 24-68, *A*).

Surgical intervention becomes necessary when presenting symptoms indicate a compromised circulation or danger of rupture; generally, medical management with hypotensive agents to reduce stress on the vessel is the preferred initial treatment until surgical repair can be performed.

Aneurysms can be characterized morphologically as follows: (1) saccular—a sac type of formation with a narrowed neck projecting from the side of the artery; (2) fusiform—a spindle-shaped formation with complete circumferential involvement of the artery. Dissections can be characterized in at least two systems according to type, origin, and extent of the lesion (Table 24-10).

Procedural Considerations

Several methods of surgical treatment are described in the classic study by Crawford (1990). In situations where ascending aortic aneurysm or aortic dissection produces annular dilation with subsequent aortic valve insufficiency, a modified Bentall-DeBono procedure with a composite graft-valve conduit and reimplantation of the coronary ostia may be performed to replace the aortic valve and the aneurysmal aorta (Quigley et al, 2008; Isselbacher, 2008) (Figure 24-69). Retrograde cardioplegia is usually employed to arrest the heart; if necessary, selective coronary infusion may be used. The Bentall-DeBono procedure necessitates reimplanting the right and left coronary ostia into the prosthetic graft; in patients with CAD, vein grafts may be inserted and anastomosed proximally to the prosthesis.

The type of CPB depends on the location of the aneurysm or dissection. Generally, the atrium can be cannulated for venous return and the femoral or axillary artery is used for arterial inflow (because the weakened ascending aorta cannot be safely cannulated). Deep hypothermia with circulatory arrest and cerebroplegia may be needed to protect the heart and brain in particularly complex lesions of the aortic arch where placement

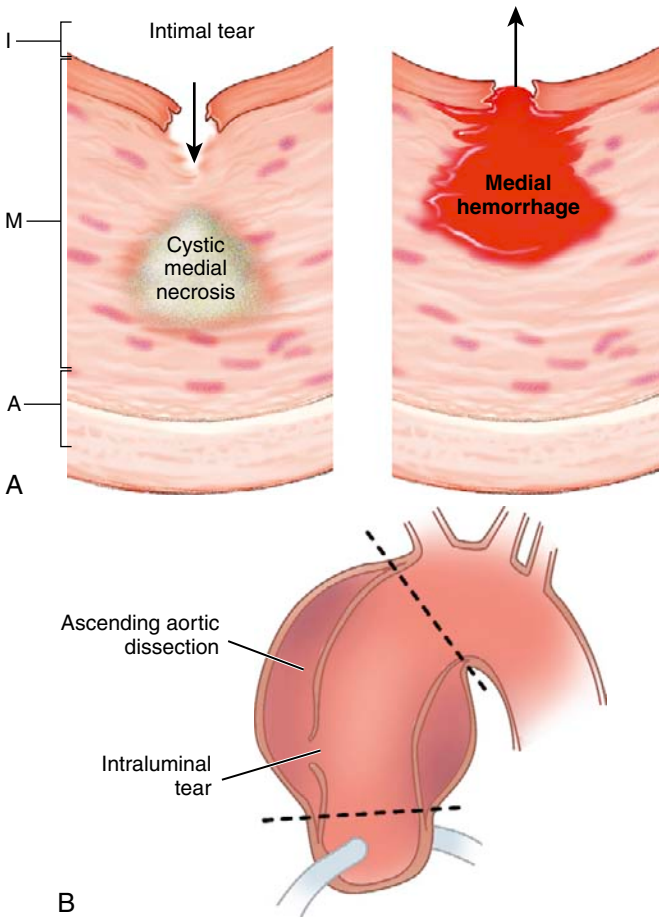


FIGURE 24-68 Aortic dissection. **A**, Proposed mechanism of the initiation of an aortic dissection (*A* = adventitia; *M* = media; *I* = intima). **B**, Intimal tear in the ascending aorta causing a dissection.

of a cross-clamp is difficult. Cerebral oximetry may be used to monitor oxygenation of the brain.

Traditionally, during the open repair of descending thoracic aortic aneurysms, the heart is not arrested; it continues beating to perfuse the upper body. Femoral bypass may be instituted to perfuse the kidneys and lower extremities; however, normothermia usually is maintained. Hypothermic CPB can be used to repair complex descending and thoracoabdominal aneurysms to provide protection against paralysis and renal, cardiac, and visceral organ system failure. Increasingly, an endovascular stent (see Figure 24-22) is used for aneurysms and dissections (Svensson, 2009); the prosthesis is inserted through the femoral artery and guided under fluoroscopy to the area of the descending aortic aneurysm.

In complex lesions involving the ascending aorta, arch, and descending aorta, the ascending aorta and arch repair may be performed with an open technique. Subsequently, repair of the descending aorta may be performed with an endovascular graft (see Repair of Descending Thoracic Aortic Aneurysm p. 1070) (Isselbacher, 2008).

Repair of Ascending Thoracic Aortic Aneurysm or Dissection

Procedural Considerations. To the basic setup are added aneurysm instruments. Valve instruments, coronary instruments, and an array of tube grafts, valves, or valved conduits should be available. Bicaval cannulation for venous drainage is preferred, but if the cavae cannot be safely accessed, the femoral vein is used initially for venous drainage. Once the aneurysm is controlled, the femoral venous line can be Y-ed to a vena caval cannula.

TABLE 24-10

Commonly Used Classification Systems to Describe Aortic Dissection

Type	Site of Origin and Extent of Aortic Involvement
DEBAKEY	
Type I	Originates in ascending aorta, propagates at least to aortic arch and often beyond it distally
Type II	Originates in and is confined to ascending aorta
Type III	Originates in descending aorta and extends distally down aorta or, rarely, retrograde into aortic arch and ascending aorta
STANFORD	
Type A	All dissections involving ascending aorta, regardless of site of origin
Type B	All dissections not involving ascending aorta
DESCRIPTIVE	
Proximal	Includes DeBakey types I and II or Stanford type A
Distal	Includes DeBakey type III or Stanford type B

Modified from Libby P et al: *Braunwald's heart disease,* ed 8, Philadelphia, 2008, Saunders.

Operative Procedure

1. The patient is positioned for a median sternotomy.
2. Cannulation for CPB is performed.
3. The sternum is opened, and the aneurysm is inspected.
4. The involvement of the aortic annulus is then considered.
   a. If the aortic annulus is not involved, the aneurysm is incised longitudinally and a woven graft is anastomosed proximally and distally to the healthy aorta (Figure 24-70). Felt strips incorporated into the anastomosis may be used to bolster friable tissue.
   b. If the aortic annulus is involved, the ascending aorta is incised to the annulus and the aneurysm may be excised. The leaflets are excised, and the annulus is measured. The proximal end of a valved conduit is inserted. An eye electrocoagulator is used to create openings in the graft at the location of the right and left coronary ostia, which are mobilized and anastomosed to the graft. (If the patient has concomitant CAD, saphenous vein grafts are inserted.) The distal end of the conduit is sutured to healthy aorta.
5. Bypass is discontinued, and all incisions are closed.

Repair of Aortic Arch Aneurysm

Procedural Considerations. Aneurysm instruments and woven grafts are available. If deep hypothermia is to be used, the patient's head may be covered with bags of ice at the beginning of the procedure to reduce cerebral oxygen demand. Precautionary measures (e.g., padding) to prevent

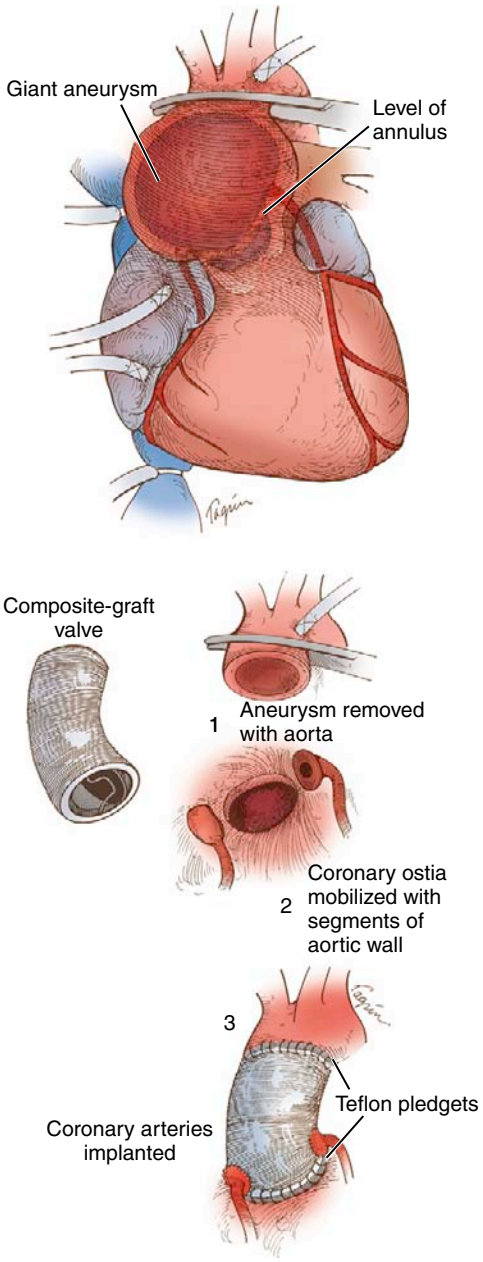


FIGURE 24-69 Bentall-DeBono procedure (see text).

frostbite are instituted. The location of the aneurysm will determine the positioning. Aneurysms of the proximal arch can be accessed through a median sternotomy; distal arch aneurysms may require a modified thoracotomy position to optimize exposure. Selective cerebral perfusion may be used during circulatory arrest to perfuse the brain. *Retrograde* cerebral perfusion is performed via the superior vena caval venous line that is Y-ed off the arterial line; arterial blood is slowly infused through the SVC line into the cerebral circulation while the distal aortic anastomosis is performed. *Antegrade* cerebral perfusion is achieved by infusing arterialized blood through one or more catheters into aortic arch vessels (i.e., brachiocephalic artery and left common carotid artery).

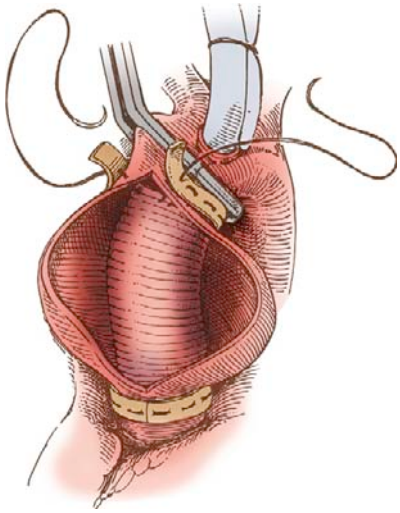


FIGURE 24-70 Resection and graft repair of ascending aortic aneurysm.

Operative Procedure

1. Cannulation of the right atrium and femoral or axillary artery is performed.
2. Once the patient is cooled to the desired temperature, the arch vessels are individually cross-clamped (Figure 24-71, *A* and *B*). (If circulatory arrest is indicated, cross-clamps are not used.) The aneurysm is incised, a tube graft (with or without side branches) is selected, and the anastomosis to the descending aorta is performed.
3. An opening is made into the side of the graft, and the graft is anastomosed to the common origin of the brachiocephalic, left carotid, and left subclavian vessels. Alternatively, when a graft with side branches is used, individual anastomoses to the head vessels are created. The graft is cross-clamped proximally to the arch and deaired (Figure 24-71, *C*).
4. The proximal aorta is anastomosed to the graft while the patient is rewarming. The graft is deaired, and the patient is weaned from bypass (Figure 24-71, *D*).
5. All incisions are closed.

Repair of Descending Thoracic Aortic Aneurysm

Procedural Considerations. *Endovascular* repair (see Figure 24-22) of descending aortic aneurysms and dissections has largely replaced the traditional open technique, although anatomic considerations may increase the difficulty of placing the straight endovascular tube graft into the angled portion of the proximal descending aorta (just distal to the left subclavian artery). Additionally, endovascular insertion requires nondiseased tissue for implantation of the device in the areas proximal and distal to the lesion (the "landing zones"); in patients with diffuse atherosclerotic disease or extensive dissection, viable tissue may not be present (Thompson and Bertling, 2009). It is not unusual to deploy more than one graft in order to cover the lesion. Endovascular instruments, guidewires, introducer sheaths, pigtail catheters, intravascular dye, dilators, catheters, an array of stent graft sizes, and deployment devices are required. The procedure is performed with fluoroscopy and is usually performed on an OR bed that

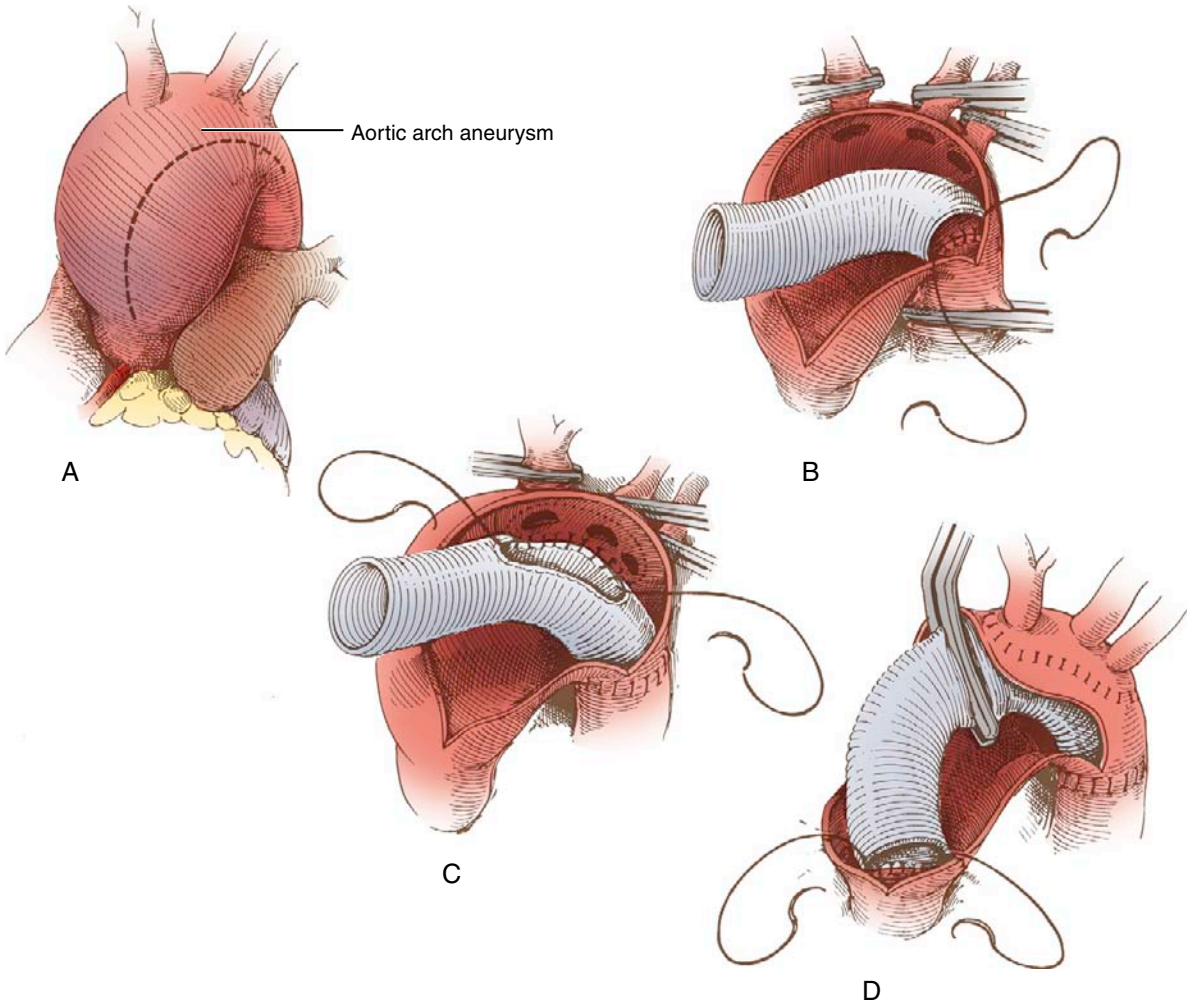


FIGURE 24-71 Repair of aortic arch aneurysm. **A**, Incision. **B**, Distal anastomosis. **C**, Anastomosis of graft to common origin of arch vessels. **D**, Proximal anastomosis.

allows imaging without extensive manipulation of the bed. Radiation precautions must be taken. The guidewires may be more than 6 feet in length so the scrub person should protect the sterility of the distal portion of the guidewire by anchoring the wire with towels or other sterile objects when not being used. The postoperative period is considerably shorter than that for a thoracotomy approach. Potential complications include bleeding and migration of the device (requiring adjustment and/or insertion of another device) (Thompson and Bertling, 2009).

For *open* repair, thoracotomy instruments and supplies are added to the basic setup; additional long aortic cross-clamps may be needed. Prosthetic grafts are available. The patient is positioned for a left posterolateral thoracotomy. Femoral vein–femoral artery bypass may be performed to perfuse the lower body. In this situation, the heart perfuses the upper body proximal to the aneurysm and normothermia is maintained.

If hypothermic CBP with circulatory arrest is employed, instruments and supplies per the surgeon's request should be available. Protective covering for the patient's head, face, and extremities may be required to avoid frostbite.

Operative Procedure—Endovascular Repair

1. One or both femoral arteries are accessed via a percutaneous (Seldinger) or cutdown technique. A hypodermic needle is inserted into the femoral artery. A guidewire is passed through the needle and threaded into the aorta. Fluoroscopy may be used to image the aortic lumen and measure targeted segments of the aorta. The hypodermic needle is removed and a sheath inserted (through which the device will be inserted).
2. A delivery catheter housing the graft is inserted into the descending aorta.
3. A monitoring device may be inserted through the contralateral femoral artery to measure intraluminal pressures.
4. Under fluoroscopy, the graft is guided into position and deployed into the aorta (see Figure 24-22). The device self-expands; a balloon may be inflated against the inside of the graft to secure the prosthesis against the aortic lumen.
5. Fluoroscopy is used to image the aorta and to confirm exclusion of the aneurysm/dissection.
6. The deployment devices and other intraluminal catheters and wires are removed and the incision(s) is (are) closed.

Operative Procedure: Open Repair

1. Cannulation for femoral vein–femoral artery bypass is performed.
2. A thoracotomy incision is made, the aneurysm is exposed, and the surrounding structures are inspected. (Occasionally the surgeon makes two thoracotomy incisions for better access to and control of the aorta.) Renal involvement is assessed; if indicated, measures to protect the kidneys are instituted (e.g., local cooling).
3. Normothermic femoral bypass is initiated.
4. The aneurysm is incised longitudinally, and the aorta is sized.
5. A woven graft (Figure 24-72) is inserted, and the aneurysmal remnants are wrapped around the graft.

ASSISTED CIRCULATION

Mechanical circulatory support has been available for more than 35 years (Gemmato et al, 2005), expanding the treatment for heart failure into a rapidly growing specialty that also includes coronary artery revascularization, left and right ventricular reconstruction, circulatory assist device implantation, and cardiac transplantation (McCarthy, 2008). Formerly, ventricular assist devices were reserved for those patients who could not be weaned from CPB after open-heart operations, or who had end-stage cardiomyopathy. Current indications and choices have expanded and a variety of active and passive devices are available to support the circulation for short-, intermediate-, and long-term support (Wilson et al, 2009). Selected ventricular assist devices have been approved for "destination" therapy, while other devices are indicated for patients awaiting a donor heart ("bridge-to-transplant" devices) (McCarthy, 2008; Naka and Rose, 2008; Miller et al, 2007).

Biologic assistance in the form of an autogenous muscle wrap (*cardiomyoplasty*) may be useful in some patients who may not be candidates for transplantation, but the procedure is used infrequently. The left latissimus dorsi muscle is dissected from the back and repositioned around the heart, where it is sewn around the ventricle. This (skeletal) muscle is then transformed into a continuously beating muscle by a cardiomyostimulator that paces the muscle with increasing frequency, allowing the muscle to become fatigue-resistant. The muscle wrap squeezes the heart in synchronization with natural electrical impulses moving through the heart muscle.

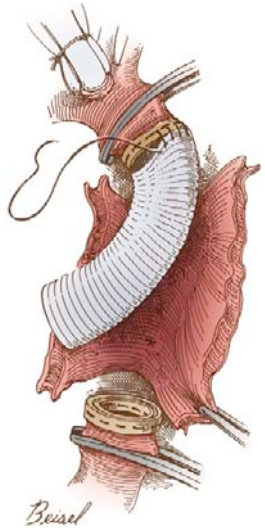


FIGURE 24-72 Resection and graft replacement for descending thoracic aortic aneurysm.

Intra-Aortic Balloon Pump

The most widely used short-term device is the intra-aortic balloon pump (IABP). The IABP (Figure 24-73) employs the principle of counterpulsation to increase coronary blood flow and decrease afterload (i.e., the resistance the ventricle must overcome to open the aortic valve).

Operative Procedure

1. A flexible guidewire is passed through a percutaneous needle into the femoral artery. The needle is removed, and graduated dilators are inserted over the guidewire to dilate the overlying tissue and the artery wall.
2. The IABP catheter (with the furled balloon) is inserted into the artery and advanced to a position just distal to the left subclavian artery. The catheter can be marked at the proximal end with a silk tie to measure the distance the catheter should be inserted.
3. The balloon is unfurled and activated.

Ventricular Assist Device

VADs are designed to augment cardiac output from the left (LVAD), right (RVAD), or both (biventricular—BiVAD) ventricles and to decrease the workload of the heart by diverting blood from the ventricle or ventricles to an artificial pump that maintains systemic perfusion. Patients with an LVAD can become better transplant candidates because the LVAD enhances anabolism, ambulation, and improved organ function. LVADs are employed as a bridge to cardiac transplantation by supporting the circulation while a suitable donor heart can be found. Based on the results of the Randomized Evaluation of Mechanical Assistance for the Treatment of Congestive Heart Failure (REMATCH) trial (Lietz et al, 2009; Long et al, 2005; Park et al, 2005; Rose et al, 2001), the use of the HeartMate (vented electric) LVAD (see Thoratec HeartMate LVAD section) was approved by the U.S. Food and Drug Administration in November 2002 for *destination therapy*/permanent replacement for the left ventricle. Although complications (e.g., bleeding, thromboembolism, infection, device failure) persist, they have been reduced with the newer VADs (Naka and Rose, 2008).

Among the increasing number of designs are the axial flow pump based on Archimedes' third-century screw pump that was used to raise well water for irrigation; the pump is inserted into the left ventricle to propel blood flow and the distal end is anastomosed to the descending aorta. Miniaturized centrifugal pumps, totally implantable pulsatile devices incorporating a transcutaneous energy transmission (and power regeneration) system, and artificial hearts (Naka and Rose, 2008) are some of the innovative responses for the treatment of heart failure.

Procedural Considerations. Insertion of an assist device may be indicated for patients who cannot be weaned from CPB with the use of IABP; device insertion also may be scheduled. Depending on the system, components of the system should be collected and prepared according to the manufacturer's instructions. Device components may include external centrifugal

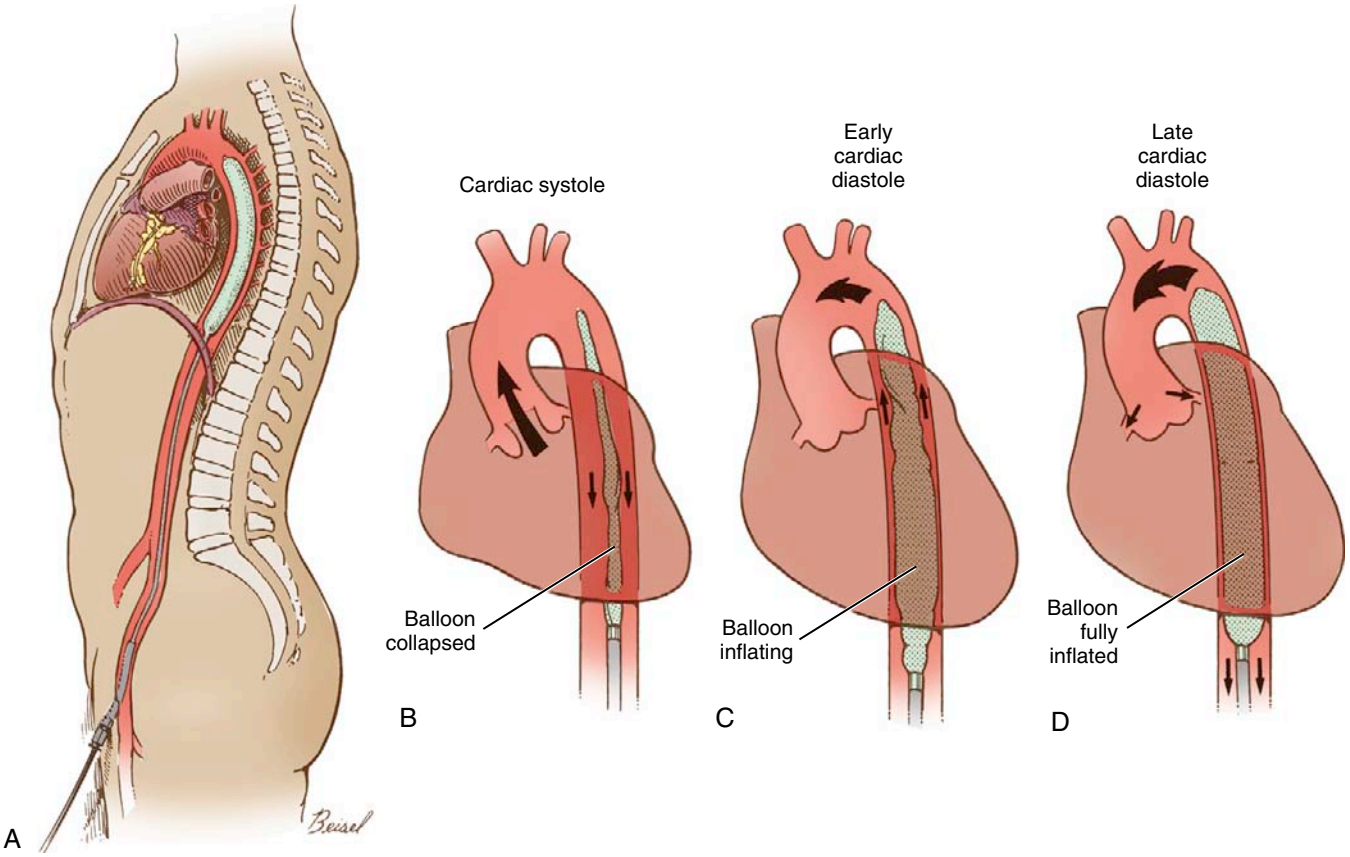


FIGURE 24-73 Phases of balloon pumping. **A**, Balloon inflation occurs from closure of aortic valve to end of diastole. Inflation causes retrograde flow of blood in aorta, increasing coronary perfusion pressure without increasing myocardial work or oxygen demand. Inflation also causes antegrade flow, increasing mean arterial pressure, renal flow, and cerebral flow. **B**, Balloon deflation occurs from just before opening of aortic valve to closure of aortic valve. Deflation encourages antegrade flow, decreasing afterload or resistance to left ventricular ejection. Deflation also decreases oxygen required by left ventricle, shortens systolic ejection, and increases stroke volume. **C** and **D**, When the balloon reinflates, the cycle is repeated.

pumps, internal pneumatically (Figure 24-74) or electrically powered assist devices, or wholly implantable systems with transcutaneous, rechargeable power sources.

The LVAD device described in the following section is approved for support of the left ventricle when right ventricular function is normal. Prosthetic valves are incorporated into the circuit to maintain unidirectional blood flow. All VADs will differ and preparation should be specific to the device. In preparation for VAD insertion, perioperative nurses are encouraged to discuss the type of VAD, insertion considerations, possible complications, and trouble-shooting scenarios with the surgeon.

Operative Procedure

THORATEC HEARTMATE LVAD

1. A median sternotomy incision is made and extended to the umbilicus (Figure 24-74, *A*).
2. A preperitoneal pouch is made for placement of the assist device.
3. CPB is established, and the aorta is cross-clamped. The atrial septum is inspected for defects, which are closed if found.
4. A Dacron graft is anastomosed to the aorta (Figure 24-74, *B*).
5. The left ventricular apex is mobilized, and an opening is created in the apex (Figure 24-74, *C*).
6. A connector is inserted into the apex, and the flange is sewn to the surrounding left ventricular myocardium with pledgetted sutures. The inflow conduit is attached to the apical connector (Figure 24-74, *D* to *G*).
7. An opening is made into the diaphragm near the location of the apical connector and inflow conduit. The conduit is passed through the diaphragm and attached to the assist device.
8. The aortic graft is attached to the outflow conduit, which is connected to the assist device (Figure 24-74, *H* and *I*).
9. The driveline is tunneled to the left lower quadrant, where it exits through the skin. The driveline can be connected to the drive console or to a battery pack. Blood flows from the left ventricular apex, to the device, and back into the body through the aortic conduit (Figure 24-74, *J*).
10. CPB is discontinued, and incisions are closed.

To remove or replace the pump, the patient is returned to the OR, the sternotomy is reopened, the cannulae are removed, and the device is removed (or replaced).

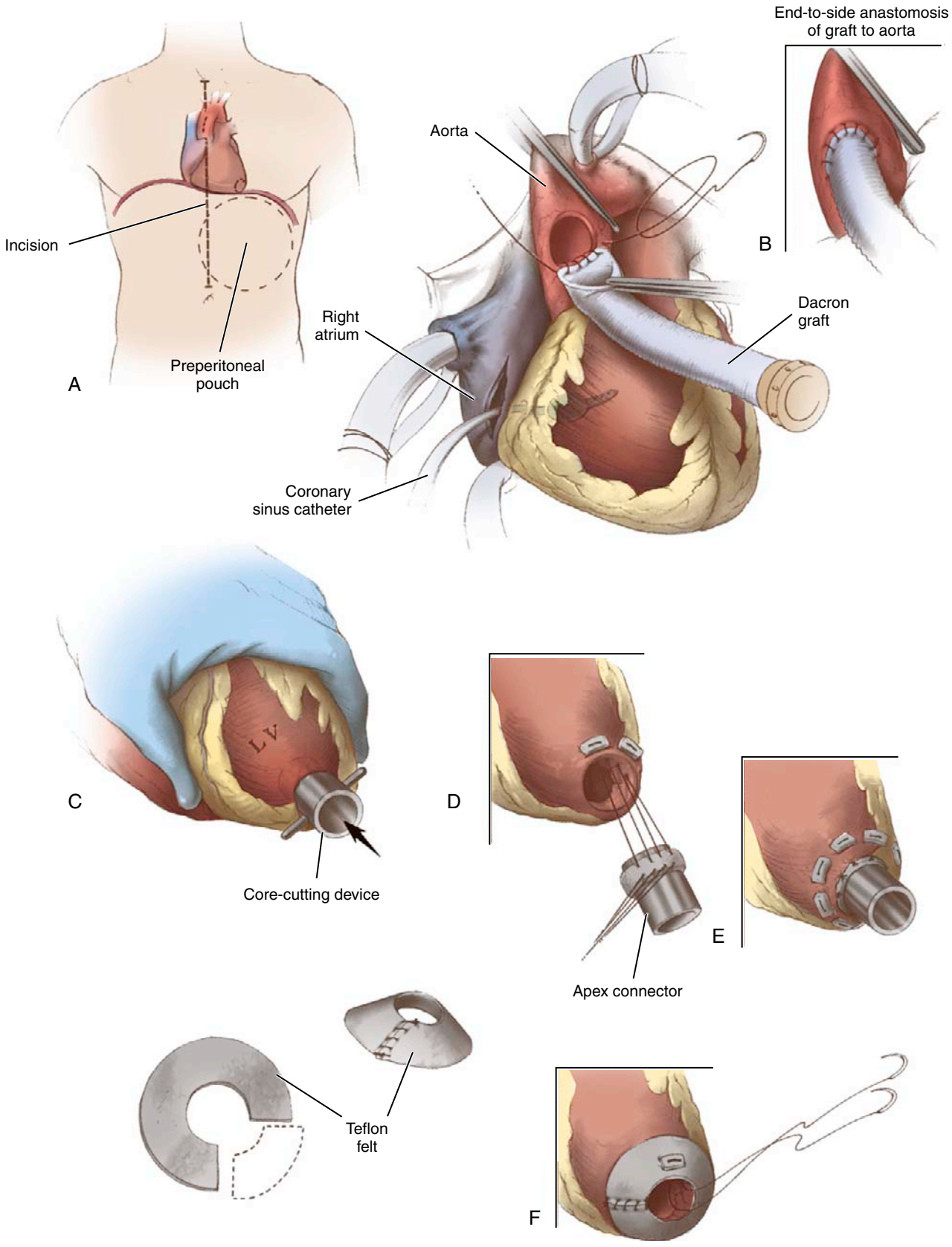


FIGURE 24-74 Left ventricular assist device (see text).

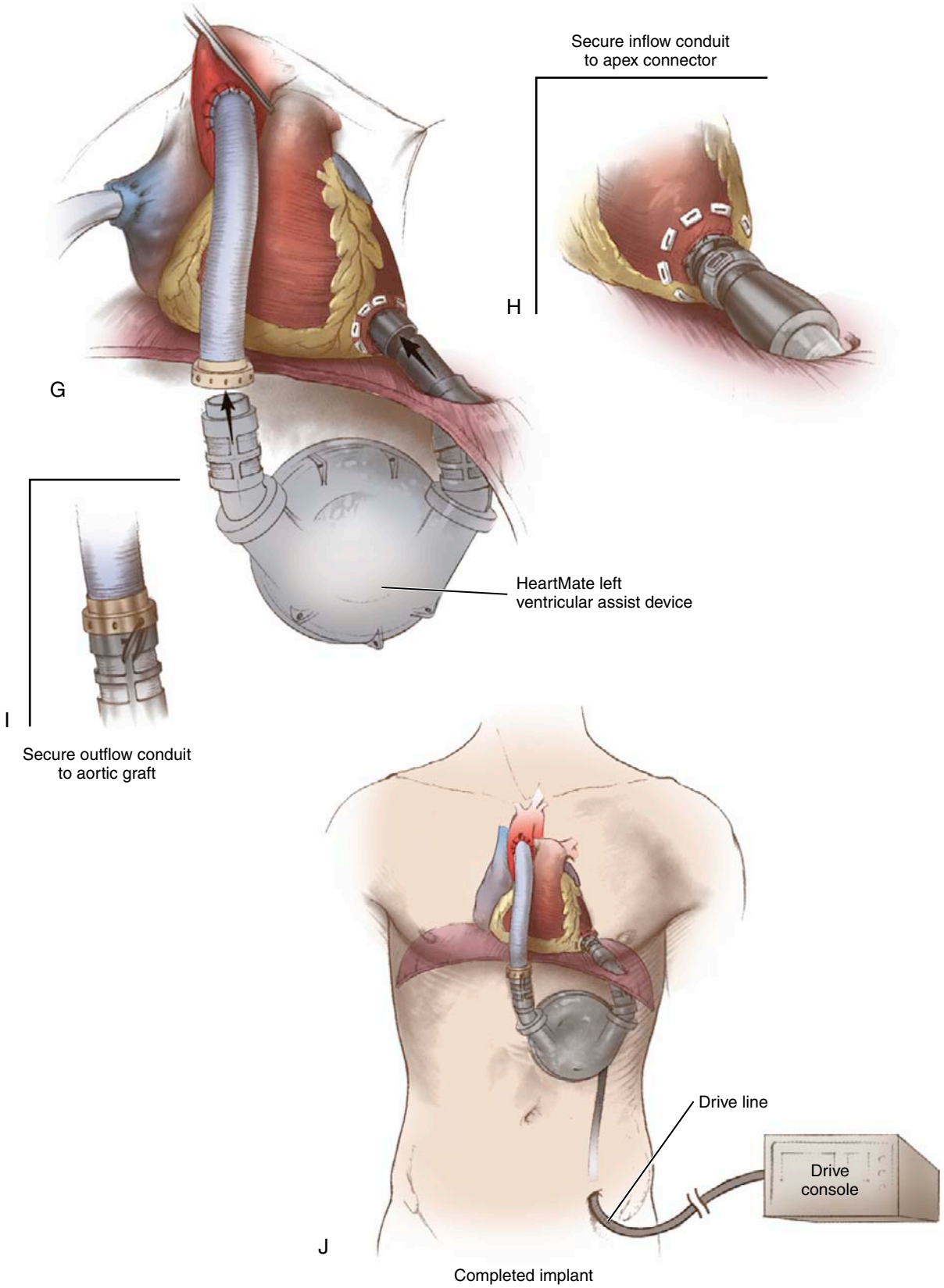


FIGURE 24-74, cont'd Left ventricular assist device.

Total Artificial Heart

The total artificial heart (TAH) continues to be refined and implanted in patients with end-stage biventricular failure. Complications associated with thromboembolism and infection have been reduced, but not eliminated, with technical and material refinements of VAD systems. Long-term right or left VADs have been increasingly employed as a bridge to cardiac transplantation by supporting the circulation until a suitable donor heart can be found (Naka and Rose, 2008).

Implantation of the first totally artificial heart by AbioCor—approved for implantation by the Food and Drug Administration (FDA) in 2006—was performed in June 2009 in a 76-year-old male who did not qualify for heart transplantation because of his age. The device employs two pumping chambers made of titanium and plastic. An internal rechargeable battery powers the device (Rothman, 2009). With greater emphasis on interventions for heart failure, nurses can anticipate an increased demand for univentricular and biventricular mechanical support.

HEART AND HEART-LUNG TRANSPLANTATION

Heart Transplantation (Figure 24-75)

Orthotopic transplantation (replacing one heart with another) is most commonly performed; less commonly, heterotopic (piggyback) and combined heart-lung procedures are performed. Important considerations continue to be recipient and donor selection, the immune response, and infection control. Older recipients and donors (older than 65 years) have demonstrated acceptable morbidity and survival (McCarthy, 2008; Hunt, 2006).

Modification of the traditional transplantation technique (e.g., atrial-atrial anastomoses) has reduced some of the dysrhythmias and valvular dysfunction associated with the traditional method of transplantation. End-to-end anastomoses between the donor and recipient SVC and the donor and recipient IVC are created, producing a more physiologic atrial contribution to ventricular filling and less distortion of the mitral and tricuspid annuli (McCarthy, 2008; Blanche et al, 1997). Tricuspid suture or ring annuloplasty may be performed on the donor heart to minimize tricuspid insufficiency (Jeevanandam et al, 2004). Revised pulmonary venous connections produce fewer dysrhythmias. These changes also lead to less AV valve regurgitation. Pulmonary artery and aortic anastomoses are performed in the traditional manner.

Procedural Considerations. Individual instrument setups are necessary for the donor and the recipient.

Operative Procedure

DONOR HEART. The donor heart is exposed through a median sternotomy. The aorta, pulmonary artery, and venae cavae are dissected. The venae cavae are occluded, the left atrium is opened to decompress the ventricle, and the heart is rapidly cooled and arrested.

The heart is excised by incision of the SVC and the IVC, the left atrium, the aorta, and the pulmonary artery (Hunt, 2006). The donor heart is immediately placed into cold saline and transported to the site where it will be inserted into the recipient.

RECIPIENT HEART. The recipient is placed on bypass with cannulation of the IVC and the SVC; caval tapes are placed around the cavae. The patient is cooled to approximately 32° to

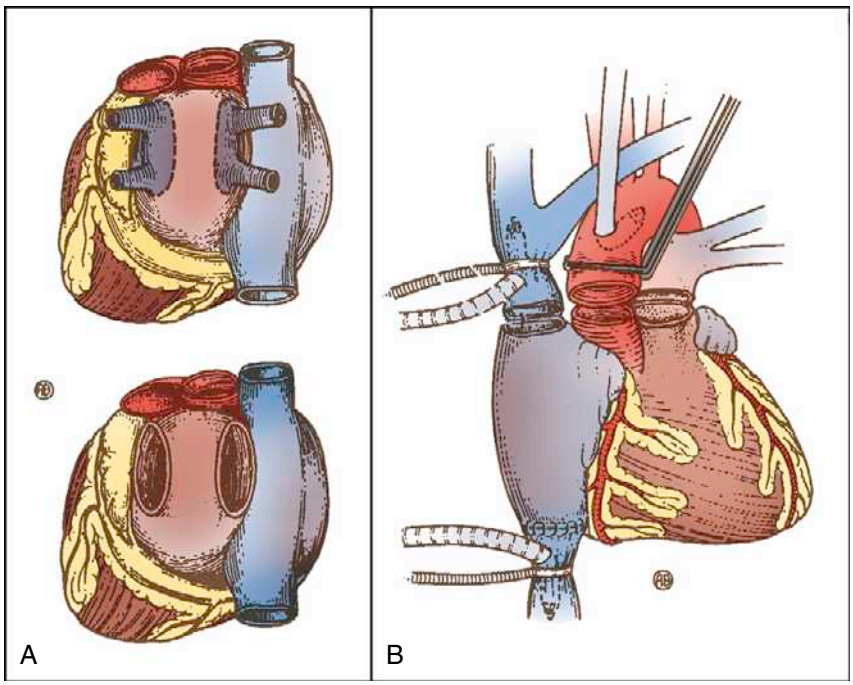


FIGURE 24-75 **A**, Heart transplantation with pulmonary venous anastomoses on right or left side, and caval anastomoses at the superior and inferior vena cavae. **B**, Aorta and pulmonary artery are joined last.

34° C (89.6° to 93.2° F), and the caval tapes are tightened. The pulmonary trunk and aorta are dissected immediately above their respective semilunar valves; the left atrium is incised to leave intact portions of the left atrial wall and the atrial septum of the recipient; and the right atrium is incised, retaining the SVC and IVC for anastomosis to the donor heart. The recipient heart is then removed.

The donor heart is placed in the pericardial well. The pulmonary anastomoses are performed (see Figure 24-75, *A*). The SVC and IVC are anastomosed with running cardiovascular sutures (see Figure 24-75, *B*). The donor and recipient aortas and pulmonary arteries are similarly joined. Air is removed from the left side of the heart. Before the pulmonary artery is sutured, all caval and atrial suture lines are carefully inspected for significant bleeding areas, and the cross-clamp is removed. Figure 24-76 illustrates the traditional (but less frequently anastomosed) right atrial suture line; aortic and pulmonary anastomoses are similar to the technique just described.

Defibrillation of the ventricles is usually effected with a single direct-current shock. A needle vent in the ascending aorta allows residual air to escape. The patient is then gradually weaned from the bypass. Cannulae are removed from the venae cavae and the aorta. The incisions are closed as described previously.

Heart-Lung Transplantation

Newer techniques for lung and heart-lung transplantation incorporate the bicaval anastomoses used for orthotopic heart transplantation and also employ a bibronchial anastomosis that reduces bleeding and enhances the integrity of the airway. To maximize the allocation of scarce donor organs, transplantation procedures for the lungs may use a single lung or bilateral lungs; heart-lung transplantation is infrequent (Cooper, 2004). Preservation of the *donor's* sinus node and the *recipient's* recurrent laryngeal, vagus, and phrenic nerves are important surgical considerations.

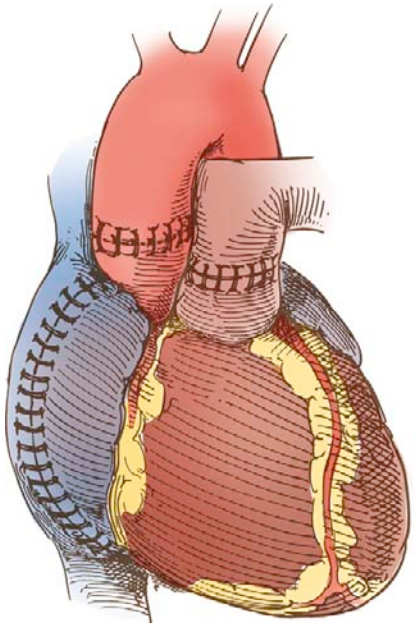


FIGURE 24-76 Traditional atrial anastomosis for heart transplantation.

Operative Procedure. The recipient's diseased heart and lung(s) are excised separately or en bloc, with care taken not to injure the major nerves listed previously. The recipient's right atrium, SVC, and IVC are saved to create bicaval attachments to the donor heart. The bronchi are transected. The donor heart and lungs are brought onto the field. The right lung is placed in the right pleural space, and the left lung is positioned in the left pleural space. The bronchial and the bicaval anastomoses are performed, and rewarming is begun. The aortic anastomosis is performed, the aorta is deaired, and the cross-clamp is removed.

SURGERY FOR CONDUCTION DISTURBANCES

Disturbances of the conduction system affect the rate, rhythm, and effectiveness of the contracting heart. Surgical techniques have been developed to treat a variety of supraventricular dysrhythmias (e.g., atrial fibrillation [AF] and Wolff-Parkinson-White reentry tachycardia) and both ischemic and nonischemic ventricular tachydysrhythmias (e.g., ventricular tachycardia or fibrillation). Preprocedural electrophysiologic mapping of the patient's conduction pathways identifies and locates aberrant pathways, tachydysrhythmias, and the existence of additional pathways, as well as the effects of medications on a particular dysrhythmia. Indications for pacemaker implantation (including resynchronization therapy) and antitachycardia-antifibrillation devices have been expanded. Many (but not all) pacemaker and internal cardioverter defibrillator (ICD) insertions are currently performed in the electrophysiology (EP) laboratory or the cardiac catheterization suite. Ablation procedures for AF may be performed in the EP laboratory. Depending on the anticipated origin of the problem, the electrophysiologist inserts a catheter percutaneously into the femoral vein or artery and threads the catheter retrograde to the right or left atrium and ventricle. The electrophysiologist tests various areas of the heart in an attempt to reproduce the dysrhythmia and then ablates the area of the heart where the rhythm disturbance originates. Postoperative considerations are similar to those for atrial fibrillation surgery. Surgical correction is performed in the OR.

AF is the most common cardiac dysrhythmia, affecting more than 2 million adults in the United States (AHA, 2009b). Atrial fibrillation is an abnormal heart rhythm that causes discomfort and stasis of blood in the atria. AF was considered a "benign" condition in the past, but the serious consequences associated with the dysrhythmia have made it the subject of intense study. AF interferes with the atrial kick (which contributes a significant amount of "preload") and the dysrhythmia can lead to insufficient cardiac output. Moreover, the stasis of blood within the atria promotes the formation of thrombus (clotting), which leads to cerebrovascular accident or pulmonary embolism.

Although *intermittent* AF commonly occurs after CABG, it is potentially preventable by treatment with amiodarone, beta-blockers, angiotensin-converting enzyme (ACE) inhibitors, and/or nonsteroidal antiinflammatory drugs. Treatment includes restoration of sinus rhythm (when possible), control of ventricular rate, and administration of anticoagulants. New techniques to treat *continuous* AF are based on research demonstrating that the pulmonary veins are an important source of the ectopic beats that can initiate paroxysms of AF (Haissaguerre et al, 1998). Surgical interventions for AF have

expanded beyond Cox's original Maze procedures (Cox et al, 1991), in which extensive atrial incisions were sutured to create a maze through which electrical impulses were directed from the SA node to the AV node. The early research of Cox (Cox et al, 1991) demonstrated that electrical impulses are unable to cross incised and sutured tissue and consequently cannot regenerate the reentry circuits producing the dysrhythmia. Cox revised the cut-and-sew technique of the initial Maze procedures with a cryosurgical technique that ensures the creation of transmural lesions in the vicinity of the pulmonary veins and in other areas of the heart, generating impulses producing AF. This "mini-Maze" can be performed through a sternotomy or through a minimally invasive thoracic route and requires placement of fewer lesions in the left and right atria. Currently, the focus is on the selective ablation (with cryotherapy [Figure 24-77] or ultrasonic or radiofrequency [RF] energy sources) of tissues surrounding, for example, the pulmonary veins to reestablish normal conduction pathways.

Surgery for Atrial Fibrillation (The "Maze" Procedure)

Surgery for AF may also be performed through an open sternotomy or right mini-thoracotomy incisions. The appropriate supplies (including energy sources) should be available (Seifert et al, 2007). By creating small areas of scar tissue in the cardiac muscle, electrical impulses are forced to follow an alternative conduction path or "maze."

Operative Procedure—Sternotomy

1. The surgeon performs a midline sternotomy.
2. Cannulation of the superior and inferior venae cavae is performed for total cardiopulmonary bypass.
3. The ascending aorta is occluded, and cardioplegic solution is infused through the aortic root and into the coronary arteries.
4. A right atriotomy is performed, and the first set of lesions is ablated in the right atrium (Figure 24-78, *A*).
5. A left atriotomy is performed, and the left atrial lesions are ablated (Figure 24-78, *B*).
6. The atriotomies are closed, and the aorta is unclamped.
7. Cardiopulmonary bypass is discontinued, and the cannulae are removed.
8. Chest tubes and pacing wires are inserted, and the wound is closed.

Postoperative Considerations. Postoperatively, patients are monitored for heart rhythm problems. In patients treated for AF, it may take up to 3 months for the heart to resume beating in a normal manner. Additional postoperative considerations include monitoring for bleeding, infection, and other potential complications related to heart surgery.

Insertion of Permanent Pacemaker

A permanent pacemaker (pulse generator and electrodes) initiates atrial or ventricular contraction, or both. Complete heart block and bradydysrhythmias (i.e., slow heart rates) are the most common indications for pacemaker implantation. The development of multiprogrammable and physiologic pacemakers has made possible the treatment of many forms of dysrhythmias and neuroconductive disturbances as well as tachydysrhythmias.

FIGURE 24-77 Articulated cryo probe for Maze procedure.

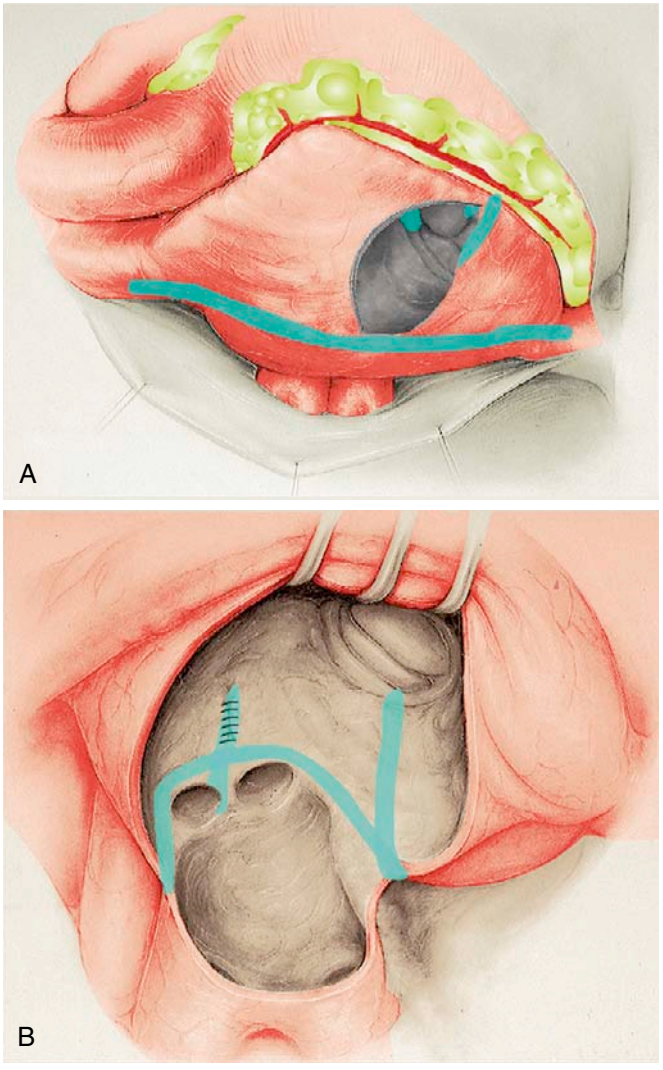


FIGURE 24-78 **A**, First lesion set for Maze procedure. **B**, Second lesion set for Maze procedure.

A temporary pacemaker may also be used for acute forms of heart block and dysrhythmias that occasionally occur during and after cardiac surgery (Hayes and Zipes, 2008).

Dual-site pacing of both the right and the left ventricle is another treatment for patients with dilated cardiomyopathy and heart failure. *Cardiac resynchronization therapy* (CRT) employs leads placed on the right atrium and the right ventricle. Left ventricular pacing is achieved with an electrode introduced transvenously into the coronary sinus and extended into the great cardiac vein (or a tributary) to a position in the left side of the heart; this electrode functions as the second ventricular lead. The three electrodes are connected to the pacemaker generator. Resynchronization improves the mechanical pumping action between the right and left ventricles and optimizes AV synchrony; as a result, hemodynamic function is improved in heart failure patients.

The *transvenous* or the *epicardial* approach may be used to place the electrodes. The transvenous route is most commonly used because it does not require a major thoracotomy or a general anesthetic and is therefore safer for high-risk patients. Permanent epicardial electrodes may be placed during cardiac operations when the chest is opened and the heart is exposed; however, if a permanent pacemaker is required, it is likely to be inserted transvenously during the postoperative period (pacing is achieved with the temporary electrodes placed during surgery). To avoid opening the sternum a subxiphoid approach may be used to place epicardial leads.

Insertion of Transvenous (Endocardial) Pacing Electrodes

Procedural Considerations. The patient is placed in the supine position. Continuous ECG monitoring is essential. A defibrillator and emergency drugs should be available because lethal dysrhythmias can occur during catheter insertion. The patient should be made as comfortable as possible because this procedure can sometimes be lengthy and is frequently performed using local or local standby anesthesia (monitored anesthesia care).

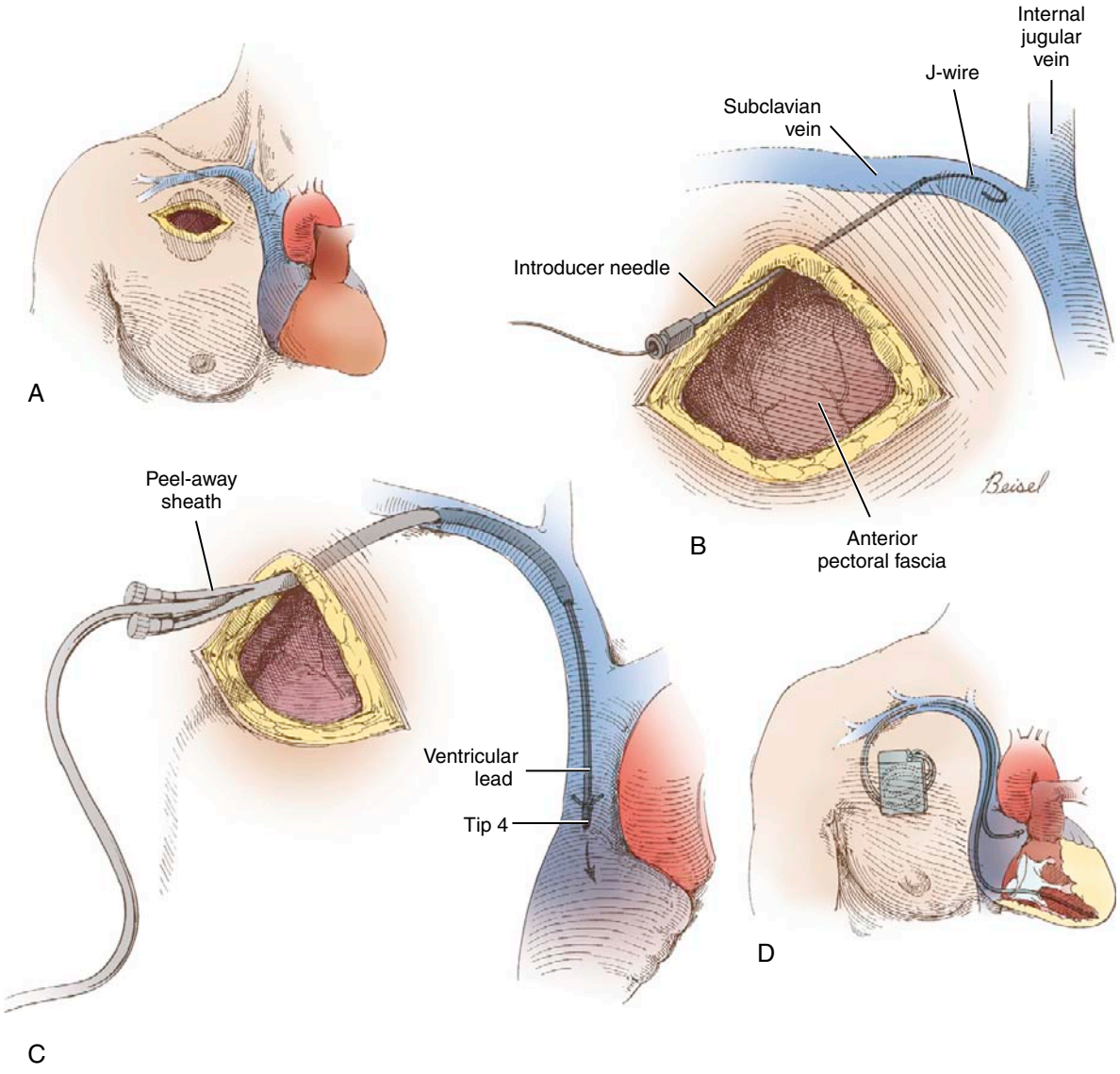


FIGURE 24-79 Insertion of transvenous pacemaker (see text).

Fluoroscopy is required; thus either a portable image intensifier is needed or the procedure is done in the special studies section of the radiology or cardiac catheterization department. A minor set of instruments is used, plus the following:

- Vascular dissecting instruments
- Tunneling instrument
- Sterile pacemaker and electrodes
- Introducer set
- External pacemaker (for testing) or a pacing system analyzer (PSA)
- Alligator test cables
- Screwdriver and other accessory items as needed

Operative Procedure

1. The skin and subcutaneous tissue are infiltrated with a local anesthetic, and the patient is placed in the Trendelenburg position (to engorge the vein for easier access and to avoid air emboli).
2. A skin pocket is made close to the subclavian vein (Figure 24-79, *A*). The vessel may be encircled with a heavy suture.
3. A venotomy is performed with an introducer needle (Figure 24-79, *B*). A guidewire is threaded to the desired cardiac chamber, and the needle is removed. The pacing electrode is inserted through a peel-away dilator sheath, which is withdrawn after the lead insertion (Figure 24-79, *C*). The guidewire is withdrawn. A stylet is then inserted to help position the electrode.
4. The electrode is advanced under direct fluoroscopic vision into the right atrium, through the tricuspid valve, and into the right ventricle (Figure 24-79, *D*).
5. The surgeon attempts to entrap the tip of the electrode in the trabeculae carneae cordis of the right ventricular apex to stabilize it. Once the electrode is positioned and tested with alligator test cables and the pacing analyzer to confirm proper placement and function, the stylet is removed. If a dual-chamber pacemaker is inserted, the second lead is entrapped in the right atrial appendage (Figure 24-79, *D*).
6. The electrode or electrodes are brought down and attached to the pulse generator.
7. The pulse generator is placed into the pocket, and the incision may be irrigated with an antibiotic solution. If the pocket must be made farther away from the vein, a tunneling device may be used to thread the electrode to the pocket.
8. The incision is closed in layers with absorbable sutures.

Insertion of Myocardial (Epicardial) Pacing Electrodes

A subxiphoid left anterior thoracotomy approach or sternotomy approach can be used; the setup is the same as that described for placement of endocardial electrodes. The subxiphoid process

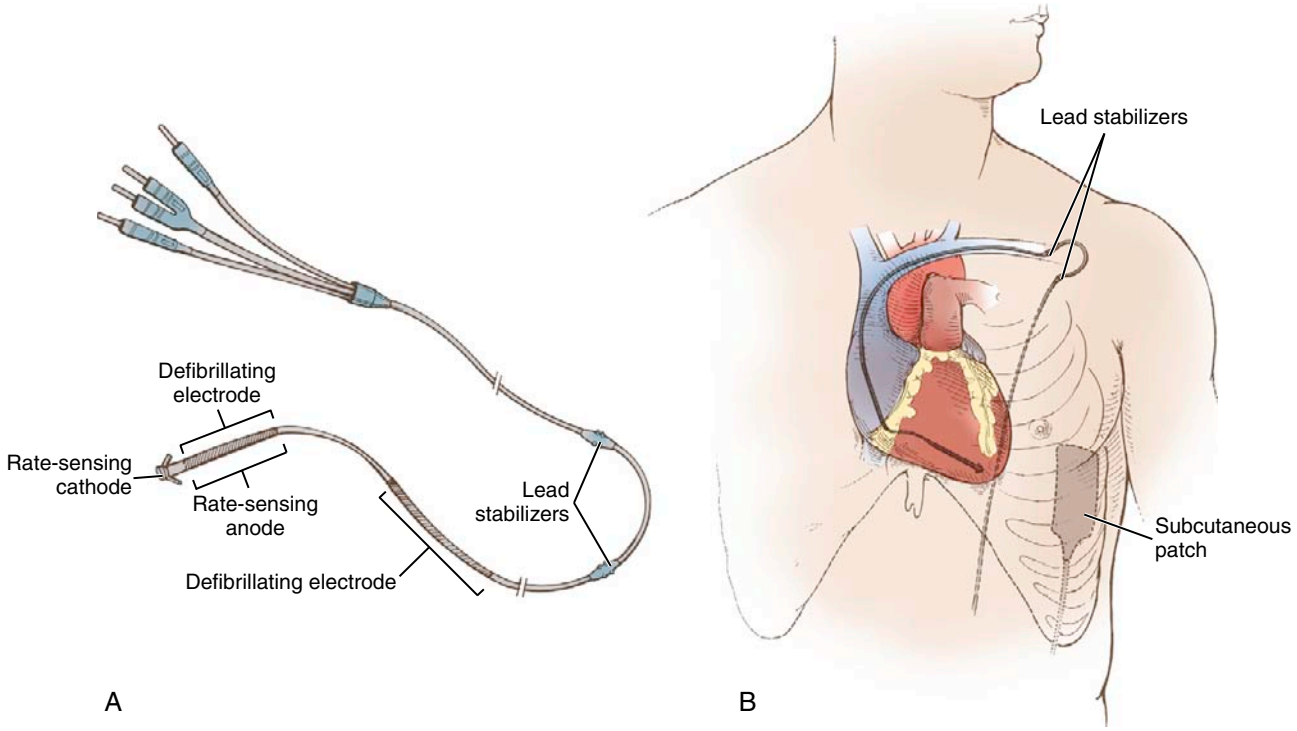


FIGURE 24-80 Nonthoracotomy internal cardioverter defibrillator (ICD) insertion. **A**, The lead system is composed of sensing and defibrillating electrodes in one unit and is inserted transvenously. **B**, The proximal end of the electrodes is tunneled to the abdomen (or the chest) and attached to the generator (not shown). The rate-sensing cathode at the tip relays information to the generator, which initiates an electrical shock by means of the defibrillating electrodes. A second (patch) electrode, placed subcutaneously on the left chest wall, may be necessary if the transvenous electrode alone cannot successfully defibrillate the patient during testing of the unit. If the nonthoracotomy system does not result in suitable defibrillation thresholds, a left thoracotomy or subxiphoid approach may be used to place sensing leads and defibrillation patches directly on the heart.

and left upper quadrant area are infiltrated with the anesthetic agent. A small transverse incision is made below the xiphoid process and is extended down to the linea alba. A tunnel is created under the xiphoid process to the pericardium, which is incised to expose the heart. The pacing electrode, mounted on its carrier, is screwed into the ventricular myocardium, and the carrier is removed. The remainder of the procedure is the same as that described for insertion of the endocardial electrode.

For the sternotomy approach, the mediastinum is opened for a concomitant cardiac procedure and an area of myocardium is chosen for placement of the pacing electrodes. The electrode tips are either screwed into or sutured to the myocardium and are attached by an appropriate cable to an external pulse generator or pacing analyzer for testing. The pocket and subcutaneous tunnel are created as described for insertion of the endocardial electrode.

Insertion of Implantable Cardioverter Defibrillator

Surgery or pharmacologic intervention may not prevent malignant ventricular dysrhythmias (ventricular fibrillation and ventricular tachycardia) in persons who survive sudden cardiac death. The ICD is an electronic device designed to monitor cardiac electrical activity and deliver prompt defibrillator shocks. The ICD differs from a pacemaker in that the former senses ventricular tachycardia or fibrillation and the latter senses asystole. Current models are capable of tiered therapy, whereby increasingly stronger impulses are delivered depending on the underlying dysrhythmias; some devices can also be used to terminate AF. These devices are capable of pacing as well as defibrillating (pacing cardioverter defibrillators [PCDs]). The ICD device consists of a generator and sensing and defibrillator electrodes (Figure 24-80). Many ICD electrodes currently employed consist of transvenous electrodes inserted into the generator much like a transvenous pacemaker system. Myocardial or thoracic subcutaneous patches may be added if the transvenous catheters alone do not adequately defibrillate the heart. Patients with previously applied defibrillator patches may present for removal of a patch or patches; perioperative nurses should be prepared for emergency intervention if there is excessive bleeding or lethal dysrhythmia. EP studies are performed before and after insertion to diagnose the dysrhythmia and to evaluate device function, respectively.

The transvenous route with fluoroscopy is commonly employed, and insertion is similar to that described for transvenous pacemaker insertion (Figure 24-80, *B*). The free ends of the lead system are tunneled to the generator, which is implanted in a subcutaneous pocket in the chest wall. The device is tested, and the incisions are closed.

REFERENCES

Alfieri O et al: The double-orifice technique in mitral valve repair: a simple solution for complex problems, *J Thorac Cardiovasc Surg* 122(4):674–681, 2001.

American College of Surgeons (ACS): Patient education, 2009a., available at www.facs.org/patienteducation/. Accessed June 30, 2009.

American College of Surgeons (ACS): Surgical organizations with patient education, 2009b, available at www.facs.org/patienteducation/proresources.html#sso. Accessed June 30, 2009.

American Heart Association (AHA) (2009a): For patients, available at www.americanheart.org/presenter.jhtml?identifier=1200000. Accessed June 30, 2009.

American Heart Association (AHA): Heart disease and stroke statistics—2009 update, 2009b, available at www.americanheart.org/presenter.jhtml?identifier=1200026. Accessed 6/22/09; http://circ.ahajournals.org/cgi/reprint/CIRCULATIONAHA.108.191261(Circulation) www.americanheart.org/downloadable/heart/1240250946756LS-1982%20Heart%20and%20Stroke%20Update.042009.pdf.

American Heart Association (AHA): Review of 1994 Revisions to Classification of Functional Capacity and Objective Assessment of Patients with Diseases of the Heart, 2009c, available at www.americanheart.org/presenter.jhtml?identifier=1712. Accessed July 5, 2009.

American Society of Anesthesiologists (ASA): Patient education, cardiac surgery, 2009, available at www2.asahq.org/google/index.asp?q=cardiac+surgery. Accessed June 30, 2009.

Angelini GD et al: Effects of on- and off-pump coronary artery surgery on graft patency, survival, and health-related quality of life: long-term follow-up of 2 randomized controlled trials, *J Thorac Cardiovasc Surg* 137(2):295–303, 2009.

Association of periOperative Registered Nurses (AORN): *The geriatric patient: AORN's age-specific competencies series*, Denver, 1997a, The Association.

Association of periOperative Registered Nurses (AORN): *The neonate, infant, and toddler patient: AORN's age-specific competencies series*, Denver, 1997b, The Association.

Association of periOperative Registered Nurses (AORN): *The premature infant patient: AORN's age-specific competencies series*, Denver, 1997c, The Association.

Association of periOperative Registered Nurses (AORN): *The preschool, school-age, and adolescent patient: AORN's age-specific competencies series,* Denver, 1997d, The Association.

Association of periOperative Registered Nurses (AORN): *Competencies for perioperative practice*, Denver, 2008, The Association.

Babb M: Clinical risk assessment: identifying patients at high risk for heart failure, *AORN J* 89(2):273–288, 2009.

Bickler PE et al: Effects of skin pigmentation on pulse oximeter accuracy at low saturation, *Anesthesiology* 102:715–719, 2005.

Bishop P: Position the patient. In Phippen ML et al, editors: *Competency for safe patient care during operative and invasive procedures*, Denver, 2009, Competency & Credentialing Institute.

Blanche C et al: Heart transplantation with bicaval and pulmonary venous anastomoses: a hemodynamic analysis of the first 117 patients, *J Cardiovasc Surg (Torino)* 38:561–566, 1997.

Brown ML et al: Ministernotomy versus conventional sternotomy for aortic valve replacement: a systematic review and meta-analysis, *J Thorac Cardiovasc Surg* 137(3):670–679, 2009.

Bruce CJ, Connolly HM: Right-sided valve disease deserves a little more RESPECT, *Circulation* 119:726–734, 2009.

Bujdoso PJ: Blanket warming: comfort and safety, *AORN J* 89(4):717–722, 2009.

Cameron DE et al: Aortic root replacement in 372 Marfan patients: evolution of operative repair over 300 years, *Ann Thorac Surg* 87:1344–1350, 2009.

Camp SL et al: Quality improvement program increases early tracheal extubation rate and decreases pulmonary complications and resource utilization after cardiac surgery, *J Card Surg* 24(4):414–423, 2009.

Campeau L: Grading of angina pectoris, *Circulation* 54:522, 1975.

Carapetis JR: Rheumatic heart disease in developing countries, *N Engl J Med* 357(5):439–441, 2007.

Carpentier A: Cardiac valve surgery: the French correction, *J Thorac Cardiovasc Surg* 86:323, 1983.

Cheng D et al: Stentless versus stented bioprosthetic aortic valves: a systematic review and meta-analysis of controlled trials, *Innovations* 4(2):61–73, 2009.

Cherry C et al: Ebstein's anomaly: a complex congenital heart defect, *AORN J* 89(6):1098–1110, 2009.

Chitwood WR: Current status of endoscopic and robotic mitral valve surgery (Supplement), *Ann Thorac Surg* 79:S2248–S2253, 2005.

Chitwood WR et al: Robotic mitral valve repairs in 300 patients: a single-center experience, *J Thorac Cardiovasc Surg* 136(2):436–441, 2008.
Clancy CM: Reducing central line-related bloodstream infections, *AORN J* 89(6):1123–1125, 2009.
Coglianes EE, Davidoff R: Predicting outcome in patients with asymptomatic aortic stenosis, *Circulation* 120:9–11, 2009.
Collins P et al: The radial artery versus saphenous vein patency (RSVP) trial investigators, *Circulation* 117:2859–2864, 2008.
Cooper DKC: The surgical anatomy of experimental and clinical thoracic organ transplantation, *Tex Heart Inst J* 31(1):61–68, 2004.
Cox JL et al: The surgical treatment of atrial fibrillation. III. Development of a definitive surgical procedure, *J Thorac Cardiovasc Surg* 101(4):569–583, 1991.
Crawford ES: The diagnosis and management of aortic dissection, *JAMA* 264(9):2537–2541, 1990.
Dal-Bianco JP et al: Management of asymptomatic severe aortic stenosis, *J Am Coll Cardiol* 52:1279–1292, 2008.
De Varennes B et al: Initial results of posterior leaflet extension for severe Type IIIb ischemic mitral regurgitation, *Circulation* 119:2837–2843, 2009.
Dickson VV, McMahon JP: Optimal patient education and counseling. In Moser DK, Riegel B, editors: *Cardiac nursing: a companion to Braunwald's heart disease*, St Louis, 2008, Saunders.
DiNardo JA, Zvara DA: *Anesthesia for cardiac surgery*, ed 3, Malden, MA, 2008, Blackwell Publishing.
Edmunds LH: Cardiopulmonary bypass after 50 years, *N Engl J Med* 351(16):1603–1606, 2004.
Edwards FH et al: Gender-specific practice guidelines for coronary artery bypass surgery: perioperative management, *Ann Thorac Surg* 79: 2189–2194, 2005.
Elliott P et al: Genetic loci associated with C-reactive protein levels and risk of coronary heart disease, *JAMA* 302(1):37–48, 2009.
Engelman R et al: Workforce on Evidence-Based Medicine, Society of Thoracic Surgeons. The Society of Thoracic Surgeons practice guideline series: antibiotic prophylaxis in cardiac surgery, part II: Antibiotic choice, *Ann Thorac Surg* 83(4):1569–1576, 2007.
Falk-Brynhildsen K, Nilsson U: Cardiac surgery patients' evaluation of the quality of theatre nurse postoperative follow-up visit, *Eur J Cardiovasc Nurs* 8(2):105–111, 2009.
Fang JC, O'Gara PT: The history and physical examination: an evidence-based approach. In Libby P et al, editors: *Braunwald's heart disease*, ed 8, Philadelphia, 2008, Saunders.
Fattouch K et al: Off-pump versus on-pump myocardial revascularization in patients with ST-segment elevation myocardial infarction: a randomized trial, *J Thorac Cardiovasc Surg* 137(3):650–657, 2009.
Fedak PWM et al: Evolving concepts and technologies in mitral valve repair, *Circulation* 117:963–974, 2008.
Feindel CM: Aortic root enlargement in the adult. In Cohn LD, editor: *Operative techniques in thoracic and cardiovascular surgery: a comparative atlas*, New York, 2006, Elsevier.
Frasure-Smith N, Lesperance F: Depression and anxiety as predictors of 2-year cardiac events in patients with stable coronary artery disease, *Arch Gen Psychiatry* 65(1):62–71, 2008.
Frumento RJ, Bennett-Guerrero E: Prime solutions for extracorporeal circulation. In Mongero LB, Beck JR, editors: *On bypass: advanced perfusion techniques*, Totowa, NJ, 2008, Human Press.
Gardner TJ: Building a healthier world, free of cardiovascular diseases and stroke, *Circulation* 119:1838–1841, 2009.
Gemmato CJ et al: Thirty-five years of mechanical circulatory support at the Texas Heart Institute, *Tex Heart Inst J* 32(2):168–177, 2005.
Gourlay T, Qureshi T: Blood flow during cardiopulmonary bypass. In Mongero LB, Beck JR, editors: *On bypass: advanced perfusion techniques*, Totowa, NJ, 2008, Human Press.
Gray RJ, Sethna DH: Medical management of the patient undergoing cardiac surgery. In Libby P et al, editors: *Braunwald's heart disease*, ed 8, Philadelphia, 2008, Saunders.
Groom RC et al: Detection and elimination of microemboli related to cardiopulmonary bypass, *Circulation Cardiovasc Qual Outcomes* 2:191–198, 2009.
Grundy SM: Is lowering low-density lipoprotein an effective strategy to reduce cardiac risk? Promise of low-density lipoprotein-lowering therapy for primary and secondary prevention, *Circulation* 117:569–573, 2008.
Haissaguerre M et al: Spontaneous initiation of atrial fibrillation by ectopic beats originating in the pulmonary veins, *N Eng J Med* 339(10):659–666, 1998.
Halpin LS, Barnett SD: Preoperative state of mind among patients undergoing CABG, *J Nurs Care Qual* 20(1):73–80, 2005.
Hayes DL, Zipes DL: Cardiac pacemakers and cardioverter-defibrillators. In Libby P et al, editors: *Braunwald's heart disease*, ed 8, Philadelphia, 2008, Saunders.
Hayman LL: Primary prevention in childhood. In Moser DK, Riegel B, editors: *Cardiac nursing: a companion to Braunwald's heart disease*, St Louis, 2008, Saunders.
Hill JA, Olson EN: Cardiac plasticity, *N Engl J Med* 358(13):1370–1380, 2008.
Hjortnaes J et al: Translating autologous heart valve tissue engineering from bench to bed (Abstract). Tissue Eng Part B Reviews. May 18. [Epub ahead of print], 2009. available at www.ncbi.nlm.nih.gov/pubmed/19450137?ordinalpos=8&itool=EntrezSystem2.PEntrez.Pubmed.Pubmed_ResultsPanel.Pubmed_DefaultReportPanel.Pubmed_RVDocSum. Accessed July 5, 2009.
Hlatky MA et al: Criteria for evaluation of novel markers of cardiovascular risk: a scientific statement from the American Heart Association, *Circulation* 119:2408–2416, 2009.
Horvath KA, Zhou Y: Transmyocardial laser revascularization and extravascular angiogenic techniques to increase myocardial blood flow. In Cohn LH, editor: *Cardiac surgery in the adult*, ed 3, New York, 2007, McGraw Hill.
Hu KK et al: Use of maximal sterile barriers during central venous catheter insertion: clinical and economic outcomes, *Clin Infect Dis 39*, November 15, 2004.
Hunt SA: Taking heart—cardiac transplantation past, present, and future, *N Engl J Med* 355:231–235, 2006.
Hussey LC et al: Risk factors for sternal wound infection in men versus women, *Am J Crit Care* 10(2):112–116, 2001.
Isselbacher EM: Diseases of the aorta. In Libby P et al, editors: *Braunwald's heart disease*, ed 8, Philadelphia, 2008, Saunders.
Jansens JL et al: Robotic hybrid procedure and triple-vessel disease, *J Card Surg* 24(4):449–450, 2009.
Jeevanandam V et al: A one-year comparison of prophylactic donor tricuspid annuloplasty in heart transplantation, *Ann Thorac Surg* 78:759–766, 2004.
Jin R et al: Is obesity a risk factor for mortality in coronary artery bypass surgery, *Circulation* 111:3359–3365, 2005.
Journal of the American Medical Association (JAMA): JAMA patient's page, 2009. Available at www.jama.com.
Kamstrupp PR et al: Genetically-elevated lipoprotein (a) and increased risk of myocardial infarction, *JAMA* 301:2331–2339, 2009.
Khonsari S et al: *Cardiac surgery: safeguards and pitfalls in operative technique*, ed 4, Philadelphia, 2008, Wolters Kluwer/ Lippincott Williams & Wilkins.
Kirtane AJ et al: Safety and efficacy of drug-eluting and bare metal stents: comprehensive meta-analysis of randomized trials and observational studies, *Circulation* 119:3198–3206, 2009.
Kokotsakis J et al: Right axillary artery cannulation: surgical management of the hostile ascending aorta, *Tex Heart Inst J* 32(2):189–193, 2005.
Korngold EC et al: Amino-terminal pro-B-type natriuretic peptide and high-sensitivity C-reactive protein as predictors of sudden cardiac death among women, *Circulation* 119:2868–2876, 2009.
Kouchoukos NT et al: *Kirklin/Barratt-Boyes Cardiac Surgery*, ed 3, Philadelphia, 2003, Churchill Livingstone, vol. I.
Kuchukarian N et al: Eleven-year experience in diagnosis and surgical therapy of right atrial masses, *J Card Surg* 22:39–42, 2007.
Kumar AS: *Techniques in valvular heart surgery*, New Delhi, India, 2008, CBS Publishers and Distributors.

Kumar N et al: A revised terminology for recording surgical findings of the mitral valve, *J Heart Valve Dis* 4:70–75, 1995, discussion 76–77.

Kutcher MA et al: Percutaneous coronary interventions in facilities without cardiac surgery on site: a report from the National Cardiovascular Data Registry (NCDR), *J Am Coll Cardiol* 54(1):16–24, 2009.

Lachman N et al: Pericardiectomy: a functional anatomical perspective for the choice of left anterolateral thoracotomy, *J Card Surg* 24(4):411–413, 2009.

Lamendola C: Insulin resistance, diabetes, and cardiovascular disease. In Moser DK, Riegel B, editors: *Cardiac nursing: a companion to Braunwald's heart disease*, St Louis, 2008, Saunders.

Lee TH, Bonow RO: Guidelines: management of valvular heart disease. In Libby P et al, editors: *Braunwald's heart disease*, ed 8, Philadelphia, 2008, Saunders.

Leeson A et al, editors: *Cardiac catheterization and coronary intervention (Oxford Specialist Handbooks)*, New York, 2008, Oxford University Press.

Li Y et al: Comparison of drug-eluting stents and coronary artery bypass surgery for the treatment of multivessel coronary disease: three-year follow-up results from a single institution, *Circulation* 119:2040–2050, 2009.

Libby P et al, editors: *Braunwald's heart disease*, ed 8, Philadelphia, 2008, Saunders.

Lietz K et al: Impact of center volume on outcomes of left ventricular assist device implantation as destination therapy: analysis of the Thoratec HeartMate Registry, 1998 to 2005, *Circ: Heart Fail* 2(1):3–10, 2009.

Long JW et al: Long-term destination therapy with the HeartMate XVE left ventricular assist device: improved outcomes since the REMATCH study, *Congestive Heart Failure* 11:133, 2005.

Lopes RD et al: Endoscopic versus open vein-graft harvesting in coronary-artery bypass surgery, *N Engl J Med* 361(3):235–244, 2009.

Lorenz RA et al: Perioperative blood glucose control during adult coronary artery bypass surgery, *AORN J* 81(1):126–150, 2005.

Lundblad R et al: Surgical repair of postinfarction ventricular septal rupture: risk factors of early and late death, *J Thorac Cardiovasc Surg* 137(4):862–868, 2009.

Lytle BW: Who are we—who we will be, *J Thorac Cardiovasc Surg* 135(5):965–975, 2008.

Mancini ME, Bubien RS: Care of patients with sudden cardiac death, cardiac arrest, and life-threatening dysrhythmias. In Moser DK, Riegel B, editors: *Cardiac nursing: a companion to Braunwald's heart disease,* St Louis, 2008, Mosby.

Mascagni R et al: Edge-to-edge technique to treat post-mitral valve repair systolic anterior motion and left ventricular outflow tract obstruction, *Ann Thorac Surg* 79:471–474, 2005.

McCarthy P: Surgical management of heart failure. In Libby P et al, editors: *Braunwald's heart disease*, ed 8, Philadelphia, 2008, Saunders.

McSweeney JC, Lefler LI: Women and cardiovascular disease. In Moser DK, Riegel B, editors: *Cardiac nursing: a companion to Braunwald's heart disease*, St Louis, 2008, Saunders.

Menasche P: Stem cell therapy for heart failure: are arrhythmias a real safety concern? *Circulation* 119:2735–2740, 2009.

Mentzer RM et al: Myocardial protection. In Cohn LH, editor: *Cardiac surgery in the adult*, ed 3, New York, 2007, McGraw Hill Medical.

Miller LW et al: Use of a continuous-flow device in patients awaiting heart transplantation, *N Engl J Med* 357:885–896, 2007.

Miller M, Beauman G: Preoperative assessment. In Conte JV et al: *The Johns Hopkins manual of cardiac surgical care*, ed 2, St Louis, 2008, Mosby.

Mirzaie M et al: A new storage solution for porcine aortic valves, *Ann Thorac Cardiovasc Surg* 13:102–109, 2007.

Mongero LB, Beck JR: *On bypass: advanced perfusion techniques*, Totowa, NJ, 2008, Human Press.

Moons P et al: Care of adults with congenital heart disease. In Moser DK, Riegel B, editors: *Cardiac nursing: a companion to Braunwald's heart disease,* St Louis, 2008, Saunders.

Morrow DA, Gersh BJ: Chronic coronary artery disease. In Libby P et al, editors: *Braunwald's heart disease*, ed 8, Philadelphia, 2008, Saunders.

Mosca L et al: Evidence-based guidelines for cardiovascular disease prevention in women: 2007 update, *Circulation* 115:1481–1501, 2007.

Moser DK, Riegel B: Care of patients with acute coronary syndrome: ST segment elevation myocardial infarction. In Moser DK, Riegel B, editors: *Cardiac nursing: a companion to Braunwald's heart disease*, St Louis, 2008, Mosby.

Moss CJ, Moss R: Assist the anesthesia provider. In Phippen ML et al, editors: *Competency for safe patient care during operative and invasive procedures*, Denver, 2009, Competency & Credentialing Institute, 2009.

Naka Y, Rose EA: Assisted circulation in the treatment of heart failure. In Libby P et al, editors: *Braunwald's heart disease*, ed 8, Philadelphia, 2008, Saunders.

Nasso G et al: Arterial revascularization in primary coronary artery bypass grafting: direct comparison of 4 strategies—results of the Stand-n-Y mammary study, *J Thorac Cardiovasc Surg* 137(35):1093–1100, 2009.

Newby LK, Douglas PS: Cardiovascular disease in women. In Libby P et al, editors: *Braunwald's heart disease*, ed 8, Philadelphia, 2008, Saunders.

Oakley RE et al: Choice of prosthetic heart valve in today's practice, *Circulation* 117:253–256, 2008.

Otto CM, Bonow RO: Valvular heart disease. In Libby P et al, editors: *Braunwald's heart disease*, ed 8, Philadelphia, 2008, Saunders.

Ozcan AV et al: 30-year patency of saphenous vein graft in coronary bypass graft surgery (case report), *Ann Thorac Surg* 85(4):e23, 2008.

Pagana KD, Pagana TJ: *Mosby's diagnostic and laboratory test reference*, ed 9, St Louis, 2009, Mosby.

Park SJ et al: Left ventricular assist devices as destination therapy: a new look at survival, *J Thorac Cardiovasc Surg* 129(1):9–17, 2005.

Patel MR et al: ACCF/SCAI/STS/AATS/AHA/ASNC 2009 Appropriateness Criteria for Coronary Revascularization: A Report by the American College of Cardiology Foundation Appropriateness Criteria Task Force, Society for Cardiovascular Angiography and Interventions, Society of Thoracic Surgeons, American Association for Thoracic Surgery, American Heart Association, and the American Society of Nuclear Cardiology. Endorsed by the American Society of Echocardiography, the Heart Failure Society of America, and the Society of Cardiovascular Computed Tomography *Journal of the American College of Cardiology* 53:530–553, doi:10.1016/j.jacc.2008.10.005 (Published online 5 January 2009), available at http://content.onlinejacc.org/cgi/content/full/j.jacc.2008.10.005. Accessed July 7, 2009.

Pear SM, Williamson TH: The RN first assistant: an expert resource for surgical site infection prevention, *AORN J* 89(6):1093–1097, 2009.

Pepper J et al: Stentless versus stented bioprosthetic aortic valves. A Consensus Statement of the International Society of Minimally Invasive Cardiothoracic Surgery (ISMICS) 2008, *Innovations* 4(2):49–60, 2009.

Petersen C, editor: *Perioperative nursing data set*, revised 2nd edition, Denver, 2007, Association of periOperative Registered Nurses, Inc.

Pradhan AD et al: Symptomatic peripheral arterial disease in women: nontraditional biomarkers of elevated risk, *Circulation* 117:823–831, 2008.

Pretre R, Turina MI: Deep hypothermic circulatory arrest. In Cohn LH, editor: *Cardiac surgery in the adult*, ed 3, New York, 2007, McGraw Hill.

Puskas JD et al: Off-pump techniques benefit men and women and narrow the disparity in mortality after coronary bypass grafting, *Ann Thorac Surg* 84:1447–1456, 2007.

Quigley GD et al: Diseases of the aorta. In Conte JV et al: *The Johns Hopkins manual of cardiac surgical care*, ed 2, St Louis, 2008, Mosby.

Quill JL et al: Mitral leaflet anatomy revisited, *J Thorac Cardiovasc Surg* 137(5):1077–1081, 2009.

Rabago G et al: The new DeVega technique in tricuspid annuloplasty, *J Thorac Cardiovasc Surg* 21:231, 1980.

Rahimtoola SH: Choice of prosthetic heart valve for adult patients, *J Am Coll Cardiol* 41(6):893–9004, 2003.

Rahimtoola SH: The year in valvular heart disease, *J Am Coll Cardiol* 43(3):491–504, 2004.

Rich MW: The impact of aging on cardiac function. In Moser DK, Riegel B, editors: *Cardiac nursing: a companion to Braunwald's heart disease,* St Louis, 2008, Saunders.

Rogers JH, Bolling SF: The tricuspid valve: current perspective and evolving management of tricuspid regurgitation, *Circulation* 119:2715–2718, 2009.

Rose E et al: Long-term use of a left ventricular assist device for end-stage heart failure: the Muenster experience, *N Engl J Med* 345:1435–1443, 2001.

Rothman C: Surgeons perform first artificial heart implant in New Jersey. The Star Ledger (New Jersey), Wednesday, June 24, 2009, available at www.nj.com/news/index.ssf/2009/06/first_artificial_heart_implant.html. Accessed July 9, 2009.

Ruz MEA, Lennie TA: Inflammation. In Moser DK, Riegel B, editors: *Cardiac nursing: a companion to Braunwald's heart disease*, St Louis, 2008, Saunders.

Salerno TA: Warm heart surgery: reflections on the history of its development, *J Cardiac Surg* 22:257–259, 2007.

Sarin EL et al: Off-pump coronary bypass grafting is associated with reduced operative mortality and in-hospital adverse events in patients with left main coronary artery disease, *Innovations* 4(2):80–85, 2009.

Sasaki H: The right gastroepiploic artery in coronary artery bypass grafting, *J Cardiac Surg* 23:398–407, 2008.

Savino JS, Cheung AT: Cardiac anesthesia. In Cohn LH, editor: *Cardiac surgery in the adult*, ed 3, New York, 2007, McGraw Hill.

Schulze CJ et al: Phosphorylcholine-coated circuits improve preservation of platelet count and reduce expression of proinflammatory cytokines in CABG: a prospective randomized trial, *J Cardiac Surg* 24(4):363–368, 2009.

Seifert PC: Nurses in perioperative settings. In Moser DK, Riegel B, editors: *Cardiac nursing: a companion to Braunwald's heart disease,* St Louis, 2008, Saunders.

Seifert PC: Care of the cardiac surgical patient. In Drain CB, Odom-Forren J, editors: *Perianesthesia nursing: a critical care approach,* St Louis, 2009, Saunders.

Seifert PC, Collins J: Cardiac surgery. In Phippen ML et al, editors: *Competency for safe patient care during operative and invasive procedures*, Denver, 2009, Competency & Credentialing Institute.

Seifert PC et al: Surgery for atrial fibrillation, *AORN J* 86(1):23–40, 2007.

Sellke FW et al: Comparing on-pump and off-pump coronary artery bypass grafting: numerous studies but few conclusions: a scientific statement from the American Heart Association Council on Cardiovascular Surgery and Anesthesia in collaboration with the interdisciplinary working group on quality of care and outcomes research, *Circulation* 111:2858–2864, 2005.

Sellke F, Ruel M: *Atlas of cardiac surgical techniques: a volume in the surgical techniques atlas series*, Philadelphia, 2009, Saunders.

Serruys PW et al: Percutaneous coronary intervention versus coronary-artery bypass grafting for severe coronary artery disease, *N Engl J Med* 360(10):961–972, 2009.

Sethares K et al: Care of patients undergoing cardiac surgery. In Moser DK, Riegel B, editors: *Cardiac nursing: a companion to Braunwald's heart disease,* St Louis, 2008, Saunders.

Seymour GJ et al: Infection or inflammation: the link between periodontal and cardiovascular diseases. *Future Cardiology* 5(1):5-9, 2009, available at www.medscape.com/viewarticle/587591). Accessed April 3, 2009.

Shimokawa T et al: Intermediate-term patency of saphenous vein graft with a clampless hand-sewn proximal anastomosis device after off-pump coronary bypass grafting, *Ann Thorac Surg* 87:1416–1420, 2009.

Simmonds PK et al: Cardiovascular pharmacologic agents. In Conte JV et al: *The Johns Hopkins manual of cardiac surgical care*, ed 2, St Louis, 2008, Mosby.

Singh SK et al: The impact of diabetic status on coronary artery bypass graft patency: insights from the radial artery patency study, *Circulation* 118(suppl 1):S222–S225, 2008.

Smith PK: Treatment selection for coronary artery disease: the collision of a belief system with evidence, *Ann Thorac Surg* 87(5):1328–1331, 2009.

Sniecinski RM, Levy JH: The inflammatory response to cardiopulmonary bypass, In Mongero LB, Beck JR, editors: *On bypass: advanced perfusion techniques*, Totowa, NJ, 2008, Human Press.

Society of Thoracic Surgeons (STS): STS patient information, available at www.sts.org/sections/patientinformation/. Accessed June 30, 2009.

Sommer RJ et al: Pathophysiology of congenital heart disease in the adult. Part I: Shunt lesions, *Circulation* 117:1090–1099, 2008a.

Sommer RJ et al: Pathophysiology of congenital heart disease in the adult. Part II: Simple obstructive lesions, *Circulation* 117:1228–1237, 2008b.

Sommer RJ et al: Pathophysiology of congenital heart disease in the adult. Part III: Complex congenital heart disease, *Circulation* 117:1340–1350, 2008c.

Starr A, Edwards ML: Mitral replacement: clinical experience with a ball-valve prosthesis, *Ann Surg* 154:726, 1961.

Stoney WS: *Pioneers of cardiac surgery*, Nashville, 2008, Vanderbilt University Press.

Stout KK, Verrier ED: Acute valvular regurgitation, *Circulation* 119:3232–3241, 2009.

Superko HR, King S: Is lowering low-density lipoprotein an effective strategy to reduce cardiac risk? Lipid management to reduce cardiovascular risk, *Circulation* 117:560–568, 2008.

Svenarud P et al: Effect of CO_2 insufflation on the number and behavior of air emboli in open-heart surgery, *Circulation* 109:1127–1132, 2004.

Svensson L: Aortic dissection endovascular stenting: less pain, survival gain? *AnnThorac Surg* 87:1332–1333, 2009.

Tang GH et al: Tricuspid valve repair with an annuloplasty ring results in improved long-term outcomes, *Circulation* 114(suppl):I-577–I-581, 2006.

Tavilla G et al: Long-term follow-up of coronary artery bypass grafting in three-vessel disease using exclusively pedicled bilateral internal thoracic and right gastroepiploic arteries, *Ann Thorac Surg* 77:794–799, 2004.

The Criteria Committee of the New York Heart Association: *Nomenclature and criteria for diagnosis of diseases of the heart and great vessels*, ed 9, Boston, 1994, Little, Brown & Co, pp. 253-256.

Thompson J, Bertling G: Endovascular leaks: perioperative nursing implications, *AORN J* 89(5):839–846, 2009.

Tinkham MR: The endovascular approach to abdominal aortic aneurysm repair, *AORN J* 89(2):289–302, 2009.

Todd R, Phippen M: Cardiac catheterization and electrophysiology. In Phippen ML et al, editors: *Competency for safe patient care during operative and invasive procedures*, Denver, 2009, Competency & Credentialing Institute.

Toumpoulis IK et al: Assessment of independent predictors for long-term mortality between women and men after coronary artery bypass grafting: are women different from men? *J Thorac Cardiovasc Surg* 131:343–351, 2006, available at http://jtcs.ctsnetjournals.org/cgi/content/full/jtcs; 131/2/343. Accessed July 4, 2009.

Walton-Geer PS: Prevention of pressure ulcers in the surgical patient, *AORN J* 89(3):538–548, 2009.

Warziski MT et al: Obesity. In Moser DK, Riegel B, editors: *Cardiac nursing: a companion to Braunwald's heart disease*, St Louis, 2008, Saunders.

Webb JG et al: Transcatheter aortic valve implantation: impact on clinical and valve-related outcomes, *Circulation* 119:3009–3016, 2009.

Wilson SR et al: Evaluation for a ventricular assist device: selecting the appropriate candidate, *Circulation* 119:2225–2232, 2009.

CHAPTER 25

Pediatric Surgery

LEIGH ANN DiFUSCO

Pediatrics is a specialty focused on the health and well-being of neonates, infants, children, and adolescents. The pediatric patient often needs surgery for congenital anomalies that threaten life or the child's ability to function. Trauma also impacts a child's health far more often than an adult's; injury is a common reason for surgical intervention. Pediatric surgery is an area of practice unto its own because the pediatric patient is so very different from an adult. The field is even further subdivided into all the surgical specialties. It is important to recognize that the difference between pediatric care and adult care is not just a size issue; from birth onward, the body and organs exist in a continual state of development, and multiple physiologic changes occur with age. Major areas of distinction are the airway and pulmonary status, cardiovascular status, temperature regulation, metabolism, fluid management, and psychologic development. A thorough knowledge of these differences is integral to the provision of nursing care for the pediatric patient in the OR.

Advances in surgical interventions for children have been phenomenal in the last two decades for many reasons. The advancement of improved diagnostic and interventional technology, the development of new anesthetics and pharmacologic agents for pain management, and the creation of even smaller and more delicate instrumentation have revolutionized perioperative care of the pediatric population. Numerous pediatric surgeries that were once performed as open cavity procedures are now being done endoscopically with minimally invasive techniques, resulting in shorter hospital stays and faster recovery times. Improvements in the transport of critically ill children and the intensive care management of neonatal and pediatric patients as well as the development of new surgical procedures are also saving more lives yet presenting medical professionals with a new and unique set of problems as complex, medically fragile children are now surviving into adulthood.

PEDIATRIC SURGICAL ANATOMY

Airway/Pulmonary Status

Respiratory mechanics alter dramatically from infancy to adulthood, resulting from increases in airway size, transformations in the rigidity of airway and chest structures, and major changes in neuromuscular status. A proportionally large head, a short neck, and a large tongue in relation to jaw size create more of a challenge for airway management. The glottis is very anterior, moving from the level of the second cervical vertebra to the level of the third to fourth vertebrae in the adult. The epiglottis is floppy and more curved, and the vocal cords are slanted anteriorly. The airway forms an inverse cone with the narrowest portion at the cricoid cartilage until 8 years of age; endotracheal tube size is therefore very important, since a tube that passes easily through the glottis may be too tight at the subglottic area, compromising the child's airway in the immediate postoperative period because of swelling. The infant is an obligate nasal breather, and the chest wall of an infant is very compliant, leading to increased work of breathing with any type of airway compromise. Infants also have type 2 respiratory muscle fibers until age 2 years, which fatigue more easily than type 1 muscle fibers. Premature infants are at risk for postanesthetic apnea until 60 weeks after conception age. There is a depression in the CO_2 response curve in infants; compared to an adult, the respiratory rate does not increase as readily in response to a rising CO_2 level, although all ages undergo a CO_2 response depression related to inhalational agents and narcotics. One of the most important considerations is that children have a much smaller pulmonary functional residual capacity; a child becomes hypoxic more quickly if the airway is lost. Alveolar maturation is not complete until 8 years of age. Smaller airways have higher resistance; airway resistance decreases approximately 15 times from infancy to adulthood, again with a major change occurring around 8 years of age. It is important to note that smaller airways can become compromised with even a minor amount of swelling. Be aware that loose teeth are common in children aged 5 to 14 years; a dislodged tooth is a potential airway foreign-body risk.

Cardiovascular Status

The most dramatic changes in the cardiovascular system occur at birth with the transition from fetal circulation. Even in full-term infants, persistent transitional circulation may occur. Heart rate is the predominant determinant of cardiac output in infants and children; bradycardia drastically decreases cardiac output and requires swift intervention. There is a decreased cardiac compliance because of a lower proportion of muscle to connective tissue until age 1 to 2 years, making infants preload insensitive. Young children are predisposed to parasympathetic hypertonia (increased vagal tone), which can be induced by painful stimuli such as laryngoscopy, intubation, eye surgery, or abdominal retraction. Attention to blood loss in young patients is very important because the patient's total blood volume is very small. Blood volume in neonates is 80 to 90 ml/kg; at 1 to 6 years it is 70 to 75 ml/kg; and at age 6 years to adult it is 65 to 70 ml/kg. At birth, 70% to 90% of the hemoglobin is fetal hemoglobin with a high affinity for oxygen. It is normal for hemoglobin levels to fall at about 2 to 3 months of age (physiologic anemia) to a hematocrit level of 29% and a hemoglobin level of 10 mg/dl as the infant's body begins to produce its own

blood cells. A cardiology evaluation is essential if a murmur is auscultated. A murmur can be from a patent foramen ovale, which normally closes at 3 to 12 months; a patent ductus arteriosus, which can be present for up to 2 months; a previously undetected cardiac anomaly; or an innocent flow murmur. The evaluation is critical because anesthetic agents cause vasodilation and potentiate cardiac dysrhythmias.

Temperature Regulation

Infants and young children are most at risk of hypothermia because of their increased body surface area/weight ratio and thin fat layer. Cold stress leads to increased oxygen consumption, resulting in hypoxia, respiratory depression, acidosis, hypoglycemia, and pulmonary vasoconstriction. Hypothermia alters drug metabolism, prolongs the action of neuromuscular blockers, and delays emergence from anesthesia. The child's temperature must be monitored continuously throughout the intraoperative experience. An axillary temperature probe is acceptable for short procedures in healthy children; an esophageal or rectal temperature probe provides more accurate monitoring of the child's temperature for longer cases. Hyperthermia should also be avoided, because it leads to increased oxygen consumption and increased fluid losses.

It is vital to maintain normothermia in children, and the easiest way to do this is by exposing only the area on which surgery is being performed. Additional thermoregulatory interventions include altering the room temperature before the child enters the room, using a water-filled temperature-regulating blanket under the patient, or using a forced air–warming blanket over nonsurgical areas of the child. An overhead heater can be used during the anesthetic induction and patient preparation period immediately before prepping and draping. The anesthesia ventilation circuit can be heated and humidified, as can insufflated carbon dioxide during minimally invasive surgical procedures. For surgical procedures with large areas of exposure, warmed solutions should be available for use instead of room temperature solutions. Intravenous (IV) solutions can also be warmed before administration.

Metabolism

Infants have a higher basal metabolic rate than adults, and it is greatest at 18 months. Most importantly, children younger than age 2 years have immature liver function; pharmacologic response is altered, and there is slower hepatic clearance, decreased hepatic enzyme function, and decreased protein binding. Drug distribution is different in neonates and infants compared with older children and adults because of an increased percentage of total body weight and extracellular body fluid. Infants have an immature blood-brain barrier and decreased protein binding, which results in an increased sensitivity to sedatives, opioids, and hypnotics.

Fluid Management

Renal function at birth is immature, and the ability of the kidneys to concentrate urine is limited, so the infant is much more prone to dehydration. Complete maturation of renal function occurs at about 2 years. Compared to an adult, a child has a higher body water weight, a higher body surface area, and an increased metabolic rate, resulting in increased fluid requirements per kilogram of body weight. Despite these significant points, it is also important to remember that the body weight of the child, the length of time without fluids, and surgical losses are the primary factors in the calculations of the child's hydration needs.

PSYCHOLOGIC DEVELOPMENT

A child's comprehension of and responses to the environment are based on his or her developmental age. A key factor is that a child's developmental age does not necessarily match the chronologic age. Nursing care should be tailored to the developmental age of the child to optimize the child's ability to understand the situation, to minimize the child's and family's stress and anxiety, and to facilitate the development of a trusting and supportive medical relationship. The types of fears are also related to the child's level of psychologic development. Predictable stages mean predictable behaviors. The stages of growth have been described from a variety of different aspects; Dr. Jean Piaget described the stages by changes in cognition and the ability to think, and Dr. Erik Erikson based the stages on psychosocial and emotional needs. Their work provides an excellent guideline for assessing the pediatric patient's developmental level in order to use appropriate interventions (Table 25-1).

Perioperative Nursing Considerations

Assessment

The initial patient assessment provides information necessary to develop a plan of care specific to the needs of each particular pediatric patient related to age, developmental level, and diagnosis. The unique aspects of care of the pediatric surgical patient revolve around the fact that the child is constantly growing and changing. The perioperative nurse must have a good understanding of the normal physical and psychologic parameters for pediatric patients and be able to recognize and act upon deviations from these parameters (Rapid Response Team box). In addition, the perioperative nurse must be familiar with normal growth and developmental factors for each age-group. During any given day, the perioperative nurse may care for a variety of pediatric patients ranging from neonates through adolescents. In some instances, children undergoing an ambulatory surgical procedure may visit the OR complex and ambulatory surgery area with their families 1 to 2 weeks before surgery, depending on the developmental level of the child and the availability of a preoperative pediatric education program. If the child has a complex medical history or an extensive surgical procedure is planned, the child and family members will meet with a member of the anesthesia team during this advance visit. A tour may be provided by a child life specialist (Patient and Family Education), along with pictures and age-appropriate explanations of what the child will see and experience. Visiting before the day of surgery can help decrease the anxiety related to the novelty of the experience.

Occasionally the child's history and physical, surgical consent, and any necessary tests or lab work are done in advance in the surgeon's office setting, and the child and family have no introduction to the surgical experience until the day of surgery. Information related to the child's scheduled procedure is either

TABLE 25-1

Developmental Stages

Approximate Ages	Piaget's Stage	Erikson's Stage	Developmentally Based Fears	Appropriate Nursing Interventions
Infancy to 1 yr (Erikson) Infancy to 2 yr (Piaget)	Sensorimotor Uses senses and motor skills to understand world Develops memory; begins to imitate others	Trust vs. mistrust—develops belief that world can be counted on to meet basic needs Who to trust? Identifies strangers at 7-8 mo	Separation	Use soothing voice; sing, hold child, give child objects to hold to provide distractions. Meet child, family without touching child at first. Allow personal item into OR for comfort/security.
Toddlerhood	Preoperational Use of symbols, creative play (can pretend) Is very egocentric	Autonomy vs. shame, doubt Develops free will; increasing control of their bodies Feels regret, sorrow for inappropriate behavior	Separation Forced dependence	Give only simple choices; involve child in actions when possible, use distractions, sing songs child may recognize. Allow personal item into OR for comfort/security.
Early childhood, preschool	Preoperational continues	Initiative vs. guilt Begins to explore, imagine Feels remorse for actions Thinking dominated by perceptions—distorted reasoning	Separation Body mutilation	Magical thinkers—use stories during induction. Likes colorful Band-Aids. Allow child to handle unfamiliar objects to decrease stress (e.g., mask, pulse oximeter probe). Allow personal item into OR for comfort/security.
Middle childhood, elementary school age (Erikson) Ages 7-11 yr (Piaget)	Concrete operations Uses symbols, logic, principles to solve problems Classifies, sorts everything	Industry vs. inferiority Beginning to understand time and unseen body functions Is cooperative; desires recognition for achievements	The unknown Body mutilation Inadequate performance	Provide simple information to decrease stress. Be honest at all times. Do not expect child to act like an adult yet. Allow personal item into OR for comfort/security.
Adolescence, puberty	Formal operations Uses logical and abstract thinking Understands hypothetical concepts	Identity vs. role diffusion Peer group has increased importance Body image, clothing, activities help define identity	Altered body image Death	Query patient about concerns; offer information to decrease fears. Provide as much privacy as possible if disrobing is necessary. Use mental imagery to decrease stress. Offer to hold hand to provide comfort; personal item still permitted.

Modified from Taylor E: Providing developmentally based care for toddlers, *AORN J* 87(5):992-999, 2008; Taylor E: Providing developmentally based care for school-aged and adolescent patients, *AORN J* 90(2):261-269, 2009; *Stages of social-emotional development in children,* available at www.childdevelopmentinfo.com/development. Accessed August 23, 2009.

sent home with the family from the surgeon's office or mailed to the family the week before the surgery is scheduled. The surgical facility contacts the family the day before surgery to inform them when the child should arrive at the facility and to review preoperative eating and drinking instructions. In these instances, the initial interview performed by the perioperative nurse is especially crucial to provide a thorough, documented assessment of the child's growth (height and weight), current physical status (vital signs, heart and breath sounds, skin integrity), current medication history, allergies, nothing-by-mouth (NPO) status, recent illnesses, current medical concerns, and behavioral responses to the interview process. The perioperative nurse confirms the intended surgical procedure with the child and family as it is written on the surgical consent as well as their understanding of the operation. This information is critical to the intraoperative nursing team's plan of care during the surgical procedure.

Children may undergo surgery at ambulatory surgery facilities or in a hospital setting. Certain criteria must be met for children to qualify for surgery at an ambulatory facility (Ambulatory Surgery Considerations). Children who are inpatients may be visited by a perioperative nurse in the hospital on the day before surgery. The nurse reviews the patient's chart, giving particular attention to the patient's age, developmental level, diagnosis, and intended surgical procedure. Current nursing diagnoses and the ongoing plan of care are examined. A discussion with the primary nurse can facilitate data collection, assist in providing continuity of care, and provide the perioperative nurse with information regarding preoperative education previously provided. The perioperative nurse can meet the child and any family members present at the time of the visit. The interview can be used to gather information helpful to developing the intraoperative plan of care and to decreasing the anxiety related to the child's impending surgery

RAPID RESPONSE TEAM

Cardiopulmonary arrest in hospitalized children is a rare event, but one that occurs in 0.19 to 2.45 of 1000 admissions. Comparable figures for adult cardiopulmonary arrest range from 2.6 to 6.5 per 1000 admissions. Rapid response teams (RRTs), common in facilities providing care to adults, have demonstrated effectiveness in preventing complications by initiating interventions when a patient begins to decline. The goal of RRTs is to interrupt the cascade of events that often results in cardiac arrest. Clinicians are generally familiar with the signs of impending cardiopulmonary arrest in adults. The origin of cardiopulmonary arrest in adults is generally cardiac related and is often preceded by hypotension. Despite the fact that some hospitalized children may suffer arrest attributable to dysrhythmia, airway obstruction, or other events, the majority of cardiopulmoary arrests in children are often related to respiratory failure. Children have greater reserves than adults and may not appear to be unstable as quickly as an adult. By the time a child exhibits signs of secondary cardiopulmonary arrest the period of hypoxemia has been longer, vital organs have been deprived of oxygen, and outcomes are generally worse. Clinicians must recognize the differences between adults and children to intervene appropriately when caring for pediatric patients.

The trend towards dedicated pediatric RRTs is increasing. In facilities where pediatric RRTs exist, staff that are credentialed with Basic Life Support (BLS) or Advanced Life Support (ALS) initiate resuscitation and emergency services within the scope of their certification and activate the RRT. Staff who are not certified in BLS or ALS must contact the RRT and remain with the victim until assistance arrives. Often, patient care areas with high acuity (such as the OR, pediatric intensive care unit [PICU], cancer intensive care unit [CICU], newborn infant center, emergency department, or cardiac catheterization lab) do not routinely use the RRT, except in those instances where a parent or visitor exhibits signs consistent with intervention. The OR also benefits from the close proximity of anesthesia and critical care attending physicians within the patient care areas. When critical incidents occur in the OR during times of limited resources (weekends, off-shifts, holidays), the staff have the option of activating the Code Team, rapid response team or communicating with the charge nurse in the PICU to mobilize additional clinical support in addition to in-house attending physicians, residents, and fellows already assigned to the OR.

Modified from Institute for Health Care Improvement: *Children count in the 100,000 Lives Campaign,* available at www.ihi.org/IHI/Topics/CriticalCare/IntensiveCare/ImprovementStories/ChildrenCountinthe100000LivesCampaign.htm. Accessed August 23, 2009; Children's Hospital of Philadelphia: *Administrative Policy and Procedure Manual, A-4-19 Resuscitation and emergency services;* Tibballs J, van der Jagt EW: Medical emergency and rapid response teams, *Pediatr Clin North Am* 55:989-1010, 2008; Van Voorhis KT, SchadeWillis T: Implementing a pediatric rapid response system to improve quality and patient safety, *Pediatr Clin North Am* 56:919-933, 2009.

PATIENT AND FAMILY EDUCATION

The Role of the Nurse Educator and Child Life Specialist in Supporting Education

In the pediatric setting, patient and family education is accomplished through many avenues. Patient and family education manuals contain teaching and information inserts that include but are not limited to explanations of conditions, procedures, diagnostic studies, and home management techniques. These manuals also contain lesson plans that a provider can access before providing teaching to a patient or family at the bedside or in a family learning center.

Many institutions have family learning centers on-site that adapt teaching and learning techniques to suit both inpatient and outpatient clients and their families. A patient may be referred to the family learning center in preparation for discharge, so that medical care can be effectively managed at home. Family learning centers promote learning in a safe, quiet environment with one-to-one instruction by a nurse educator. Care is simulated using mannequins, models, and other realistic tools and validated by return demonstration from the patient or caregiver. In addition, patients and caregivers are provided with feedback and additional materials to support the management of medical care in the home environment.

Institutions may also assign child life specialists to pediatric units and floors. Child life specialists are experts in child development who promote effective coping through play, preparation, education, and self-expression activities. They provide emotional support for families, and encourage optimum development of children facing a broad range of challenging experiences, particularly those related to healthcare and hospitalization. Understanding that a child's well-being depends on the support of the family, child life specialists provide information, support, and guidance to parents, siblings, and other family members. They also play a vital role in educating caregivers, administrators, and the general public about the needs of children under stress.

by providing a familiar face on the day of the procedure. The focus of this visit is to discuss the perioperative process, not always to provide preoperative education regarding the surgery. In pediatric centers in the inpatient setting, preoperative education may be provided by the primary nurse, child life therapist, or clinical nurse specialist. During the preoperative visit the perioperative nurse can explain, at a developmentally appropriate level, what the child will experience in the preoperative, intraoperative, and postoperative phases of care. The perioperative nurse may briefly describe the roles of various staff members who will be a part of the team responsible for the child's care in the OR. Common concerns that families express are the length of time that they will be separated from their child and their child's pain management. Explanations to children should be provided within a developmental framework, taking into account each child's cognitive and psychosocial abilities. Medical play items, audiovisual aids, puppets, and photographs are all helpful in the education process.

The perioperative nurse who will be participating in the intraoperative care of the child will review the patient's

AMBULATORY SURGERY CONSIDERATIONS

Guidelines for Pediatric Ambulatory Surgery

Candidates for ambulatory surgery in a pediatric institution should:

- Be categorized as either class I or class II in accordance with the American Society of Anesthesiologists (ASA) guidelines; in some cases, patients who are categorized as class III may be eligible for ambulatory surgery with the approval of the medical director or attending surgeon
- Be older than 6 months of age

Procedures that are eligible for scheduling in ambulatory surgical settings should:

- Be no more than 4 hours in duration and have a total 4 hours of direct supervised recovery unless exceeded by patient condition demands that cannot be anticipated before surgery
- Be able to be performed using local or regional anesthetics, monitored anesthesia care (MAC), or general anesthetic with a duration of less than 4 hours
- Be able to be performed without the risk of extensive blood loss, major prolonged invasion of body cavities, or direct involvement of major blood vessels

Modified from Children's Hospital of Philadelphia: *Ambulatory Surgery Policy and Procedure Manual, 5.2.1 approved surgical procedures for ambulatory surgical centers; Ambulatory Surgery Policy and Procedure Manual, 2.1.1 patient selection criteria for the ambulatory surgery center.*

information and meet with the patient and the family before the child is transferred to the OR. In addition to reviewing the documentation, the nurse validates the patient's identification using two patient identifiers, confirms that the surgeon has marked the child's surgical site per institutional protocol, and seeks verbal verification from the patient, parent, or legal guardian about the scheduled procedure, making sure that it matches what is written on the surgical consent (Figure 25-1). If implants are to be used, availability must be confirmed before the patient's transport to the surgical suite. Frequently children will be given a premedication in the 20- to 45-minute period before their transportation to the OR. A premedication such as midazolam can greatly decrease a child's anxiety, minimizing the stress of separation for both child and family. The surgeon and anesthesia provider will each meet with the child and family, usually while the OR is being prepared for the patient. The perioperative nurse will assess the child's psychologic state, review the intended surgical procedure with the child and family, and ensure that they have no additional questions or concerns. A final communication among the anesthesia provider, surgeon, and nursing staff for the room confirms the team's state of readiness for the delivery of care before the nurse transports the child to the OR.

Informed Consent. Informed consent from the parent or legal guardian of the pediatric patient is required unless the patient is an emancipated minor. An emancipated minor is one who is legally under the age of consent but is recognized as having the legal capacity to consent. Minors may become emancipated by pregnancy, marriage, high school graduation, independent living, and military service. It is important for children to develop a trusting relationship with medical professionals and that these older children are in agreement (within their developmental capabilities) with their family's decision regarding surgery.

FIGURE 25-1 Perioperative nurse and parent verify the surgical site marking on pediatric patient matches consent.

Child Abuse and Neglect. Perioperative nurses are obligated to screen all pediatric patients for abuse or neglect. Child abuse and neglect are defined as "physical or mental injury, sexual abuse or exploitation, negligent treatment or maltreatment" (Betz and Sowden, 2008). Child abuse is found in all segments of society, crossing cultural, ethnic, religious, socioeconomic, and professional groups. The perioperative nurse is in a unique situation to assess for the presence of abuse because the patient will be disrobed in the OR. Box 25-1 lists the clinical manifestations of child abuse. Every state has a child abuse law that dictates legal responsibility for reporting abuse and suspicion of abuse, and nurses are mandated reporters. Failure to report suspected child abuse could result in a fine or other punishment, according to individual statutes (Betz and Sowden, 2008).

Nursing Diagnosis

Nursing diagnoses related to the care of pediatric patients undergoing surgery might include the following:

- Anxiety related to separation from family and friends
- Fear related to developmental level (fear of the unknown, fear of painful procedures and surgery)
- Risk for Infection related to surgical intervention and other invasive procedures
- Risk for Imbalanced Fluid Volume related to invasive surgery and accompanying blood loss
- Risk for Hypothermia related to loss of body surface heat to environment and immature temperature-control mechanism

Outcome Identification

Perioperative nursing care is predicated on relevant nursing diagnoses and their corresponding desired outcome. Outcomes should be measurable with criteria by which to judge their attainment. Thus for the desired outcome, "The patient will demonstrate some ability to manage anxiety," measurable criteria (e.g., the child will have posture, facial expressions,

BOX 25-1

Clinical Manifestations of Child Abuse and Neglect

SKIN INJURIES
Skin injuries are the most common and easily recognized signs of maltreatment of children. Human bite marks appear as an ovoid area with tooth imprints, suck marks, or tongue thrust marks. Multiple bruises in inaccessible places are indications that the child has been abused. Bruises in different stages of healing may indicate repeated trauma. Bruises that take the shape of a recognized object are generally not accidental.

TRAUMATIC HAIR LOSS
Traumatic hair loss occurs when the child's hair is pulled or used to drag or jerk the child. The result of the pulling on the scalp can cause the blood vessels under the skin to break. An accumulation of blood can help differentiate between abusive and nonabusive loss of hair.

FALLS
If a child is reported to have experienced a routine fall but appears to have severe injuries, the inconsistency of the history with the trauma sustained indicates suspected child abuse.

EXTERNAL HEAD, FACIAL, AND ORAL INJURIES
Cuts, bleeding, redness, or swelling of the external ear canal; facial fractures; tears or scarring of the lip; oral, perioral, and/or pharyngeal lesions; loosened, discolored, or fractured teeth; dental caries; tongue lacerations; unexplained erythema or petechiae of the palate; and bilateral black eyes without trauma to the nose may all indicate abuse.

DELIBERATE OR UNEXPLAINED THERMAL INJURIES
Immersion burns, with a clear line of demarcation; multiple small circular burns, in varying stages of healing; iron burns (show iron pattern); diaper area burns; and rope burns suggest intentional harm.

SHAKEN BABY SYNDROME
A shaken baby may suffer only mild ocular or cerebral trauma. The infant may have a history of poor feeding, vomiting, lethargy, and/or irritability that occurs periodically for days or weeks before the initial healthcare consult. In 75% to 90% of the cases, unilateral or bilateral retinal hemorrhages are present but may be missed unless the child is examined by a pediatric ophthalmologist. Shaking produces an acceleration-deceleration (shearing) injury to the brain, causing stretching and breaking of blood vessels that results in subdural hemorrhage. Subdural hemorrhage may be most prominent in the interhemispheric fissure. However, cerebral edema may be the only finding. Serious insult to the central nervous system may result, without evidence of external injury.

UNEXPLAINED FRACTURES AND DISLOCATION
Posterior rib fractures in different stages of healing, spiral fractures, or dislocation from twisting of an extremity may provide evidence of nonaccidental injury in children.

SEXUAL ABUSE
Abrasions or bruising of the inner thighs and genitalia; scars, tearing, or distortion of the labia/hymen; anal lacerations or dilation; lacerations or irritation of external genitalia; repeated urinary tract infections; sexually transmitted disease; nonspecific vaginitis; pregnancy in young adolescent; penile discharge; and sexual promiscuity may provide evidence of sexual abuse.

NEGLECT
The symptoms of neglect reflect a lack of both physical and medical care. Manifestations include failure to thrive without a medical explanation, multiple cat or dog bites and scratches, feces and dirt in the skinfolds, severe diaper rash with the presence of ammonia burns, feeding disorders, and developmental delays.

Modified from Betz CL, Sowden LA: *Mosby's pediatric nursing reference,* ed 6, St Louis, 2008, Mosby.

gestures, and activity levels that reflect decreased anxiety and will demonstrate increased focus) might be identified.

Outcomes identified for the selected nursing diagnoses for the pediatric patient could be stated as follows:

- The child will demonstrate some ability to manage anxiety.
- The child will verbalize less fear.
- The child will remain free from signs and symptoms of surgical site and invasive procedure site infection.
- The child will be maintained in a state of fluid and electrolyte balance.
- The child will be maintained in a state of normothermia.

Planning

Assessment data, combined with information about the planned surgical procedure, enable perioperative nurses to anticipate requirements for surgical positioning, instrumentation, equipment and supplies, medications, and activities necessary for the provision of safe, competent care for the pediatric patient. Knowledge of the child's developmental level allows the nurse to plan her or his approach and interactions with the child and family (Figure 25-2). The perioperative nurse identifies criteria appropriate to the child and surgical setting for each of the desired outcomes. A Sample Plan for Care for the pediatric patient is shown on p. 1091.

FIGURE 25-2 Perioperative nurse engages in play with a young toddler during preoperative assessment.

Implementation

Age-appropriate communication is important in implementing the pediatric nursing plan of care. Implementation begins during the perioperative nursing assessment and continues

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Anxiety related to separation from family and friends

OUTCOME
The child will demonstrate some ability to manage anxiety; a toy or other comfort/security object will remain with the child, and he or she will cooperate with requests.

INTERVENTIONS
- Provide an atmosphere of warmth and acceptance for both child and family members.
- Maintain a calm and relaxed manner; try to smile at the child. Talking with the child, being calm, and smiling can provide comfort.
- Explain to the child when he or she will be reunited with parents.
- Speak softly and slowly. When speaking, try to get down to the child's eye level so he or she can see your face. Do not assume you were understood. Repetition may be necessary.
- Allow the child to keep familiar security objects (e.g., toy, blanket).
- Administer preoperative sedation as prescribed; note effects.
- Encourage parents to stay with the child as long as permitted and according to their wishes.
- Encourage parents to hold child until child falls asleep, if desired (may vary according to institution policy).
- Touch the child, and hold his or her hand.

NURSING DIAGNOSIS
Fear related to developmental level (fear of the unknown, fear of painful procedures and surgery)

OUTCOME
The child will verbalize less fear; he or she will respond in an age-appropriate manner to comfort measures and recognize that the perioperative nurse is present to help.

INTERVENTIONS
- Assess the child's growth and development, noting any variations from expected normal age-appropriate maturational levels.
- Provide preoperative education for the child and family, using audiovisual aids such as photographs, drawings, items for medical play, or a tour of the surgical suite.
- Provide explanations according to the child's level and the parent's level of understanding; use age-appropriate terminology that is familiar to the child, such as for body function.
- Place unfamiliar equipment out of the child's view to decrease fear.
- Encourage the child to handle items that may seem strange or threatening.
- Reassure the child that certain body parts can be removed without producing harm (e.g., blood, tonsils, appendix).
- Provide ongoing age-appropriate explanations for procedures/events during the perioperative period. Do not try to explain everything at once; explain procedure-by-procedure.
- Allow choices whenever possible, such as wearing pajamas or clothing to the OR.
- Respect need for modesty; expose only those body parts necessary.
- Provide diversional activities to decrease fear.
- Use pain assessment questions if the child is fearful of procedures.
- Be honest about the possibility of pain or discomfort; do not lie to the child.
- Reassure the child that you are there to help.

NURSING DIAGNOSIS
Risk for Infection related to surgical intervention and other invasive procedures

OUTCOME
The child will remain free from signs and symptoms of infection at the surgical site and invasive procedure sites; the surgical site will heal by first intention, and white blood cell count and differential will remain within normal limits.

INTERVENTIONS
- Administer antibiotic prophylaxis as prescribed.
- Follow Standard Precautions.
- Maintain aseptic technique, and monitor members of the surgical team for breaks in technique.
- Teach family members signs and symptoms of surgical site infection:
  - Redness
  - Swelling
  - Warmth
  - Tenderness
  - Pain
- Teach family members importance of and proper handwashing techniques.
- Apply dressing to surgical site before sterile drapes are removed to prevent contamination of incision.

NURSING DIAGNOSIS
Risk for Imbalanced Fluid Volume related to invasive surgery and accompanying blood loss

OUTCOME
The child will maintain fluid balance as evidenced by blood pressure within expected/acceptable range, palpable peripheral pulses, moist mucous membranes, and absence of peripheral edema.

INTERVENTIONS
- Maintain and protect patency of intravenous lines.
- Review laboratory analyses for results of total blood volume.
- Calculate estimated total blood volume using formula of 85 to 90 ml/kg of body weight if total blood volume has not been determined by laboratory tests.
- Provide gram scales for weighing sponges discarded from operative field; weigh sponges, and report estimated loss.
- Provide suction units with reservoirs that measure in 5-ml to 10-ml increments.
- Measure and record quantity of irrigating fluid used.
- Provide appropriate amounts of intravenous fluid replacement (e.g., 250-ml containers).
- Measure and record urinary output and output from other drainage tubes.
- Send laboratory specimens for analysis as indicated; review results indicating fluid status.

NURSING DIAGNOSIS
Risk for Hypothermia related to loss of body surface heat to environment and immature temperature-control mechanism

OUTCOME
The child will maintain normothermia as evidenced by body temperature within normal limits/expected range.

INTERVENTIONS
- Adjust room temperature approximately 1 hour before arrival of the child: 26° to 27° C (78.8° to 80.6° F) for infants and newborns; 23° to 24° C (73.4° to 75.2° F) for older children.
- Keep child covered as much as possible.
- Consider wrapping lower extremities in soft gauze or stockinette and encasing in plastic bag for newborns and infants.
- Provide radiant heat lamp for use during placement of monitoring lines, induction of anesthesia, positioning, skin prep, and draping.
- Warm blankets, skin prep solutions (according to manufacturer's instructions), and irrigation and other solutions to body temperature before use.
- Use warmers during administration of intravenous fluids and blood products; temperature settings should not exceed 38° C (100.4° F).
- Monitor body temperature by rectal, esophageal, tympanic membrane, or other automatic temperature-monitoring device.
- Document temperature at prescribed intervals; take appropriate action for temperature extremes.

through discharge to the postanesthesia care unit (PACU) or other area. The presence of a parent during much of the preoperative period, including during anesthesia induction in the OR and after anesthesia emergence in the PACU, can help decrease anxiety for both young children and their families and facilitates family-centered care (Evidence for Practice).

Infants, reliant on family to meet their basic needs, are difficult to pacify when NPO for surgery. The facility should provide rocking chairs, pacifiers, warm blankets, and simple distractions such as music or toys. Preoperative teaching should include telling the family to provide fluids for the infant until the deadline for NPO status. Unnecessary delays should be avoided at all costs. Parents may need reassurance and support during the period immediately before surgery.

The toddler or preschooler fears parental separation and abandonment. Toddlers fear, among other things, strangers, the dark, and machines. They attribute lifelike qualities to inanimate objects, believing that the objects, like them, have feelings. Thus a blood pressure cuff that squeezes the child's arm may be perceived to be doing so because it is angry with the toddler. Toddlers may also believe that their body is held together by their skin; anything that violates the skin integrity is feared. For this reason, bandages are very important. Toddlers and preschoolers interact with the environment using their senses. To integrate this into the patient's care, the perioperative nurse should give the toddler the opportunity to touch and play with objects that he or she will encounter. An example is to give the child a small anesthesia mask to put on his or her teddy bear. Sensory information should be provided in a soft, gentle voice (i.e., what the toddler will see, feel, touch, and hear). A security object is extremely comforting. The OR should be quiet; background noise should be controlled. Instruments that are frightening should be kept from view. To allow quick induction of anesthesia the toddler should be transferred into the surgical suite when the room and staff are completely prepared.

The school-age child may still perceive hospitalization or surgery as a punishment but can evaluate painful intrusive actions in terms of logical function (e.g., getting an IV line hurts, but then I can get medicine in it to make me feel better). Feelings of inadequacy may be associated with something the child thinks he or she should be expected to do or know. Fear of body injury or mutilation, loss of control, and fear of the unknown characterize this developmental stage. These children benefit from simple, concrete explanations in familiar terms; a book or other teaching aid can be helpful. The concepts of time and unseen body functions can now be incorporated in the explanations. The child should be allowed to make choices when possible (e.g., letting the child decide in which hand to place the IV line or which flavor to add to the anesthetic mask).

Adolescents may fear altered body image, peer rejection, disability, and loss of control or status. The fear of death is more prevalent in this age-group than any other, and adolescents may find explanations of monitoring and safety measures reassuring. They need as much privacy as possible, and their attempts to be independent should be respected (e.g., walking into the OR instead of being wheeled in on a stretcher if the

EVIDENCE FOR PRACTICE

Timely Postoperative Visitation

Parental visitation in the postanesthesia care unit (PACU) has been identified as a standard of care in some hospitals, but not all. In this study, researchers at a facility in Pennsylvania reviewed the literature to summarize the benefits of early parental visitation in the PACU, and then established a baseline within the unit. Through objective data collection and anecdotal reporting, they found that in 2004 only 44% of parents were reunited with children during the immediate postoperative phase. The team established a target goal of 75% parental visitation in the PACU within 6 months of initiating a quality improvement program.

Their quality improvement program consisted of a survey distributed to ambulatory surgery patients and families in April 2005 to ask families questions such as the following: Did they believe that their children were adequately prepared for the surgery? What aspects of care were most important to the family? What was the family's overall satisfaction with the ambulatory surgical experience? The results of the survey indicated that speaking with their child's surgeon after the procedure and being present with their child in the PACU as soon as possible after surgery were the top two priorities for family satisfaction.

The team decided to address barriers that prevented parental visitation in the PACU. Among the top concerns were the high acuity of patients upon arrival to the PACU; a change in efficiency related to phase I procedures and care; risks to patient safety because of negative reactions from parents related to laryngospasm, airway obstruction, and respiratory compromise; and increased risks to the safety of parents who were unable to effectively cope with seeing their child during the immediate postoperative period.

The first step in garnering support for change was recognition from nursing leadership that the concerns shared by the nursing staff regarding the delivery of patient care balanced with parental visitation were real and valid. The team worked to help the nursing staff understand that they all owned the process, and accepted that resistance was more a result of a caring and committed staff. In order for timely postoperative visitation to occur, resources, adequate systems, and support from management were readily available. In addition, the practice was championed and clear expectations were shared with the staff.

Ultimately, change could only occur with multidisciplinary acceptance of the new practices. A team represented by various stakeholders in the surgical process, including members from a family advisory committee, was created to establish a foundation for work, review the current philosophy of care and key elements of family-centered care, and develop a theoretical framework for the group's work. Any staff member who provided direct patient care was educated about the quality improvement program, and before surgery all patients were provided with education and information regarding parental visitation in the PACU.

Their target goal was reached in January 2005 and has continued to increase. In January 2007, 90% of parents were reunited with their child within 30 minutes of the patient's arrival to the PACU.

Modified from Kamerling SN et al: Family centered care in the pediatric postanesthesia care unit: changing practice to promote parental visitation, *J Perianesth Nurs* 23(1):5-16, 2008.

patient has not been sedated). The adolescent may not wish to show any fear; questions might not be asked while the parents are present. Information and explanations should be provided as reasonably and truthfully as possible. If appropriate, some choices should be allowed, such as wearing underwear to the OR. Patient care procedures that violate privacy, such as hair removal, skin preparation, or insertion of an indwelling urinary catheter, should be conducted after the patient is anesthetized.

Key points in providing perioperative care to pediatric patients include remaining alongside the child until the child is anesthetized, keeping the room quiet during induction, accepting a child's need to express fear and fearful behaviors (e.g., crying), and using simple words without double meanings to explain care. Security objects should remain with the child until induction has been completed. A child's behavior during induction is likely to be the same during emergence; thus all attempts should be made to provide calm, reassuring care. Parents should be alerted to delays in the surgery schedule; in some instances, the child may be allowed to have fluids if the surgery is delayed by several hours.

Implementing the nursing plan of care includes continual reassessment of the patient's needs as well as the efficient execution of activities that facilitate the surgical intervention. Remaining with the child during induction, positioning, and prepping the surgical site; creating and maintaining a sterile field; collecting, documenting, and disposing specimens; and administering medications are all part of helping to provide a safe environment for the pediatric surgical patient. Making sure that the pediatric patient's family receives regular updates of the child's status is also a part of the perioperative nurse's responsibilities and will decrease their anxiety and help foster a sense of trust in the healthcare professionals caring for their child.

Instrumentation. The same types of instruments used in adult surgery are used in pediatric surgery. However, pediatric instruments are usually shorter, have more delicate or less pronounced curves, and are smaller. A complete range of instrument sizes is necessary to make the appropriate size available to each child, since pediatric patients can range in size from less than 1 kg to more than 100 kg. Fewer instruments are normally required because incisions in children are shorter and shallower than those in adults. Use of basic instrument sets, grouped according to types of surgery performed (e.g., minor, major), facilitates instrument counts. These sets are easily adapted to the patient's needs as well as the surgeon's preferences and eliminate unnecessary instruments from the sterile field.

The following sets are examples of instrumentation used in pediatric surgery. The minor set is used for procedures such as inguinal hernia repair, head and neck procedures, and pyloromyotomy. The major set is used for major chest and abdominal cases, such as tracheoesophageal fistula (TEF) and diaphragmatic hernia repair, omphalocele repair, bowel resection, and pull-through for Hirschsprung's disease. Smaller and larger instruments should be in separate, additional sets to be dispensed to the surgical field as determined by the patient's size.

In addition to basic instruments, the minor pediatric instrument set should include curved Knapp iris scissors, both sharp and blunt; a Jacobsen curved clamp for delicate dissection; straight and curved Halstead mosquito clamps; sharp and blunt Senn retractors (two of each); 0.5-mm Castroviejo forceps; single-toothed Adson forceps; 6-inch fine DeBakey forceps; a small Weitlaner retractor; an Andrews-Pynchon 9½-inch suction; sizes 7- and 9-French (9F) Frazier suctions; a Castroviejo locking needle holder; and two Webster needle holders. The major pediatric instrument set should include the components of the minor set, slightly longer (7- to 8-inch) basic instruments (scissors, forceps, needle holders), and the following: curved Schnidt forceps; fine Kelly clamps; Gemini right-angled clamps; Army-Navy, small Deaver, and Richardson retractors (two of each size); Gerald forceps; Singley ring forceps; a set of malleable retractors; a grooved director; and a Poole suction.

Sutures. A variety of sutures are used with the pediatric population because of the wide range of patient size; needles from size 0 to 7-0 are routinely stocked. Both absorbable and nonabsorbable sutures on cutting and tapered needles are employed. The most frequently used sizes are 3-0 to 5-0 with ½- and ⅜-circle needles. Staples, both pediatric and regular sizes, are occasionally used. Many skin incisions are closed with subcuticular techniques, over which adhesive strips or cyanoacrylate glue is then applied. The use of tape to apply dressings is done conservatively because of the delicate nature of children's skin; frequently, either a small transparent or an elastic net dressing is used to hold gauze dressings in place.

Anesthetic Considerations. Anesthesia is approached differently in pediatric patients than it is in adults. The equipment and supplies are scaled down to match the size of the patient, and different anesthesia circuits and delivery systems may be used. The most common technique used in the pediatric population is a general inhalational anesthetic administered by facemask, laryngeal airway, or endotracheal tube. Selection of the endotracheal tube involves several considerations; the tube must be large enough to permit ventilation but small enough to minimize damage to the trachea while maintaining a seal to prevent aspiration. Pressure from the cuff can cause tracheal damage (Cote, 2005). Uncuffed endotracheal tubes are used in children up to 8 years of age. Table 25-2 provides a guide to choosing endotracheal tubes and laryngoscope blades for pediatric patients.

Microdrip IV tubing and burettes are commonly used to avoid the administration of excess fluids in pediatric patients under the age of 8 years, and only 500-ml bags of IV solution are used. The patient's IV line is usually started in the OR after induction with mask anesthesia, depending on the patient's diagnosis and medical history. Patients who require emergency surgery who have not been NPO; have increased intracranial pressure, an unusually difficult airway, or neuromuscular disease; or have been diagnosed with malignant hyperthermia require an IV placement before anesthesia induction. If the IV line is started before induction, measures should be taken to lessen the discomfort, such as an intradermal injection of 1% buffered lidocaine or saline at the site or the application of topical anesthetic creams. If possible, the surgical team should allow the child the option of sitting up or lying down during IV placement; if developmentally appropriate, hold the child's hand and tell the child about each step in the placement of an IV line.

Preoperative sedation is generally accomplished by the oral administration of midazolam. Midazolam is the most commonly used pediatric premedication in the United States and

TABLE 25-2

Recommended Sizes and Distance of Insertion of Endotracheal Tubes and Laryngoscope Blades for Use in Pediatric Patients

Age	Internal Diameter of Endotracheal Tube (mm)	Recommended Size of Laryngoscope Straight Blade	Distance of Insertion (cm)
Premature (<1250 g)	2.5	0	6-7
Full term	3.0	0-1	8-10
1 yr	4.0	1	11
2 yr	5.0	1-1.5	12
6 yr	5.5	1.5-2	15
10 yr	6.5	2-3	17
18 yr	7-8	3	19

Modified from Cote CJ: Pediatric anesthesia. In Miller RD, editor: *Miller's anesthesia*, vol 2, ed 6, Philadelphia, 2005, Churchill Livingstone.

can be given orally, nasally, rectally, intramuscularly, or intravenously (Cote, 2005). Oral midazolam should be administered in a flavored base to mask the bitter taste. Relaxation is noted 15 to 45 minutes after administration; the child should be kept in a safe, observable environment after being medicated. Other agents used for premedication include fentanyl and, infrequently, ketamine.

Depending on institutional policy, a parent may be present during induction to comfort the child and decrease the child's anxiety. The perioperative nurse should provide the parent an explanation of how the OR will appear and who will be present in the OR, how the child's anesthesia induction will be performed, and how the child will appear as the anesthetic takes effect. An additional staff person, such as a parent services' provider or child life therapist, should be present to escort the parent to and from the OR so that the perioperative nurse can focus on providing care for the patient once the child has been anesthetized.

Distraction methods during the induction of anesthesia can help minimize a child's stress and anxiety. Singing softly, telling a story, and, for the older child, providing a relaxing mental image are effective diversion techniques.

Malignant hyperthermia (MH), although very rare, may be more prevalent in the pediatric population as a result of the administration of inhalational anesthetics and succinylcholine (see Chapter 4). In addition, physiologic conditions present in some pediatric patients are associated with a higher risk of MH. These conditions are myotonia congenita, Duchenne's muscular dystrophy, Becker's muscular dystrophy, osteogenesis imperfecta, arthrogryposis, kyphoscoliosis, and King-Denborough syndrome (Gronert, 2005). Careful assessment of family history is essential to identify patients at risk for developing MH. The management of an MH crisis is described in Chapter 4.

Pain Management. In the past, many common fallacies existed about pain in the pediatric population. Some of these mistruths were that infants do not feel pain; children have better pain tolerance than adults; children cannot tell the healthcare provider where they hurt; children always tell the truth about pain; children become accustomed to pain or painful procedures; and narcotics are more dangerous for children than they are for adults. Research into this important area has revealed that infants do demonstrate behavioral and physiologic indicators of pain. Compared to adults, children have less pain tolerance; their pain tolerance increases as they mature. Children are able to indicate pain, and children as young as 3 years can use pain-rating scales. Often children may not admit to having pain; they may believe that others know how much they hurt, or they fear receiving an injection. Children may also feel that pain and suffering are punishment for some misdeed, or they may not know what the word *pain* means. Children do not become accustomed to pain or painful procedures. They actually may demonstrate increased behavioral signs of pain with repeated procedures. Many factors, such as developmental level, culture, coping ability, temperament, and activity levels, influence the behavioral manifestations of pain exhibited by the patient. Narcotics are no more dangerous for children than they are for adults and are not excluded as a treatment modality. The evaluation of a pediatric patient's level of pain is performed using a variety of assessment tools (pain scales) that are based on the age and developmental level of the child. Often, these scales are tested for reliability and validity (Research Highlight). In infants and nonverbal children, evaluation is based on physiologic changes and observation of behaviors. Children with verbal skills are able to articulate pain. One assessment strategy to use with pediatric patients is the *QUESTT* method:

Question the child.
Use pain-rating scales.
Evaluate behavior and physiologic changes.
Secure the parents' involvement.
Take cause of pain into account.
Take action, and evaluate results.

Questioning the child provides the most reliable indicator of pain. Children may not be familiar with the word *pain* and may be more comfortable with words like "ouch," "hurt," or "owie." It may also be helpful to ask the child to point to where it hurts. The FACES pain scale uses cartoon faces with a variety of expressions ranging from happy to crying. The child selects the face that best describes his or her pain (see Chapter 9). The Oucher scale has a numeric component and a component similar to the FACES scale but uses actual photographs of children. The adolescent pediatric pain tool (APPT) is a line drawing of a body; the child marks the drawing where he or she has pain. Other tools include Likert-type scales rating pain on a score of 0 (no pain) to 10 (worst pain) or incorporate several components of pain assessment (subjective and objective data).

RESEARCH HIGHLIGHT

Behavioral Observational Pain Scale (BOPS)

The Behavioral Observational Pain Scale (BOPS) is a postoperative pain measurement scale geared towards children ages 1 to 7. The scale assesses facial expression, verbalization, and body position in an attempt to score the degree of pain felt by a child. A prospective study was conducted on a day surgery unit and a neurosurgical postoperative unit to determine the validity and reliability of the BOPS. The sample size consisted of 76 children ages 1 to 7 who were scheduled for elective surgical procedures. The study was divided into interrater reliability (based on different nurses scoring patients on the BOPS), concurrent validity (comparing the BOPS to the Children's Hospital of Eastern Ontario Pain Scale to determine whether each described similar behaviors), and construct validity (assessing baseline pain scores and the effect of analgesic on pain scores at 15, 30, and 60 minutes after administration). The findings of this study indicated that there was extensive agreement between different nurses who scored patients on the BOPS. Positive correlation between the BOPS and the Children's Hospital of Eastern Ontario Pain Scales indicated that both tools described similar behaviors ($p < .001$). There was significance ($p < .01$) before the administration of analgesia and at 15, 30, and 60 minutes after medication administration; in addition, there was no significant difference ($p < .01$) between results recorded at 15 and 60 minutes. The BOPS allows for evaluation and documentation of pain scales in a manner that is reliable and consistent. The scoring system is simple, and can be easily incorporated into a postoperative unit. These findings indicate the potential for improved postoperative pain treatment when using the BOPS in children ages 1 to 7.

Modified from Hesselgard K et al: Validity and reliability of the Behavioural Observational Pain Scale for postoperative pain measurement in children 1-7 years of age, *Pediatr Crit Care Med* 8(2):102-108, 2007.

Physiologic indicators of pain, such as increased blood pressure, respirations, and heart rate and restlessness, are the same for children as for adults but may not be as reliable, except in neonates and nonverbal children. These indicators may also reflect anxiety or fear and should not be the sole indicator used to determine pain. Children may also tug or hold painful areas or show preference to a painful extremity.

Parental involvement in pain management is important. Parents know their child's normal behavior and can provide input into the behaviors being exhibited in the perioperative setting. Parents should be queried about the child's previous experiences with pain and be taught the nonverbal behaviors that may indicate pain.

Nurses should investigate all complaints of pain or discomfort and be sensitive to behavioral and nonverbal cues to determine treatment. Postoperative pain should be assessed after all surgical procedures, regardless of their nature. It is also critical to assess and document the child's response to the interventions provided for relief of pain.

Effective pain management requires a willingness to use a variety of methods and modalities to achieve optimal results. Pharmacologic methods include the administration of analgesics, both narcotic and non-narcotic. Patient-controlled analgesia (PCA) is an option for children. Children as young as 4 years have the cognitive and physical capabilities to successfully use this modality with appropriate instruction and support (Wu, 2005). Nonpharmacologic methods include distraction, relaxation, guided imagery, behavioral contracting, and cutaneous stimulation. Nonpharmacologic methods should never be used as substitutes for appropriate medication administration but instead should be used to enhance the management of pain.

Evaluation

The perioperative nurse evaluates care provided throughout the perioperative period. At the conclusion of the surgical intervention, the skin is inspected, especially at dependent pressure points and at the site of the electrosurgical dispersive pad. Inspection is carried out to detect any reddened, irritated areas or evidence of compression injury. If povidone-iodine or chlorhexidine gluconate preparations were used for skin prep, the area needs to be checked for any signs of chemical irritation. The patient's temperature is reassessed. The cardiopulmonary status is closely monitored as the child emerges from anesthesia. The perioperative nurse should assist the anesthesia team during emergence, remaining at the patient's bedside. Warm blankets are provided; hydration status is evaluated as replacement fluids continue to be administered, and fluid output is noted. The child is transferred to and positioned on the stretcher, crib, neonatal intensive care unit (NICU) warmer, or ICU bed; the airway and respiratory effort are reassessed before departing the OR. Tubes, IV lines, drains, and drainage devices must be carefully protected during the move from the operating table. Supplemental oxygen is always given during transport from the OR to the PACU for pediatric patients.

The perioperative nurse provides a hand-off report to the PACU nurse, focusing on the condition of the child, the response to surgery and anesthesia, the presence of catheters and drains, the quality and amount of wound drainage, a description of the dressings applied, and any special needs. Part of this report should focus on the outcomes established in the perioperative plan of care. For the plan of care presented in this chapter, they might be as follows:

- The patient demonstrated decreased anxiety.
- The patient was protected from infection related to operative intervention; principles of asepsis and infection control were maintained.
- The patient remained free from injuries related to positioning for the surgery.
- The patient's temperature was maintained in the desired range during the perioperative period.

The perioperative nurse may receive further feedback on the child's progress after the child is discharged from the PACU; information may be relayed by the surgeon, unit nurse, or anesthesia team. This type of informal feedback helps the perioperative nurse collect additional data regarding effectiveness of the plan of care, providing information about the achievement of identified outcomes.

Patient and Family Education and Discharge Planning

Patient and family teaching varies significantly based on the type of surgery performed. Some hospitals provide special preoperative teaching and hospital tours for pediatric patients and their parents to help them prepare for the surgical experience. Sometimes information is discussed with the child and family at the time of the office visit, when the surgery is scheduled. For same-day procedures, the day-surgery nursing staff

BOX 25-2

Sample Discharge Instructions

- Leave the wound open to the air.
- Do not apply any creams or ointments to the wound.
- For the first 24 hours, keep the incision clean and dry.
- Do not allow the incision to be under water for the first week after surgery.
- On the second day after surgery gently wash the incision twice a day with mild soap or shampoo. Make a small lather in your hand and wash with warm water. Do not rinse under water. Use a warm, wet paper towel and blot the lather away. Do not use terry cloth washcloths. The fabric loops may snag and pull on the stitches.
- If the stitches are clear, they will dissolve and do not need to be removed. If they are blue or black, they need to be removed about 10 days to 2 weeks after the surgery. Your physician will tell you how long the stitches should remain in position. Call the surgeon's office soon after going home if you need an appointment for stitch removal.
- Check the wound daily. It is normal to have some redness around the stitch holes or on the incision line. Call the surgeon's office if you notice that the area around the outside of the incision is red, hot, tender or has pus draining from it. Also call if your child has a fever.

From Children's Hospital of Philadelphia, 2008.

might teach postoperative care immediately before patient discharge. Basics of postoperative care are reviewed with the parents at this time. In some cases, written material may be provided (Box 25-2). Parents should be advised to be alert for certain signs and symptoms during the postoperative recovery period that could indicate an infectious process, such as fever, pain, nausea, redness around the incision area, drainage from the wound, or difficulty breathing. These signs and symptoms may develop days or even weeks after surgery. It is important that parents understand the necessity of not ignoring any of these signs and symptoms and of reporting them to the surgeon promptly so that an early diagnosis can be made and treatment prescribed. Although discharge information depends on the type of surgery performed, it typically includes recommendations about activity restrictions, return to school or day care, wound care, bathing or showering, diet, and follow-up appointments. The printed discharge instructions are reviewed with the parents, and their understanding is verified. This time should provide the family with an opportunity to ask questions or seek clarification of the instructions. Phone numbers for the surgeon and the main hospital are provided in case the family has concerns or questions during the child's recovery period at home. An appointment for the child's follow-up visit may be made before discharge, or the parents are instructed to call the physician's office to schedule an appointment.

Surgical Interventions

As mentioned, children require surgery for congenital malformations, an acquired disease, or trauma. The field of pediatric surgery is further subdivided into all the specialties. Several surgical procedures that may be designated pediatric are presented in previous chapters of this text under particular specialty headings. The surgical interventions presented here represent procedures that are most commonly performed on children.

VASCULAR ACCESS

Vascular access in pediatric patients may be established intraoperatively for short-term (weeks) or long-term (months, years) use. Examples of short-term use include peripherally inserted central venous catheters (PICC lines) for antibiotic therapy. Central venous lines or implanted ports are placed for long-term access to provide parenteral nutrition, chemotherapy, bone marrow transplantation, or multiple IV access lines for the critically ill patient. Common complications of vascular access include infection; thrombosis; catheter occlusion; extravasation/migration; malposition/displacement; vascular stenosis; catheter fracture/embolization; surgical damage to nerves, lymphatics, vessels, or pleura; and poor cosmesis (Turner, 2005). The potential for central line–associated bloodstream infections (CLABSIs) has been recognized in many institutions throughout the country. The Risk Reduction Strategies box addresses ways in which the integrity of these lines can be preserved.

Central Venous Catheter Placement

The preferred site of placement is the external jugular vein. The internal jugular vein may be chosen if the external jugular vein has been used or is too small. From the cannulation site the catheter is tunneled under the skin about 5 to 10 cm. This is done to inhibit contamination of the bloodstream from frequent dressing changes. Subcutaneous ports are placed in a similar fashion. In cases where the internal or external vein sites are unavailable, the catheter may be placed into the external iliac vein by way of a cutdown in the greater saphenous vein. In these cases the catheter is tunneled into the abdominal wall.

Procedural Considerations. The manufacturer's instructions for handling and preparing the catheter must be followed. The catheter must not contact lint, glove powder, or other foreign matter. Before insertion, the catheter is flushed and filled with heparinized saline (1 unit of heparin to 1 ml of saline) to prevent air bubbles from entering the circulatory system and to eliminate blood clots in the catheter lumen. Fluoroscopy is used to confirm proper placement of the catheter; lead shielding must be provided for patient and staff, with appropriate warning signs placed on room doors. The use of a lead shield for the patient should be documented in the perioperative record.

The child is appropriately positioned as dictated by the site chosen for cannulation, and organs are protected with a lead shield. The area is prepped and draped.

Operative Procedure—External Jugular Vein Site

1. The surgeon uses a needle and syringe to puncture the external jugular and aspirates to confirm blood flow.
2. The syringe is removed from the needle, and a guidewire is fed through the needle into the vein. An intraoperative x-ray is taken to confirm correct position.

RISK REDUCTION STRATEGIES

Preventing Central Line–Associated Bloodstream Infections (CLABSIs)

When patients with a central venous catheter are admitted into the OR for surgical procedures, staff may take the following precautions to prevent central line–associated bloodstream infections (CLABSIs):

- Make every effort not to access the central line for general purposes in the OR; use peripheral lines as much as possible.
- Practice hand hygiene before and after handling a central line.
- If a central line needs to be used in the OR, healthcare providers must perform a 10-second hub scrub that encompasses the threads of the catheter hub.
- If a central line dressing needs to be changed* in the OR, keep the following in mind:
  - Don nonsterile exam gloves to remove the old dressing.
  - Dried blood, crusty accumulations should be cleaned with an alcohol pad.
  - ChloraPrep is the solution of choice in some hospitals for central line dressing changes.
  - Establish a sterile field with prep solution and new dressing material.
  - If using ChloraPrep, apply the solution using a "back and forth" motion as opposed to concentric circles. The "back and forth" motion creates more friction on the skin and helps to decrease the bacterial load.
  - Scrub the area for 30 seconds (recommended time for some hospitals).†
  - Allow the prep solution to dry.
  - Don sterile gloves to apply transparent, semi-permeable dressing.‡
  - Write the date on the dressing label and apply to the central line dressing site.

*Central line dressings are routinely changed every 7 days, unless there is a need to do so (e.g., soiled, bloody). Smartsites (Clave) are changed every 72 hours unless damaged.
†If the central line is in the femoral/groin area, scrub the site for 2 minutes.
‡SorbaView dressing is only recommended for those patients who have a contraindication (e.g., sensitivity, reaction) to Tegaderm dressings.
Modified from Children's' Hospital of Philadelphia Blood Stream Infection (BSI) Task Force, 2008-2009.

3. Once the position is confirmed, the surgeon makes an incision over the insertion site. A silver probe or tendon passer is used to create a tunnel beneath the skin to the desired exit site of the catheter. A second incision is made over the tip of the probe or passer.
4. The implantable end of the catheter is attached to the end of the passer or probe and pulled through the subcutaneous tunnel. The catheter is cut to a desired length.
5. The needle is removed from the vein, leaving the guidewire in place. An obturator is placed over the guidewire, and the wire is removed. The catheter is placed through the obturator into the vein and an intraoperative x-ray is taken to confirm position.
6. The catheter is secured at the exit site on the chest wall with nonabsorbable sutures, flushed with a "super flush" of heparinized saline (10 units of heparin to 1 ml of saline in children younger than 12 months or 100 units of heparin to 1 ml of saline in children older than 12 months), and clamped.
7. An occlusive transparent dressing is placed over the catheter site. The catheter is coiled under this dressing to avoid tension on the line and accidental displacement.

MINIMALLY INVASIVE SURGERY

Improvements in instrumentation and the development of equipment in smaller sizes have resulted in the evolution of minimally invasive surgery (MIS) from that of a rapidly growing field to one of routine practice in the pediatric surgical arena. Much like the adult population, many traditional "open" pediatric surgical procedures are being replaced by MIS procedures. Because the field of pediatric MIS is relatively new, surgeons are at an advantage because they are able to combine virtual reality techniques and robotics with the most current technology and instrumentation (Harrington et al, 2008). Advantages of minimally invasive surgery include diminished postoperative pain, improved cosmetic results, decreased prevalence of adhesion formation, and accelerated recovery periods and shorter hospital stays.

Despite the technical congruence with adult MIS procedures, the pediatric populations undergoing these procedures have specific needs that must be satisfied in order to promote positive outcomes. Anesthesia providers must take the size and age of the patient into consideration because of the risk of physiologic compromise related to insufflation. Likewise, steps are taken intraoperatively to decrease the likelihood of intraabdominal injury, such as insertion of an appropriate size Foley catheter to decompress the bladder or application of thromboembolic hose or sleeves to prevent deep vein thrombosis.

Common pediatric MIS procedures for general surgery include diagnostic laparoscopy, pyloromyotomy, splenectomy, gastric fundoplication, and cholecystectomy. Thoracoscopic approaches may be used for correction of pectus excavatum, lung biopsy, sympathectomy, and closure of a patent ductus arteriosus (PDA). Procedures that are currently less common but increasing in prevalence include pancreatectomy for focal lesion, choledochal cyst excision, lobectomy for congenital cystic adenomatoid malformation (CCAM), and repair of congenital diaphragmatic hernia (CDH) and transcutaneous esophageal fistula (TEF). Minimally invasive procedures in other disciplines include (but are not limited to) ventriculoscopy, which can be used to view the ventricles of the brain; functional endoscopic sinus surgery (FESS); and nephrectomy and pyeloplasty, both of which may involve the use of a surgical robotic system.

Laparoscopic Pyloromyotomy for Pyloric Stenosis

Pyloric stenosis (Figure 25-3) is the most common cause of gastric outlet obstructions in children and is the most common condition requiring surgery in the newborn. Signs and symptoms of high gastrointestinal (GI) obstruction appear at 2 to 6 weeks of age. The first sign is bile-free projectile vomiting after feeding. The infant usually fails to gain weight adequately, and there may be a severe loss of body fluids and electrolyte imbalance, evidenced as hypochloremic, hypokalemic metabolic alkalosis. Once the diagnosis of hypertrophic pyloric stenosis is made, either through physical examination or by imaging techniques, surgical intervention is planned.

Electrolyte imbalances must be corrected before surgery. The Fredet-Ramstedt pyloromyotomy for pyloric stenosis is an open procedure that involves the incision of the muscles of the pylorus to treat congenital hypertrophy of the pyloric sphincter that is obstructing the stomach. However, laparoscopic pyloromyotomy has replaced the open procedure as the standard for repair. The laparoscopic procedure is described in the following Operative Procedure.

Procedural Considerations. The stomach is emptied just before induction of anesthesia, and the nasogastric tube is removed to guard against reflux of gastric contents around the tube during induction. The patient is positioned transverse on the OR bed so that the operating surgeon stands at the patient's feet. A video monitor is positioned above the patient's head. The abdomen is prepped in the usual manner, and trocar sites are injected with a local anesthetic. The perioperative nurse must consider the location of the incision and position the patient in a fashion that facilitates maximum exposure of the surgical site. Appropriate-sized instrumentation and sterile supplies must be available, along with the appropriate imaging equipment. Insufflation flow rate should be set to the lowest acceptable level for achieving pneumoperitoneum and increased slowly.

Operative Procedure

1. The surgeon makes a small incision in the umbilicus and places a 3-mm or 5-mm trocar through it to accommodate the telescope. Insufflation tubing is attached to this trocar and the abdomen is insufflated (maximum pressure of 10 mm Hg).
2. Using a #11 blade, the surgeon makes a small stab incision laterally, slightly above the umbilicus on each side.
3. The 3-mm laparoscopic instruments are passed directly through the stab incisions.
4. The surgeon makes an incision in the serosa on the anterior wall of the pyloric mass from the duodenal junction proximally to a point proximal to the area of hypertrophied muscle using an arthroscopic knife and laparoscopic grasper. The circular muscle is spread with the 3-mm laparoscopic pyloric spreader on the submucosal base, so that all muscle fibers are completely divided (Figure 25-4).
5. The anesthesia provider injects 60 to 120 ml of air into the stomach through an orogastric (OG) tube to ensure that there are no air bubbles at the pyloric incision.
6. The umbilical incision is closed using absorbable suture and cyanoacrylate glue applied to each incision.

Laparoscopic Nissen Fundoplication

Nissen fundoplication is indicated for infants and children who experience severe gastroesophageal (GE) reflux. The cause of GE reflux in these patients is believed to be an inadequate anti–reflux barrier. The anti–reflux barrier normally consists of a combination of anatomic and physiologic factors, including sufficient amount and strength of muscle fibers located in the lower esophageal sphincter, adequate length of the abdominal esophagus, and a high-pressure zone in the lower esophagus. An incompetent anti–reflux barrier can result in life-threatening complications, including obstructive apnea, aspiration pneumonia, esophagitis, and failure to thrive. The goal of the Nissen fundoplication is to create a competent anti-reflux barrier. Nissen fundoplications can be performed using open or laparoscopic technique. There are several types of laparoscopic fundoplications. The traditional laparoscopic wrap is described in Chapter 10. The partial laparoscopic wrap (Toupet) is described below.

Procedural Considerations. The patient is positioned supine for induction of general anesthesia. The anesthesia provider inserts an OG tube, which serves as a stent for the wrap during the procedure. Once the endotracheal tube location is confirmed and secured, the patient is moved to the foot of the OR

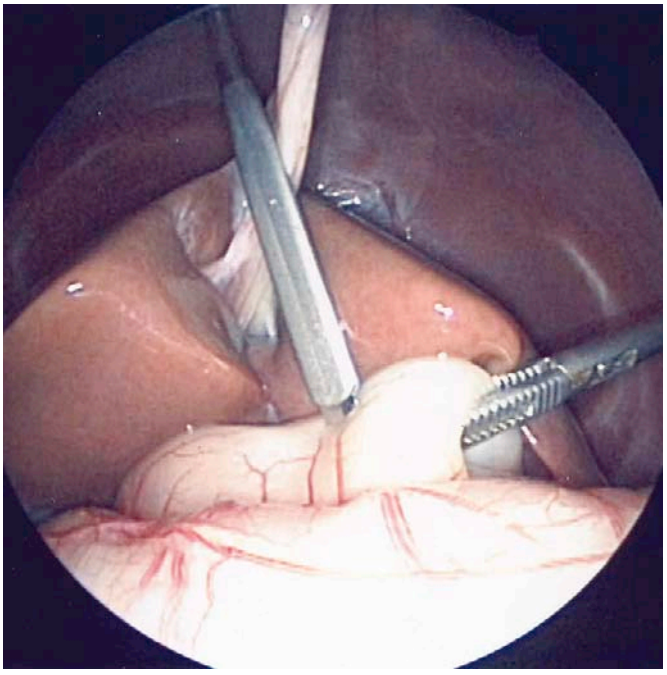


FIGURE 25-3 Pyloric stenosis.

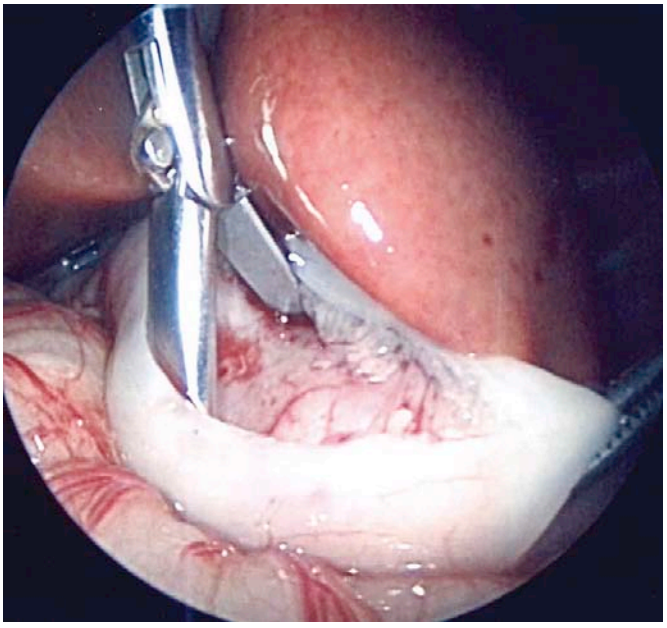


FIGURE 25-4 Laparoscopic pyloromyotomy.

bed and positioned in low lithotomy position using stirrups and protective padding. The operating surgeon stands in the area between the patient's legs. A video monitor is positioned above the patient's head. The abdomen is prepped in the usual manner, and trocar sites are injected with local anesthetic. The perioperative nurse must consider the location of the incision and position the patient in a fashion that facilitates maximum exposure of the surgical site. Appropriate-sized instrumentation and sterile supplies must be available, along with the appropriate imaging equipment. Insufflation flow rate should be set to the lowest acceptable level for achieving pneumoperitoneum and increased slowly.

Operative Procedure

1. Using a #15 blade the surgeon creates a tiny fasciotomy, places a trocar, and insufflates the abdomen with CO_2 gas. After insufflation, the abdomen is inspected for gross abnormality. Additional fasciotomies and trocars are placed to accommodate camera, telescope, and instrumentation.
2. A Colorado clamp is used to elevate the liver away from the stomach, and gastrohepatic connections are cut from the right crus. The crus is carefully dissected away from the esophagus, taking care to preserve the integrity of the peritoneum.
3. Any adhesions on the left side of the stomach are taken down in order to mobilize the fundus and provide access to the left crus.
4. The surgeon uses a blunt dissector to create a retroesophageal tunnel for the esophageal length. The hiatus is reapproximated and tightened using endoscopic suturing devices.
5. A 270-degree (Toupet) wrap is completed. Two sutures incorporate the esophagus, stomach, and crus at the 10 o'clock and 2 o'clock positions on the diaphragmatic hiatus. Four sutures create intraabdominal esophageal length with stitches anchored at the gastroesophageal junction, giving the fundoplasty the appearance of a "hot dog in a bun" (Figure 25-5).
6. The OG tube is removed and a final barrel suture is placed at the posterior portion of the wrap to anchor it to the right crus and keep it from unwrapping.
7. The stomach is inspected again to rule out gross abnormality or injury and desufflated. Incisions are closed in layers using absorbable suture and sealed with cyanoacrylate glue.

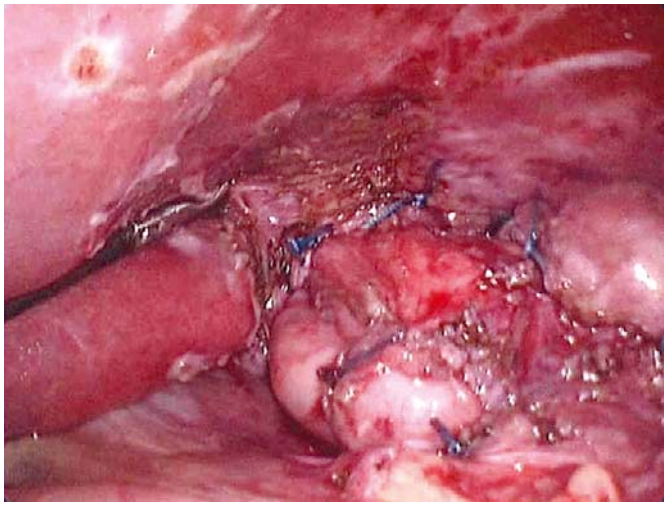


FIGURE 25-5 Laparoscopic Nissen fundoplication, 270-degree (Toupet) wrap.

Endoscopic Correction of Pectus Excavatum—Nuss Procedure

Pectus excavatum (funnel chest) is a visually obvious defect of the sternum, seen as a deep depression on the chest as a result of posterior displacement of the sternum (Figure 25-6). It is usually associated with kyphosis. The defect may be asymmetric, most often deeper on the right side, with sternal angulation. In a majority of cases, surgical treatment is cosmetic; impaired cardiorespiratory function is the underlying reason for surgical intervention in fewer cases. The procedure is most commonly performed in patients between 10 and 16 years of age, when children become embarrassed to undress in front of peers (Research Highlight). Rigid fixation has become a choice for correction of the defect, wherein a metal retaining strut is added to gain chest wall stability and prevent recurrence. This strut must be removed 2 to 4 years later (Nuss et al, 2005). Other treatments may cosmetically correct the situation over the short term but usually result in progressive retraction of the sternum.

Procedural Considerations. Adolescent endoscopic instrumentation is used along with a camera, telescopes, corresponding thoracic instrumentation, and a fixation rod. The patient is positioned supine with the arms positioned along the sides and the elbows flexed 90 degrees and propped so that they are anterior to the chest. The hands are propped so that they are anterior to the elbows. The upper chest is elevated on a soft roll or sheets. A Foley catheter may be placed, and the patient is prepped and draped in sterile fashion.

RESEARCH HIGHLIGHT

Pectus Excavatum Repair

Surgical repair of pectus excavatum is often dismissed as a strictly cosmetic intervention. However, correction of the defect may dramatically improve body image and physiologic and psychosocial functioning. In this study, 264 patients (ages 8 to 21) and 291 parents completed a pectus excavatum evaluation questionnaire during the immediate postoperative period. Responders rated questions on a scale of 1 to 4, with higher scores indicating less desirable outcomes.

A follow-up questionnaire was repeated at the 1-year mark (n = 247 patients and 274 parents). Although there was no correlation between the severity of the defect and preoperative psychosocial functioning, 97% of the patients felt that surgical repair of pectus excavatum improved the appearance of their chest, which resulted in improved perceptions of body image (score improved from 2.30 to 1.40). Parental survey results described an overall reduction of emotional (score improved from 1.81 to 1.24) and physical difficulties (score improved from 2.86 to 1.33) in the child and an increase in self-confidence (score improved from 2.14 to 1.32). These results indicate that both the physical as well as the psychosocial implications of pectus excavatum should be considered when evaluating candidates for surgery.

Modified from Kelly RE et al: Surgical repair of pectus excavatum markedly improves body image and perceived ability for physical activity: multicenter study, *Pediatrics* 22(6):1218-1222, 2008.

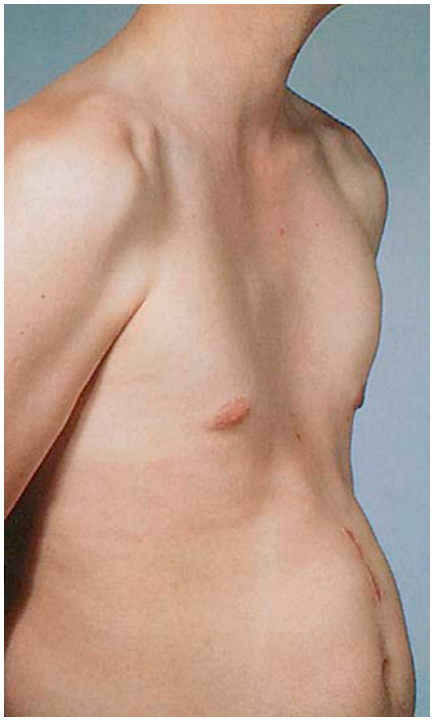


FIGURE 25-6 Pectus excavatum.

Operative Procedure

1. The surgeon measures the patient's chest to determine the size of the stabilization bar to be used, and bends an aluminum template to the desired shape of the chest. A stainless-steel bar is bent to match the aluminum template using plate benders.
2. Two lateral chest incisions are made in-line with the deepest part of the pectus using a #15 blade and subcutaneous pockets are created.
3. A port is placed into the left chest through which gentle insufflation takes place.
4. An incision is made via the subcutaneous pocket in order to pass the Lorenz introducer. The introducer is positioned through one side of the chest, across the mediastinum, and out the other side guided by thoracoscopic visualization techniques.
5. A doubled tracheostomy tape is placed at the end hole of the Lorenz introducer and brought through the anterior mediastinal tunnel. The tracheostomy tape is then tied to the stainless-steel bar, which is brought through the chest using the same tunnel and flipped using a flipping device. Chest configuration is checked for correction, contour, and symmetry.
6. A side bar (strut) is placed on each side of the bar and a stainless-steel wire is wrapped around the main bar both medially and laterally. Two sutures are placed between the chest wall and the end holes of the side and main bars. The suture knots are buried within the holes and the thoracic cavity may be irrigated with antibiotic irrigation.
7. The wounds are closed in layers using absorbable suture and a chest x-ray is obtained postoperatively to rule out pneumothorax.

Video-Assisted Thoracoscopic Surgery for Patent Ductus Arteriosus (PDA)

Although thoracoscopy was first described in 1910 (Rao, 2009), the application of video-assisted thoracoscopic surgery (VATS) to the pediatric population for cardiovascular repairs did not occur until recently. The procedure requires thoracoscopic equipment and supplies, including 0-degree and 30-degree, 4.0-mm and 2.7-mm thoracoscopes, depending on the surgeon's preference and the patient's age and size. The endoscopic instruments, made smaller for the pediatric patient, include an electrocoagulation hook; Castroviejo type of scissors; graspers and right-angle clamps; fan lung retractors of varying sizes, either medium or medium-large; large endoscopic clip appliers; trocars with ports; and suction tip, preferably one that has a porthole to occlude when suction is required. Instrumentation for closure of PDA by thoracotomy is also set up in case the thoracoscopy fails or a complication arises and the chest needs to be opened emergently.

Procedural Considerations. Before the procedure, the television cameras are set up on either side of the OR bed. The patient is placed in a right lateral position.

Operative Procedure

1. Usually four small incisions are made along the line of the posterolateral thoracotomy incision and ports are introduced.
2. The surgeon inserts the thoracoscope. The first assistant holds the lung retractor while the second assistant holds the camera. Some institutions use a mechanical articulating arm.
3. A grasper is used to elevate the pleura overlying the aorta near the insertion of the PDA and pulmonary artery, and careful dissection is begun with electrocoagulation. Suction is required to keep the area of dissection clear to enhance the surgeon's vision.
4. When the ductus has been clearly identified, a right-angle clamp may first be introduced and a tie applied to the duct. The clip applier is then inserted, and clips are applied.
5. Transesophageal or transthoracic echocardiography is usually performed by a cardiologist before closure of the porthole incisions to ensure closure of the ductus. Also, a chest tube will be inserted into the pleural space, the lungs are inflated, and the chest tube is removed; alternately, a chest tube may be left in place before porthole incision closures.

BARIATRIC SURGERY

More than 15% of children and adolescents are obese, a prevalence that has more than tripled in the past 2 decades. Obesity in adolescents is defined as having a body mass index (BMI; kg/m^2) greater than the 95th percentile for age and weight. Overweight or "at risk" for overweight has been defined as a BMI greater than the 85th percentile for age and weight (Inge et al, 2005). Risk factors that have been identified for pediatric obesity are low birth weight, bottle feeding, having a diabetic mother, and parental obesity (Inge et al, 2005).

Bariatric surgery is gaining popularity as a treatment option for obesity in some adolescents. The timing of the surgical procedure is critical. The patient must be physically mature. Skeletal maturation is generally complete by age 13 to 14 years in

BOX 25-3

Characteristics of "Good" Adolescent Patients for Bariatric Surgery

- Patient is motivated and has good insight.
- Patient has realistic expectations.
- Family support and commitment are present.
- Family is compliant with healthcare commitments.
- Family and patient understand long-term lifestyle changes are needed.
- Patient and family agree to long-term follow-up.
- Decisional capacity is present.
- Well-documented and at least temporarily successful weight loss attempts have been made.
- No major psychiatric disorders that may complicate postoperative regimen adherence are present.
- No major conduct/behavioral problems are present.
- Patient has had no substance abuse in preceding years.
- Patient has no plans for pregnancy in upcoming 2 years.

From Inge TH et al: Bariatric surgical procedures in adolescence. In Ashcraft KW et al, editors: *Pediatric surgery,* ed 4, Philadelphia, 2005, Saunders.

girls and age 15 to 16 years in boys. Bariatric surgery can be safely performed once the child has attained more than 95% of adult stature. Candidates undergo psychologic evaluation before surgery to ensure they are cognitively mature enough to participate in decision-making and to comply with postoperative regimens. Box 25-3 details desirable attributes of the adolescent bariatric surgery candidate.

Procedural Considerations

The bariatric procedure most commonly performed in adolescents is the laparoscopic Roux-en-Y gastric bypass. The adjustable gastric band (i.e., lap band) has not been approved by the U.S. Food and Drug Administration for use in adolescents. The perioperative nurse must plan carefully for this surgical intervention with an emphasis on obtaining the appropriate-sized transport vehicle and monitoring devices (e.g., larger blood pressure cuff, possibly longer electrocardiogram [ECG] leads to accommodate placement on a larger patient), an OR bed rated for the patient's weight, and appropriate-length instruments in case conversion to an open procedure is necessary. Obesity places this patient group at risk for deep vein thrombosis (DVT); the nurse should ensure that elastic stockings and sequential compression devices are available.

Operative Procedure

The operative procedure is described in Chapter 10.

GENERAL SURGERY—GASTROINTESTINAL PROCEDURES

Repair of Atresia of the Esophagus

Esophageal atresia is a congenital anomaly that may develop between the third and sixth weeks of fetal life. Several types are recognized, the most common being an upper segment of esophagus ending in a blind pouch and a lower segment of esophagus communicating by a fistula with the trachea (esophageal atresia with TEF). Ideally this defect is recognized in the first hours of life, but more often the diagnosis is made in the first 36 to 48 hours of life. Drooling, the need for frequent suctioning, and coughing or cyanosis during oral feeding are the most common presentations (Spitz, 2005). Prompt surgical intervention allows the child to breathe and eat without the danger of aspirating mucus, saliva, feedings, or stomach contents. Atresia of the esophagus is repaired through a right retropleural thoracotomy, with closure of the TEF and anastomosis of the segments of the esophagus.

Procedural Considerations. A bronchoscopy is done to promote accurate placement of the endotracheal tube before surgical repair. Additionally, a gastrostomy may be done first to decompress the air-distended stomach, thus facilitating chest movement and ventilation and preventing reflux of stomach contents into the trachea. The patient is then positioned for a right thoracotomy (sometimes rather posteriorly), prepped, and draped. The major instrument set and a thoracotomy set are required with the appropriate size of chest tube and infant chest drainage system.

Operative Procedure

1. The surgeon enters the chest through the fourth intercostal space. Removal of the rib is not necessary (Figure 25-7, *A*).
2. The pleura is gently dissected off the chest wall (Figure 25-7, *B*).
3. As the dissection proceeds posteriorly, the azygos vein is identified, which is reflected inferiorly after its highest intercostal branches are divided to expose the fistula beneath (Figure 25-7, *C*).
4. The surgeon passes an umbilical tape or vessel loop under the fistula to apply traction gently (Figure 25-7, *D*). Dissection of the mediastinum begins with the TEF and distal end of the esophagus. The vagus nerve is an important landmark for the distal end of the esophagus.
5. The fistula is clamped and transected, leaving a thin cuff of esophageal tissue on the tracheal side to allow closure of the trachea without narrowing it and compromising the lumen of the airway (Figure 25-7, *E*).
6. To close the fistula, three or four interrupted atraumatic sutures of 5-0 nonabsorbable suture are used.
7. The upper esophageal pouch is dissected; passage of a nasogastric tube by the anesthesia provider aids in its identification. The proximal pouch is identified and dissected as needed to allow it to reach the distal esophageal segment with minimal tension for anastomosis. At this point the surgeon decides whether to attempt primary anastomosis. If primary anastomosis is impossible, the distal esophagus is closed and tacked high on the prevertebral fascia. Infrequently the gap between the proximal and distal portions of esophagus is so long that esophageal replacement is required. In these cases the upper pouch is brought out to the neck in the form of a cervical esophagostomy.
8. Primary anastomosis is performed with 5-0 or 6-0 nonabsorbable suture, taking full-thickness bites along anterior and posterior borders (Figure 25-8). Some surgeons prefer the Haight, or two-layer, anastomosis (Figure 25-9). The inner layer is composed of the upper pouch mucosa sutured to the full thickness of the distal esophagus. The muscular sleeve of the upper esophagus is then pulled down over the inner anastomosis and sutured to the muscular layer of the inferior esophagus. The incision is irrigated with saline.

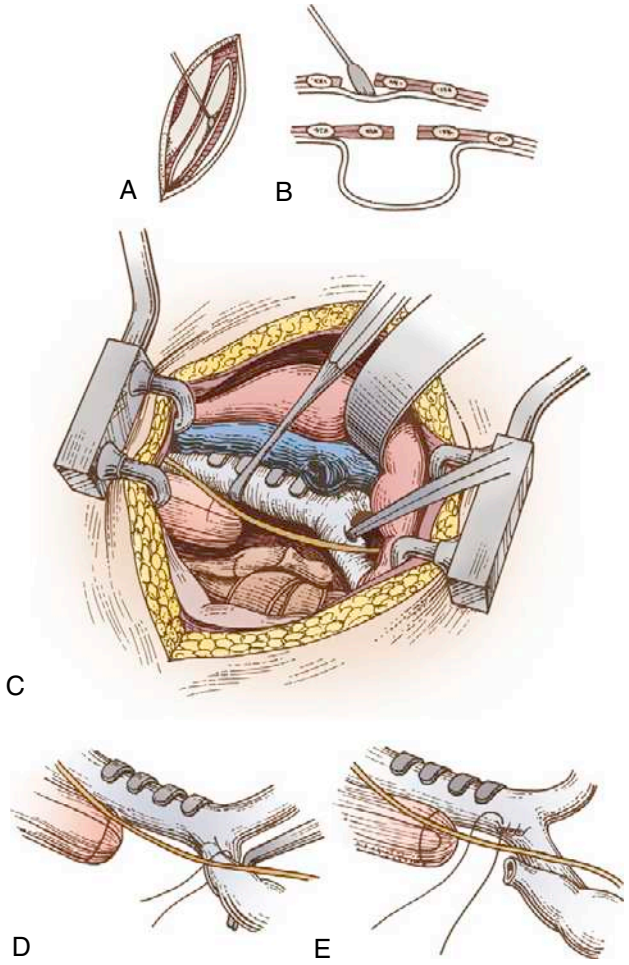


FIGURE 25-7 Repair of atresia of the esophagus. **A**, Incision at fourth intercostal space. **B**, Dissection of pleura off chest wall. **C**, Identification and division of azygos vein to expose fistula beneath. **D**, Traction applied to fistula. **E**, Transection of fistula leaving 3-mm cuff on trachea.

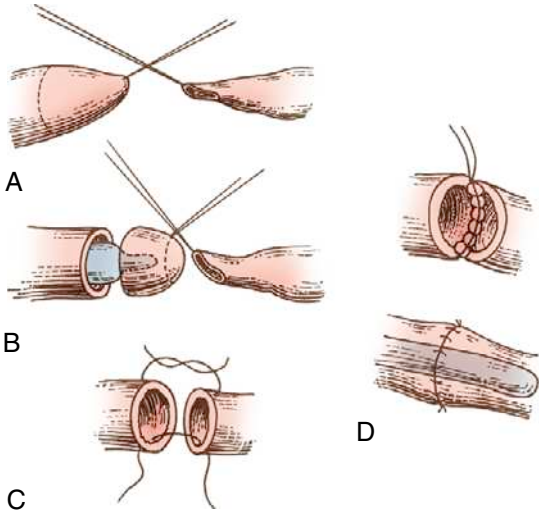


FIGURE 25-8 Primary repair of atresia of the esophagus: single-layer repair. **A**, Traction applied to proximal and distal portions of esophagus. **B**, Blind proximal pouch transected. **C**, Full-thickness bites of anterior and posterior borders. **D**, Repair completed with Replogle tube in place to allow adequate lumen of esophagus.

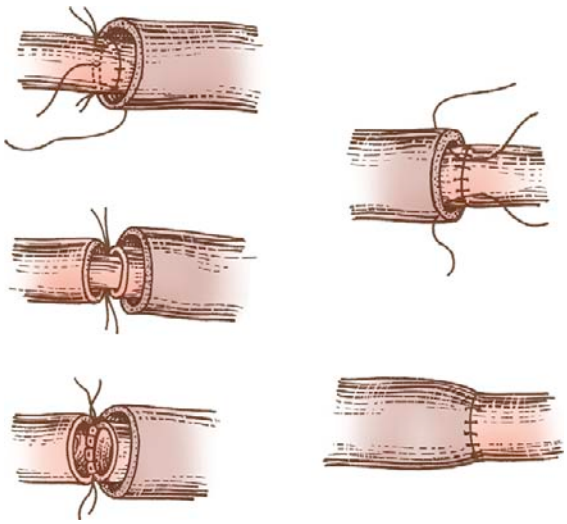


FIGURE 25-9 Haight anastomosis. Mucosal layer of proximal pouch sutured to full thickness of distal esophagus. Muscular sleeve of upper pouch pulled down over inner anastomosis and sutured to muscle of distal esophagus.

9. Some surgeons place a 14F or 16F extrapleural chest tube near the anastomosis through a posterior stab wound. It is secured with sutures to prevent it from putting direct pressure on the anastomosis.
10. Muscle layers and fascia are closed with nonabsorbable sutures.
11. Skin is closed with a continuous absorbable suture. The incision is approximated with cyanoacrylate glue or Mastisol and wound closure strips.
12. The extrapleural chest tube is water-sealed after ensuring that the number of centimeters of water and the suction-control chamber are appropriate for the size of the infant. A chest x-ray examination is performed.

When the child reaches 1 year of age, esophageal replacement is attempted through colon interposition or construction of a reverse gastric tube (Figure 25-10).

Gastrostomy

Gastrostomy is establishment of a temporary or permanent channel from the gastric lumen to the skin to permit gastric emptying, liquid feeding, or retrograde dilation of an esophageal stricture. The procedure may be completed as a separate procedure or be performed with other surgical procedures to facilitate care of the infant or child after surgery. A growing number of surgeons are inserting low-profile (e.g., button, Gastroport) devices upon initial creation of the gastrostomy, as these are preferred for children receiving long-term feedings through the device. Low-profile devices, which protrude slightly from the abdomen, are more cosmetically acceptable and allow more mobility for the child. A gastrostomy tube can be placed in the OR as an open or laparoscopic procedure, or it can be performed as a percutaneous procedure under fluoroscopy; both require the patient to receive a general anesthetic. The open surgical procedure is described in the following section.

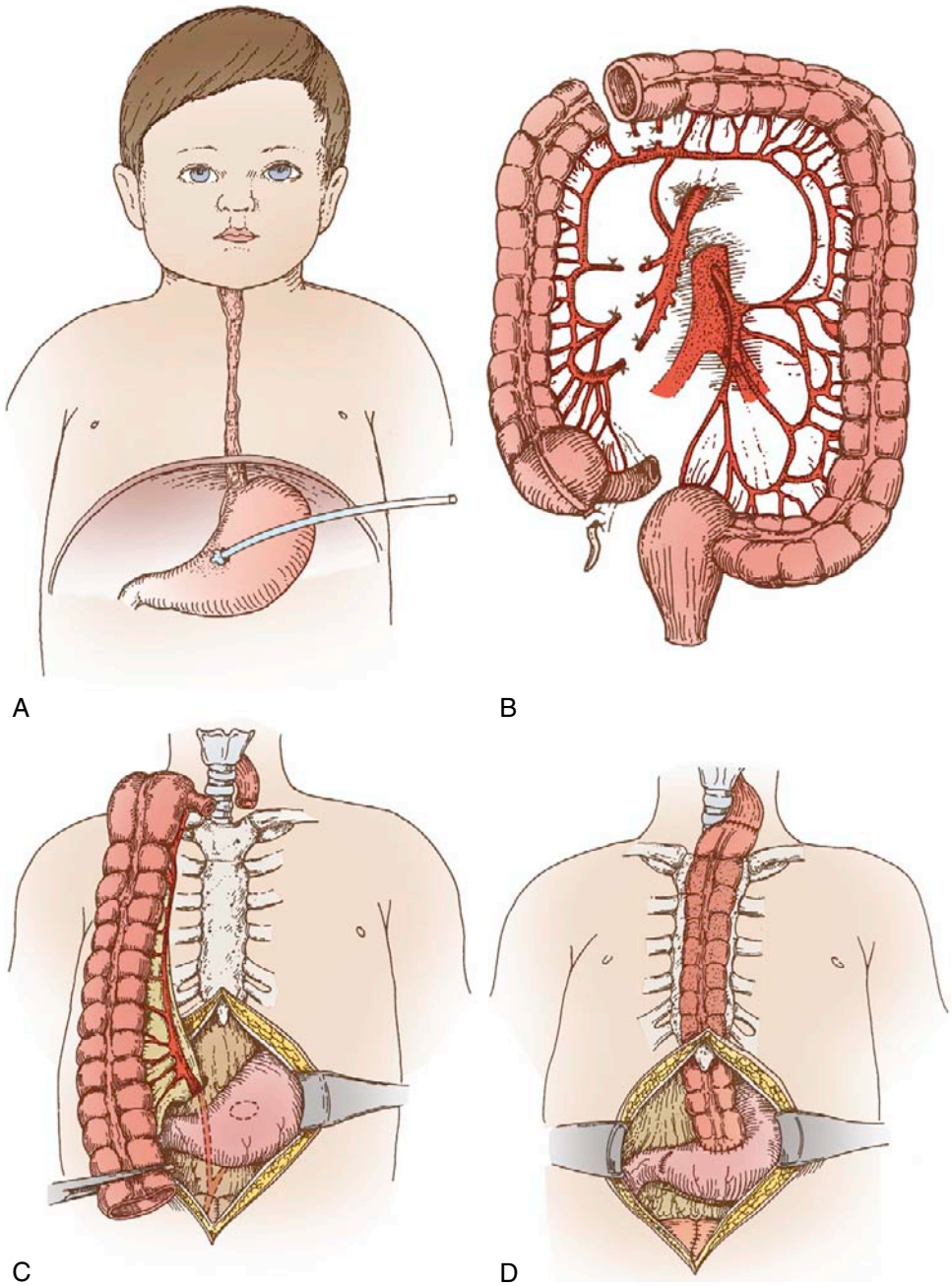


FIGURE 25-10 Esophageal replacement. **A**, Gastrostomy. **B**, Isolation of right colon and ileum. **C**, Colon pedicle prepared for anastomosis. **D**, Anastomosis.

Procedural Considerations. A minor instrument set is required, plus a gastrostomy feeding catheter (generally a 14F or 16F for infants, or an 18F, 20F, or 22F for older children) and a #11 knife blade on a knife handle. A variety of latex-free gastrostomy catheters are available.

Operative Procedure

1. The surgeon makes a short incision over the outer border of the left rectus muscle (Figure 25-11, *A*).
2. The subcutaneous tissues and rectus fascia are exposed with two small retractors (Figure 25-11, *B*).
3. The anterior rectus fascia is opened, and the rectus muscle is split for exposure of the posterior rectus sheath (Figure 25-11, *C*).
4. The peritoneum is opened for exposure of the liver edge and the greater curvature of the stomach (Figure 25-11, *D*).
5. The stomach is pulled out through the wound with Babcock forceps. A circular, nonabsorbable purse-string suture is placed: in the center of this a very small incision is made with the #11 blade through the gastric wall (Figure 25-11, *E*).

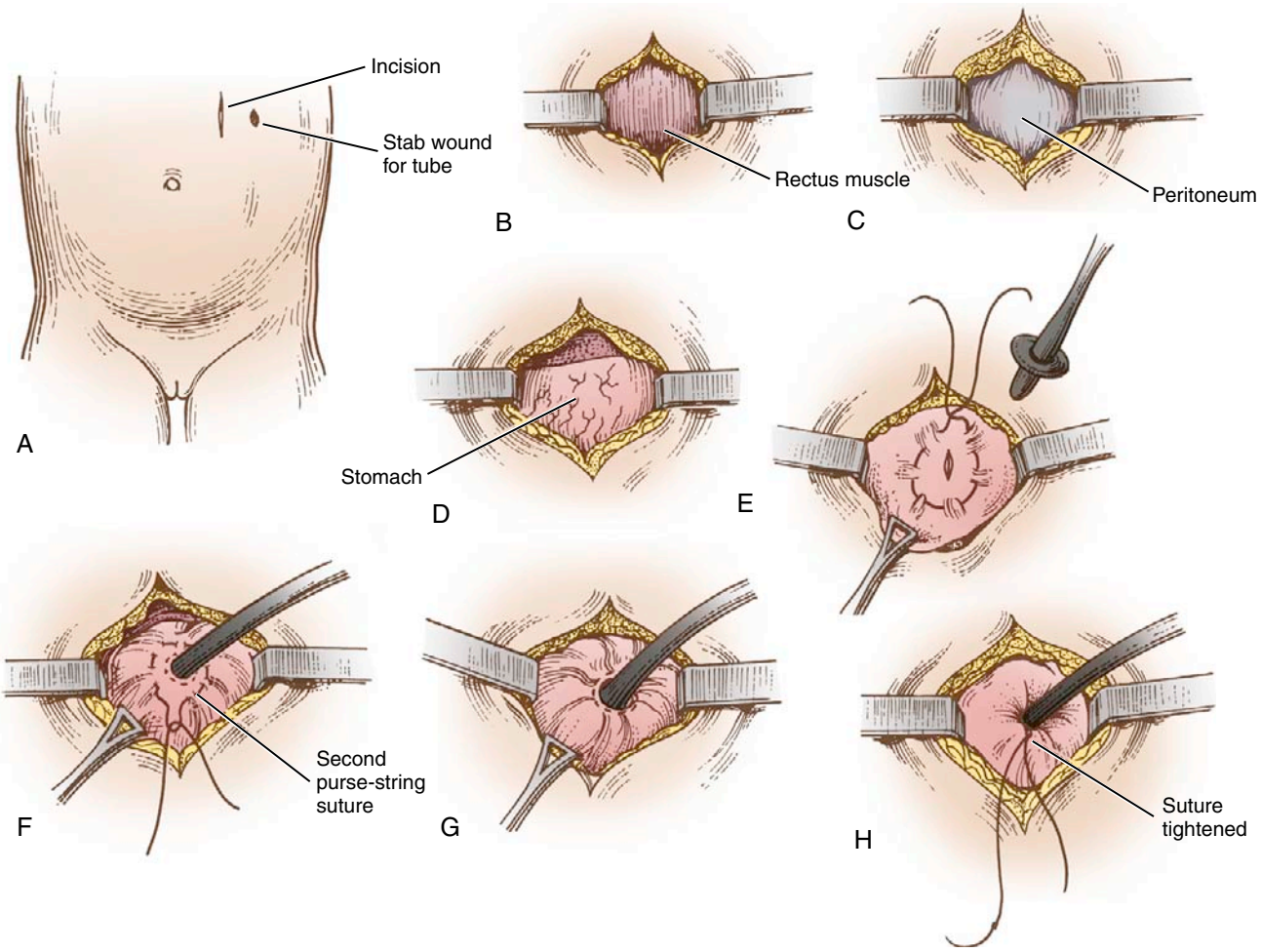


FIGURE 25-11 Gastrostomy. **A**, Incision. **B**, Rectus muscle exposed. **C**, Posterior rectus sheath exposed. **D**, Peritoneum opened. **E**, Purse-string suture placed. **F**, Second purse-string suture placed. **G**, Mushroom catheter inserted. **H**, Suture tightened.

6. A second purse-string suture is placed outside the first one, and the same needle is then taken through the peritoneum and the posterior surface of the rectus fascia to place the stomach against the peritoneum and thus prevent leaks (Figure 25-11, *F* and *G*).
7. The feeding catheter is inserted into the stomach through the small incision, and the purse-string suture is tied (Figure 25-11, *H*). Some surgeons may choose to use a dilator kit to assist with proper insertion of the tube. When inserting a gastrostomy tube with a balloon, sterile water and water-based lubricant should be used to avoid breakdown of the tube itself.
8. The catheter is then exteriorized through the skin by way of a small stab wound left, lateral to the skin incision (see Figure 25-11, *A*).
9. The stomach wall adjacent to the gastrostomy site is tacked to the undersurface of the peritoneum with interrupted nonabsorbable sutures.
10. Routine abdominal closure is performed. The gastrostomy tube is left open to straight drainage at the end of the surgical procedure.

Reduction of Intussusception

Intussusception is the telescopic invagination of a portion of intestine into an adjacent part, with mechanical and vascular impairment (Figure 25-12). It is relieved by reduction of invaginated bowel by the hydrostatic pressure of a barium enema or by laparotomy and manual manipulation. The highest incidence of intussusception occurs in infants between the ages of 5 and 9 months. More than half the cases occur within the first year of life, and only 10% to 25% of cases occur after the age of 2 years (Fallat, 2005). The most common site for intussusception is the ileocecal junction. Intussusception in most children is idiopathic; in others, causes may include Meckel's diverticulum, polyps, or hematoma of the bowel. Early diagnosis and reduction are essential to bowel viability.

Procedural Considerations. The child is prepped for surgery as described previously. Reduction by barium enema is attempted only with the collaboration of the radiologist, surgeon, and pediatrician, with the OR team on standby. If reduction is unsuccessful, a surgical reduction by laparotomy

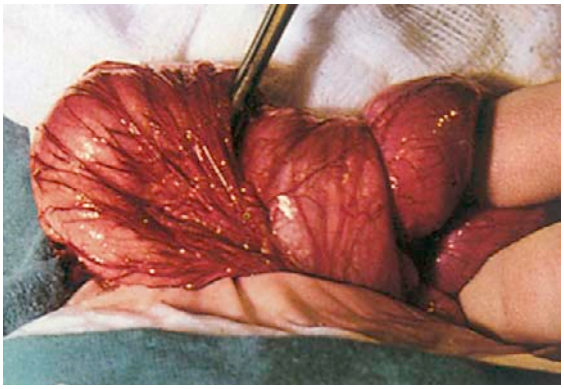


FIGURE 25-12 Operative view of intussusception.

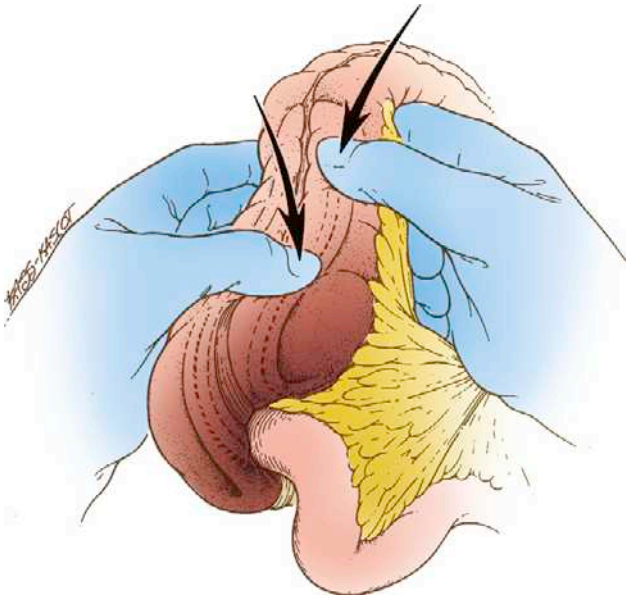


FIGURE 25-13 Manual reduction of intussusception.

or laparoscopy must be performed. The open procedure is described in the following Operative Procedure, and requires a major instrument set and pediatric bowel clamps.

Operative Procedure

1. The surgeon makes a right lower quadrant transverse or right paramedian incision and enters the peritoneum.
2. The cecum and ileum are identified; the intussusception is located and elevated with fingers.
3. If there is no evidence of bowel compromise, the bowel immediately distal to the intussusception is occluded with one hand and stripped proximally with the other in an attempt to achieve manual reduction (Figure 25-13). If the serosa splits during attempted reduction or if the mass cannot be reduced, bowel resection is done.
4. The abdomen is closed in layers, and the wound is dressed.

Bowel Resection and Colostomy for Necrotizing Enterocolitis (NEC)

Necrotizing enterocolitis (NEC) is a condition that manifests with death of intestinal lining and sloughing of corresponding tissues. Its exact cause is unknown, but it is suspected that NEC may result from two mechanisms: decreased blood flow to the bowel, which prevents the bowel from secreting the protective mucus that protects the GI tract; or bacteria within the intestine (Medline Plus Medical Encyclopedia, 2007). NEC primarily affects premature newborns. When surgical intervention is needed, the patient undergoes a bowel resection and ostomy procedure. The type of ostomy created depends on the location of the necrotic bowel. The procedures for bowel resection and colostomy are described in the following sections.

Procedural Considerations. The major instrument set and pediatric bowel clamps are required. The infant is positioned supine, and routine prepping and draping of the abdomen are done.

Bowel Resection

Operative Procedure

1. An abdominal incision is made.
2. The intestines are explored to determine the location of the obstruction. The entire bowel must be examined to rule out multiple areas of involvement in infants with atresia or stenosis. If aganglionosis of the colon is suspected, sequential biopsy specimens are sent fresh immediately to the pathology laboratory to determine the segment of large bowel to be resected.
3. Resection is performed as indicated.

Colostomy

Operative Procedure

1. A transverse incision usually is preferred, and the abdomen is entered in the right upper quadrant for a transverse colostomy or the left lower quadrant for a sigmoid colostomy.
2. The loop of colon is freed of peritoneal attachments until it can be brought easily through the abdominal wall without tension.
3. The edges of the mesentery are then sutured to the parietal peritoneum, and the serosa of the colonic loop is sutured with fine absorbable suture materials to the peritoneum and fascia as well as to the skin.
4. The colostomy may be sutured immediately. Some surgeons prefer to close the skin under a colostomy loop; others prefer to suture mucosa directly to skin edges. This decision may depend on the location of the colostomy. An important point is that each layer must be securely attached to the serosa of the colon to prevent evisceration and prolapse. The posterior wall of a loop colostomy may be divided by electrosurgery several days after surgery.

Resection and Pull-Through for Hirschsprung's Disease (Reconstruction)

Hirschsprung's disease is characterized by the absence of ganglion cells in a distal portion of the bowel. The distal colon is more frequently involved, but the disease may encompass the entire colon, with a less favorable prognosis. The absence of ganglion cells results in a lack of peristalsis. The normal proximal colon becomes dilated with stool, since intestinal contents do not pass through the involved segment normally. The child presents with an abnormally distended abdomen. Barium enema reveals proximal distention of the colon and then a transition zone where the bowel appears funnel-shaped, followed by the distal

aganglionic segment, which is narrowed. The child is taken to the OR for a leveling colostomy. Multiple frozen-section biopsy specimens from the muscularis of the proximal portion of the colon are taken to determine the presence of ganglion cells. The colostomy is performed at the most distal portion of the colon that contains ganglion cells. Some surgeons prefer a routine right transverse colostomy at this time and delay frozen-section biopsy specimens until the time of the definitive procedure. Resection and pull-through for Hirschsprung's disease, the definitive surgical procedure, consists of the removal of the aganglionic portion of the bowel and anastomosis of the normal colon to the anus. The child is returned to the OR for the definitive repair at 1 year of age if clinical and nutritional status permit.

Several surgical techniques have been devised. The procedure may be done laparoscopically or by an open approach. The Soave procedure of endorectal pull-through employs internal bypass of the involved segment. The internal sphincter muscle of the anus is kept intact for continence.

Procedural Considerations. The child is prepped and draped from the nipples down to and including the buttocks, genitalia, perineal area, and upper thighs to permit positioning for the perineal stage without redraping. (Before prepping, the rectum may be irrigated with warm saline solution.) An indwelling catheter is inserted to keep the bladder empty during the operation. The major instrument set, a minor instrument set, and pediatric intestinal clamps are needed.

Operative Procedure

1. A left paramedian incision that includes the sigmoid colonic stoma, if present, is made.
2. The surgeon frees the stoma from the abdominal wall, and mobilizes the left portion of the colon. (If there is no sigmoid colonic stoma, the extent of aganglionic intestine is established by biopsy and frozen section, and all involved colon is excised. If a stoma is present and the area has already been established as normal, the colon above it constitutes the proximal end of the resection.)
3. The mesocolon and the vessels of the intestine to be resected are divided close to the intestine, with care taken to preserve the blood supply to the rectum (Figure 25-14, *A*).
4. The mucosal tube is freed from the outer muscular layers by sharp dissection with Metzenbaum scissors and blunt dissection (Figure 25-14, *B*).
5. A muscular sleeve is transected, and 4-0 nonabsorbable traction sutures are placed on the distal edge (Figure 25-14, *C*).

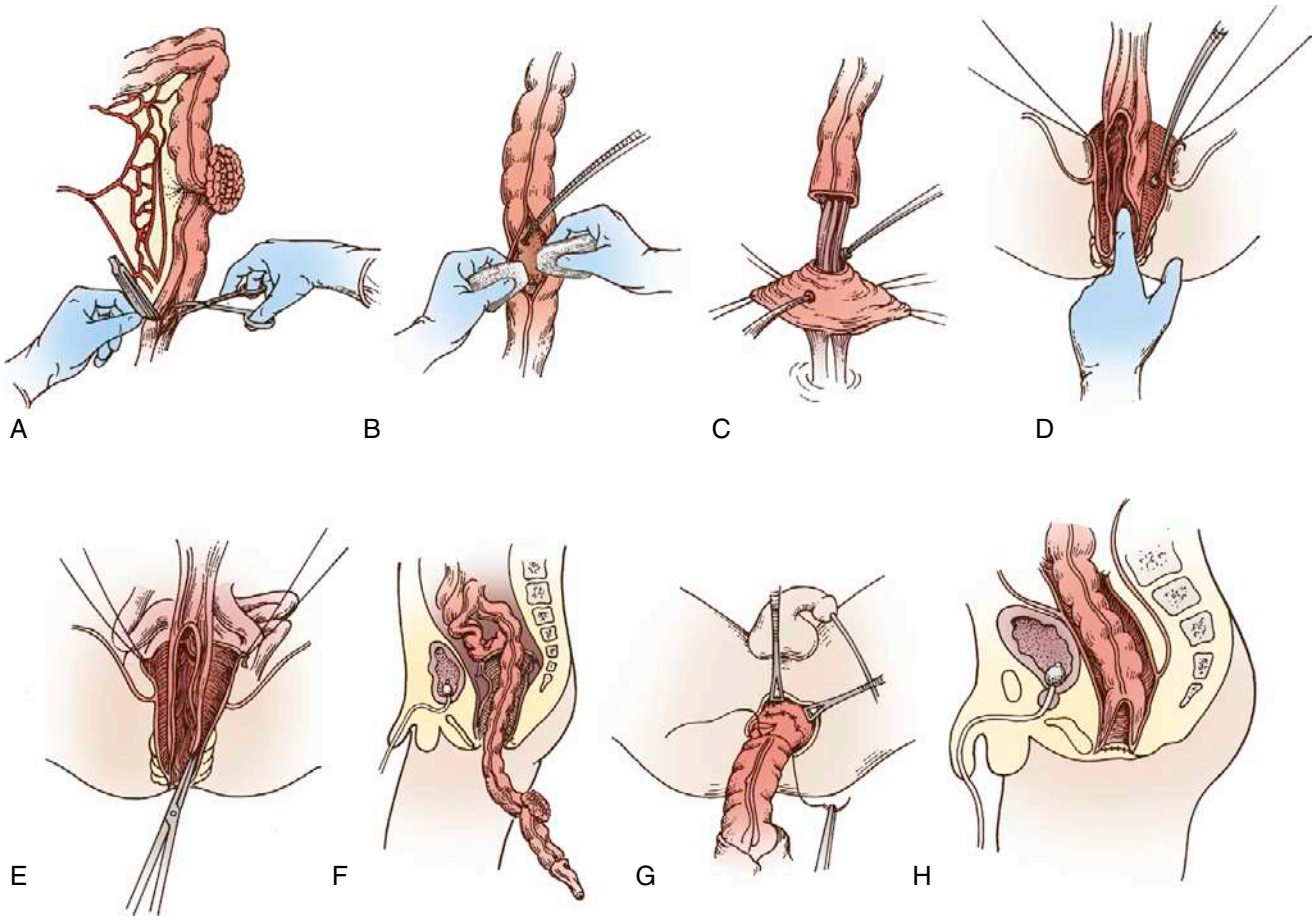


FIGURE 25-14 Pull-through for Hirschsprung's disease. **A**, Dissection of mucosal tube begun through longitudinal incision. **B**, Blunt dissection with sponges used to dissect entire circumference of tube. **C**, Muscular sleeve transected. **D**, Depth of dissection determined by insertion of finger into anus. **E**, Circumferential incision made. **F**, Mucosal tube and proximal portion of colon and stoma pulled through rectal muscular cuff. **G**, Anastomosis performed among all layers of colon and anal mucosa. **H**, Anastomosis completed.

The mucosa is stripped down to the anus. The depth of the dissection may be checked by inserting a finger into the anus (Figure 25-14, *D*).

6. When the mucosa is adequately freed, the perineal phase is started and the perineal instrument table is used.
7. The anus is dilated and retracted with Allis forceps. A circumferential incision is made, and the mucosal stripping is completed (Figure 25-14, *E*).
8. The proximal portion of the intestine is pulled through the rectal muscular sleeve and out the anus (Figure 25-14, *F*). If the portion of colon to be resected is large, it is excised abdominally before the proximal portion of the intestine is pulled through the anus.
9. Absorbable sutures are used to secure the seromuscular layers of the intussuscepted colon to the rectal muscular cuff. The colon is divided into axial or longitudinal quadrants, and an anastomosis is performed with 3-0 absorbable sutures (Figure 25-14, *G*).
10. Gowns and gloves are changed, and abdominal instruments are used. The abdominal phase of the operation is completed by approximating the proximal edge of the muscular cuff to the seromuscular layer of the colon with 4-0 nonabsorbable sutures (Figure 25-14, *H*). The abdomen is closed in the routine manner, without the use of drains.

Repair of Imperforate Anus

Congenital imperforate anus (Figure 25-15) presents in a variety of forms, classified as low, intermediate, and high lesions. Baby girls commonly have low lesions, and baby boys primarily exhibit high lesions. A covered anus and anovulvar fistula is an example of a low lesion. A high lesion consists of a blind rectal pouch, a "flat bottom," and a posterior urethral fistula or a fistula to the bladder. This type is the most prevalent and the most difficult to repair. An imperforate anus is repaired by establishing colorectoanal continuity through the external anal sphincter and closure of fistulas, if present.

Repair of Low Imperforate Anus in a Girl—Anal Transposition

Procedural Considerations. The infant is placed in the lithotomy position. A Foley catheter is inserted, and the perineum is prepped and draped. The major instrument set is required, with the addition of both a nerve and a muscle stimulator. The anesthesia team must avoid the use of neuromuscular blocking agents for the nerve/muscle stimulator to work during the surgical procedure.

FIGURE 25-15 Imperforate anus.

Operative Procecure

1. An electrical stimulator is applied to elicit muscle contractions and serve as a guide to the midline of the anus. The goal is to leave equal innervated tissue on both sides of the anus, so that the child can be continent of stool.
2. Stay sutures are placed in the fistula, and it is excised using an oval incision (Figure 25-16, *A*).
3. The surgeon dissects the bowel free from surrounding structures, taking care not to damage the vagina (Figure 25-16, *B*).
4. When the dissection is complete, a vertical midline incision is performed at the opening of the true anus and the fibers of the external sphincter are identified (Figure 25-16, *C*).
5. The mobilized rectum is pulled down through the subcutaneous tissue to its new location.

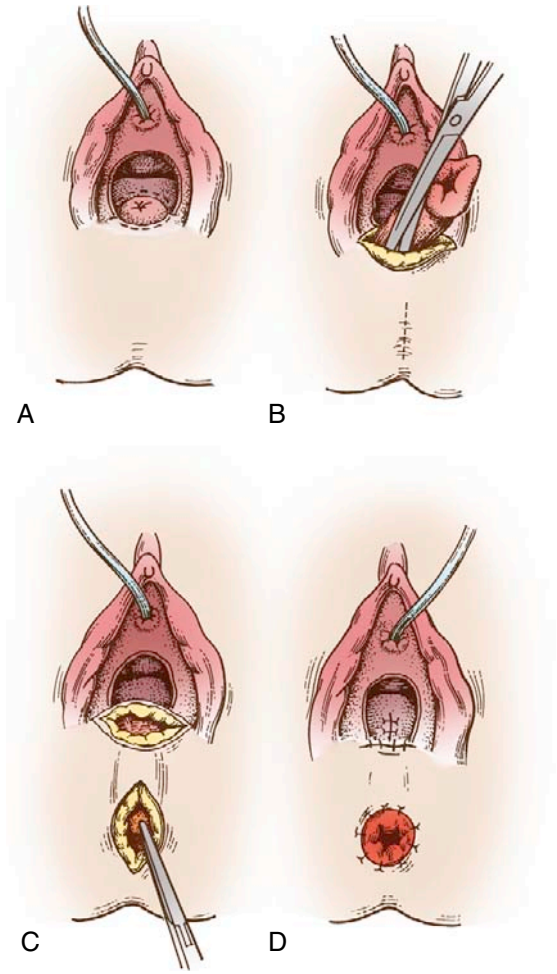


FIGURE 25-16 Anal transposition. **A**, Fistula excised by means of oval incision. **B**, Dissection of bowel from surrounding structures. **C**, Vertical midline incision at site of true anus; identification of external sphincter fibers; mobilized rectum pulled down through subcutaneous tissue to new location. **D**, External sphincter sutured to rectal mucosa; new anus constructed with interrupted sutures through all layers.

6. The end of the fistula is amputated. Using 4-0 nonabsorbable interrupted sutures, the surgeon sutures the external sphincter to the rectal serosa.
7. Using 4-0 absorbable suture, the surgeon constructs a new anus with interrupted sutures through all layers (Figure 25-16, *D*).
8. A drain may or may not be placed in the anterior incision before it is closed in layers with interrupted 4-0 absorbable sutures.
9. A Hegar dilator is used to calibrate the size of the new anus after closure.

Repair of High Imperforate Anus—Posterior Sagittal Anorectoplasty

When a high imperforate anal anomaly presents, surgical intervention is indicated within 24 to 48 hours of birth. A transverse or sigmoid colostomy is performed to irrigate the hiatal lumen and to remove meconium plugs while allowing proximal colon function. After the colostomy, further diagnostic studies, such as cystograms and vaginograms, are done. The posterior sagittal anorectoplasty (PSARP) is the definitive surgical procedure and is performed when the condition and size of the child permit—usually around 1 year of age.

The PSARP is a highly technical procedure that uses electrostimulation throughout and may require position changes.

Procedural Considerations. The child is placed in jackknife position with the hips flexed. Adequate padding must be placed under the hips to avoid compression injury to the femoral nerves. The major instrument set, nerve stimulator, and intestinal instruments are required.

Operative Procedure (Figure 25-17)

1. The surgeon uses the electrostimulator to locate the true anus, and makes a midsagittal incision through the skin from the midsacrum to the anterior border of the anal site.
2. Dissection continues through subcutaneous tissue until the external sphincter muscle layers are identified.
3. With electrostimulation, the surgeon dissects the fibers midsagittally, exactly in the midline.
4. A midsagittal split of the coccyx is performed, and the striated muscle complex found beneath the coccyx is incised sagittally, along with the visceral endopelvic fascia. Electrostimulation is used to aid in identifying muscle complexes.
5. Next, the surgeon identifies the rectal pouch and urethra, and incises the bowel vertically to expose the fistulas.
6. The fistula is closed in layers—first the mucosa with interrupted absorbable sutures and then the muscle layer with 5-0 nonabsorbable sutures.
7. The rectum is then mobilized and tapered to allow its placement within the muscle complexes. Tapering consists of excising a wedge of bowel from either the ventral or the dorsal surface. The edges are approximated, and the mucosal layer is closed with 5-0 absorbable interrupted sutures. The muscularis layer is closed with interrupted 5-0 nonabsorbable sutures.
8. Again using electrostimulation, the tapered rectum is placed deep within the muscle complex. Then 5-0 nonabsorbable sutures are used to reconstruct the muscles. The seromuscular layer of the bowel is incorporated into these sutures to keep it securely positioned within the muscle complex.
9. The external sphincter muscles and coccyx are reapproximated.
10. Excess bowel is trimmed before it is secured to the skin edges of the anus.
11. The surgeon closes the skin with running absorbable subcuticular sutures.

In cases of very high rectal pouches and fistulas, an abdominal approach may be required. After the midsagittal incisions and dissections are completed, a rubber drain is placed through the pelvis with one end in the peritoneal cavity and the other through the center of the anus to the skin, where it is temporarily sutured. The child is then turned supine, and an abdominal incision is made. The rectal pouch is mobilized, and the fistula is closed. The bowel is tapered as described previously, and the terminal portion is attached to the rubber tube, which then is used to pull the rectum through the anal orifice. The bowel is sutured to the muscle complex, and reapproximation of the coccyx and external sphincter muscle is done as described earlier.

GENERAL SURGERY—HERNIAS

Umbilical Hernia Repair

Umbilical hernias are frequently seen in pediatric populations and are 10 times more common in African American children than in Caucasians (Garcia, 2005). These hernias are also common in premature infants and are corrected by repair of the defect where the intestine protrudes at the umbilicus. An umbilical hernia is always covered by skin. Small umbilical hernias may be left untreated. They usually close within a few months to 1 year. If surgical repair is required in a large fascial defect, it may be delayed until the child is at least 2 years of age; some surgeons delay repair until 5 years of age.

Procedural Considerations. Surgical correction of umbilical hernia may be an ambulatory surgical procedure. A general anesthetic is used. A minor instrument set is required. Several variations in technique have been used; an infraumbilical approach is most common, and its description follows.

Operative Procedure

1. An incision is made below the umbilicus through the skin and subcutaneous tissue.
2. Flaps of skin and subcutaneous tissue are mobilized and held back with small retractors to expose the rectus fascia and hernial protrusion.
3. The hernia sac, which is between the rectus muscle sheaths in the midline, is completely freed from all surrounding structures.
4. The hernia sac may be invaginated, dissected free and ligated, or excised.
5. The peritoneum is closed with interrupted suture, and each suture is tagged, and then closed all at once.
6. The two edges of the rectus fascia are approximated using interrupted 3-0 nonabsorbable sutures.
7. Subcuticular closure of the skin with a continuous fine absorbable suture is performed, and a pressure dressing is applied.

Inguinal Hernia Repair with Laparoscopic Exploration of Contralateral Side

An inguinal hernia is a protrusion into the inguinal canal of a sac that contains the intestine. The testis develops high on the posterior wall of the abdomen. It gradually descends into the scrotum. Before the testis enters the inguinal canal, the processus vaginalis projects downward but retains a communication

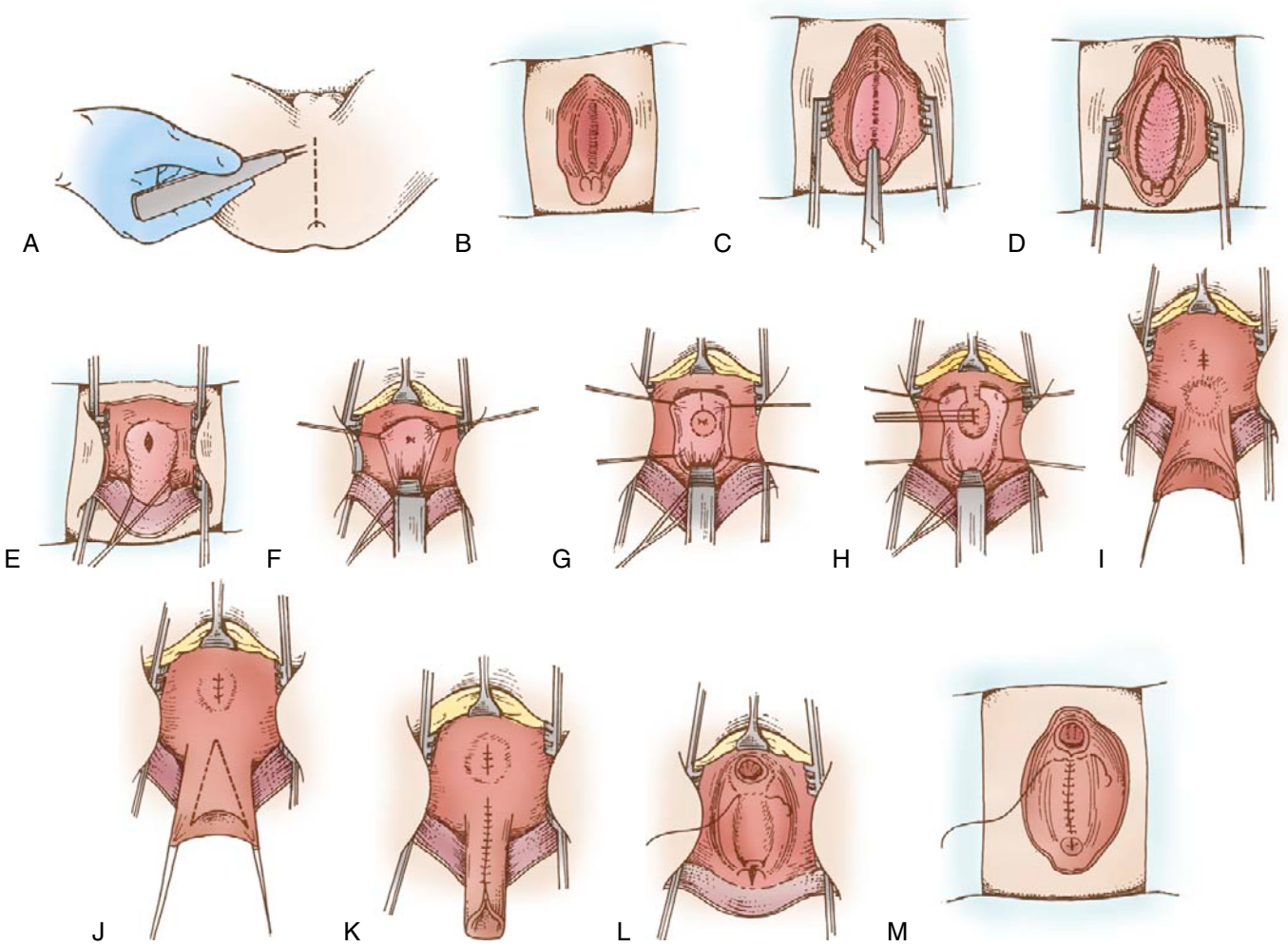


FIGURE 25-17 Posterior sagittal anorectoplasty. **A**, Line of incision and electrical stimulation to determine appropriate anal site. **B**, Midsagittal incision through coccyx and external sphincter fibers of anus, showing striated muscle complex deep to anal site; subcutaneous external sphincter extending about halfway to coccyx; superficial external sphincter inserting on coccyx; levator deeper in midline. **C**, Right-angled forceps beneath levator ani. **D**, All layers of striated muscle partially retracted laterally to expose visceral endopelvic fascia. **E**, Sagittal incision in terminal bowel after proximal dissection around rectum and placement of tape around rectum proximally. **F**, Retracted rectotomy showing fistula site. **G**, Semicircumferential incision through mucosa-submucosa for placement of first sutures to close fistula. **H**, Completed closure of fistula orifice. **I**, Stippled area where muscular bowel wall is left in place and clear area above where peritoneum may be encountered. **J**, Extent of anterior wedge resection for tapered repair of rectum *(dotted line)*. **K**, Approximation of tapered edges of rectum. **L**, First and deepest suture for approximation of levators to establish beginning of canal. **M**, After reapproximation of levator ani to coccyx, interrupted sutures are placed in edges of superficial external sphincter muscle.

with the peritoneal cavity. The upper part of the processus does not project downward; the remaining sac constitutes an indirect inguinal hernia. In a female child, a similar hernial sac is contiguous with the round ligament.

Procedural Considerations. A minor instrument set is used. A laparoscope may be used to visualize the contralateral side, as it is not uncommon for inguinal hernias to occur bilaterally. In these instances, a camera, insufflation tubing, 20-gauge intravenous catheter, 2.7-mm telescope, and light cord must be presented to the sterile field. The child is positioned supine, and routine prepping is done.

Operative Procedure

1. The surgeon makes an incision over the inguinal area in the direction of the skin crease.
2. The subcutaneous tissue is opened, and hemostats are placed on bleeding vessels, which are then ligated or electrocoagulated.
3. Right-angle retractors are placed inferiorly and medially.
4. The surgeon identifies the external ring, and uses small Metzenbaum scissors to free and clean the external oblique fascia.
5. Using a #15 blade, the surgeon opens the external oblique fascia and frees the upper flap. The lower flap is freed to expose the inguinal ligament.

6. Cord structures are opened at the upper end of the cord. Two forceps are used to grasp tissues at the same level and to separate them.
7. The hernia sac is grasped with a hemostat, and structures of the cord are peeled downward and away from the sac with forceps until the sac is freed. Care is taken to protect the spermatic cord and major vessels as the sac is freed.
8. After the sac is opened, the surgeon's index finger is inserted and the sac is pulled upward. The upward traction is maintained with two or three hemostats.
9. If laparoscopic exploration of the contralateral side is taking place, the 20-gauge intravenous catheter is inserted over the opposite inguinal area. The insufflation tube is connected, and CO_2 instilled. The contralateral side is explored using a 2.7-mm telescope.
10. The sac is ligated with 3-0 nonabsorbable suture, and excess sac is removed. Repair of the inguinal canal may be done with nonabsorbable sutures.
11. The subcutaneous tissue is closed with interrupted fine sutures; closure of the skin is with fine nonabsorbable subcuticular sutures. Cyanoacrylate glue or wound closure strips are applied.
12. If a bilateral hernia is diagnosed, steps 1-10 are repeated on the contralateral side.

Omphalocele and Gastroschisis Repair

An omphalocele is the protrusion of abdominal viscera outside the abdomen through a defect in the umbilical ring into a sac of amniotic membrane and peritoneum at the base of the umbilical cord. There is no skin covering (Figure 25-18). Gastroschisis is the protrusion of the viscera through a defect in the abdominal wall to the right of the umbilical cord. No amniotic membrane or peritoneum covers the defect.

Omphalocele occurs during the eleventh week of fetal life when the viscera fail to withdraw normally from the exocoelomic position to occupy the peritoneal cavity. The resulting abdominal wall defect can vary in size from 2 to 15 cm. The sac may contain only a few loops of bowel, or nearly all the intestines and the liver and spleen. Associated anomalies can include disorders of the cardiac, musculoskeletal, genitourinary, and nervous systems, along with malrotation and abnormal fixation of the bowel. Gastroschisis, on the other hand, is generally not associated with major congenital defects other than intestinal atresia (Davis, 2007) (Figure 25-19).

Because the infant is at risk for hypothermia, hypoglycemia, shock, sepsis, and vascular injury to the bowel, immediate management after birth is necessary (Klein, 2005). Treatment consists of inserting a nasogastric tube to prevent distention and aspiration, and beginning IV access with fluid resuscitation and antibiotic therapy. Surgical intervention is necessary to prevent rupture of the sac, infection, or both. If intrauterine rupture of the sac has occurred, the newborn is kept warm, and the bowel is inspected for perforation and torsion. In certain cases, a petroleum gauze dressing may be applied to the defect, but care must be taken to keep it moist.

Omphaloceles and gastroschisis are repaired by placement of the viscera in the abdominal cavity, with reconstruction of the abdominal wall. Surgical procedures for omphaloceles may be primary (Shuster procedure) or staged (giant omphaloceles). Mesh may be used as a barrier to create tension that helps to push the internal organs into the abdominal cavity. In some cases of gastroschisis, a silo is applied to the defect. The silo is made of a flexible ring that sits inside the abdomen and its size is gradually decreased to facilitate movement of the organs back to the abdominal cavity. Silo material may be prepackaged and kept at the patient's bedside if the patient is unable to tolerate an immediate trip to the OR.

Procedural Considerations. Particular attention to maintaining body temperature is essential because of the massive exposed surface area from which body heat can be lost. The use of nitrous oxide as an anesthetic agent is avoided during this procedure because it causes increased gas in the intestine, which in turn makes the reduction of abdominal contents into the peritoneal cavity very difficult. Repeated rectal irrigation with warm saline to evacuate meconium from the bowel may be carried out before the abdominal prep to aid in bowel decompression.

The major instrument set is required. The infant is positioned supine; the abdomen, umbilical cord, and sac are gently prepped with a povidone-iodine solution.

FIGURE 25-18 Newborn with giant omphalocele containing liver and intestine.

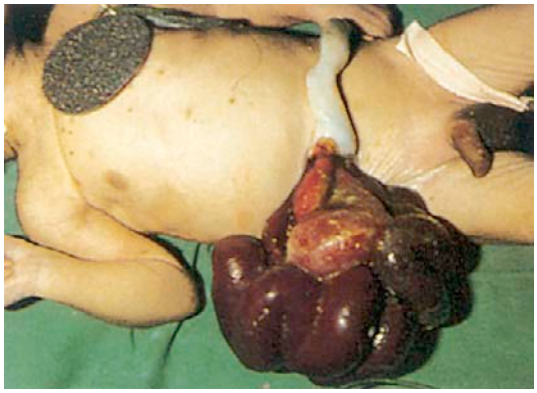


FIGURE 25-19 Gastroschisis. A large amount of small intestine has eviscerated through a defect to the right of a normal-appearing umbilical cord. No sac is visible, and the intestine is thickened, edematous, and ischemic in areas.

Gastroschisis with Silo Placement

Procedural Considerations. A major instrument set is required. The patient is positioned supine for the procedure. The abdomen, umbilical cord, and sac are gently prepped with povidone-iodine.

Operative Procedure

1. The surgeon examines the bowel and measures the size of the defect to determine silo size. The silo is applied so that the flexible ring is positioned inside the abdomen (Figure 25-20).
2. The patient returns to the OR every 48 hours for a reduction of the silo, which is accomplished by decreasing the size of the ring to help guide the contents back into the abdominal cavity.
3. The height of bowel in the silo and length of reduction are measured with each procedure. When the amount of bowel remaining in the silo is 1 cm or less, the patient is transferred to the OR for closure of the defect.
4. The silo is trimmed and the spring-loaded ring is removed. The wound site and bowel are inspected and cleaned with surgical prep material.
5. The surgeon closes the defect using synthetic purse-string sutures or, if the defect is too large, using running sutures that begin at each end of the wound and meet in the middle to preserve the umbilical cord stump.
6. The inferior aspect of skin is wrapped around the stump and secured with absorbable suture. Any redundant skin is trimmed and the stump is ligated using nonabsorbable suture.
7. A subcutaneous drain may be left in place and a dry, sterile dressing is applied.

Omphalocele Repair

Procedural Considerations. The patient is positioned supine for the procedure and the abdomen is prepped as described for silo placement.

FIGURE 25-20 Operative view of silo for the intestines.

Operative Procedure

1. The surgeon dissects the amnion of the omphalocele circumferentially from the dermis.
2. The umbilical vein is identified and ligated with absorbable suture. Umbilical cord structures and arteries are dissected and ligated with absorbable suture, and then oversewn with nonabsorbable suture.
3. Organs connected to the omphalocele are dissected, reduced (if necessary), and mobilized, and the internal mucosal layer is closed with running nonabsorbable suture.
4. The outer muscular layer is closed with interrupted nonabsorbable suture, organs are returned to the peritoneal cavity, and fascia is closed with interrupted nonabsorbable suture.
5. If necessary, an umbilicoplasty may be performed using interrupted absorbable suture. Dry, sterile dressings are placed over the incision.

In certain cases in which the defect is of medium to large size, a primary closure may not be accomplished. In these situations a staged procedure is done using prosthetic reduction. In the first stage the infant is brought to the OR and positioned and prepped as previously described. Then the following steps are performed:

1. The sac is excised, and the umbilical vein and arteries are ligated.
2. A gastrostomy may be performed at this time.
3. A barrier is then created with Silastic mesh. The mesh is secured through all layers of the edge of the defect using a continuous locking nonabsorbable suture. The open end of the barrier is closed in the same manner.
4. The open end of the cylinder is closed with umbilical tape or, alternatively, attached to a specifically designed roller clamp.
5. The mesh barrier suture line and edge of the defect are wrapped with roller gauze dipped in an iodophor solution to prevent infection. The infant is transferred to an open Isolette, and the silo is suspended from the top of the Isolette. Plastic wrap is applied to the barrier to prevent heat loss. The infant is then transported to the NICU, where daily reduction of abdominal contents is performed by adding a lower tie of umbilical tape or by adjusting the roller clamp. The abdominal viscera are gradually reduced over several days, taking care to avoid respiratory compromise from abdominal distention. When reduction has successfully approached skin level, the infant is returned to the OR for the final stage of repair.
6. The mesh barrier is removed, and the remaining abdominal contents are brought into the peritoneal cavity. The peritoneal fascia is closed with interrupted nonabsorbable sutures. The skin is closed with interrupted nonabsorbable suture. In an attempt to create the appearance of an umbilicus, a purse-string suture is used to close the inferior 2 cm of incision.

GENERAL SURGERY—ABDOMINAL PROCEDURES

Correction of Biliary Atresia—Hepatic Portoenterostomy (Kasai Procedure)

Biliary atresia is a congenital defect that results from nonpatent extrahepatic bile ducts. Bile is unable to drain from the liver to the small intestine, leading to eventual cirrhosis and death. The Kasai

procedure is the construction of a bile drainage system by use of an intestinal conduit. This procedure is indicated in patients with extrahepatic biliary atresia who are younger than 3 months. All atretic segments of the existing bile ducts are removed. An intraoperative cholangiogram and frozen-section biopsy of the hepatic duct remnant are included in the surgical procedure.

Procedural Considerations. The infant is positioned supine over a radiographic plate, or fluoroscopy is used. Both a major instrument set and bowel clamps are required, as well as radiopaque dye and a 6F or 8F catheter for the cholangiography.

Operative Procedure

1. The surgeon makes a right upper quadrant incision and exposes the gallbladder.
2. A small catheter is placed into the gallbladder and secured with a purse-string suture. Radiopaque dye is instilled into the gallbladder, and an x-ray examination is done. The surgeon observes for free flow of the dye through the ducts and into the duodenum, which occasionally is seen. These patients are then categorized as having correctable biliary atresia. In such situations, a liver biopsy is performed and the incision is closed. The majority of patients with correctable biliary atresia demonstrate progressive improvement. More commonly, however, there is a very small amount of flow or none at all, for which the Kasai procedure is performed.
3. A thorough inspection of the intraabdominal organs is then done because of the high prevalence of associated anomalies.
4. The hepatoduodenal ligament is explored, and all drainage structures are ligated (Figure 25-21, *A*).
5. The hepatic duct remnant is identified and traced to the liver hilum. The remnant is transected as high as possible using frozen-section biopsy specimens as a guide. Frozen-section biopsy specimens are also obtained at the porta hepatis to denote the presence of ductules. Precise identification of this location is essential (Figure 25-21, *B*).
6. The proximal portion of the jejunum is generally used as the intestinal conduit. A meticulous anastomosis is performed at the porta hepatis as previously identified, using a single running layer of absorbable sutures (Figure 25-21, *C*).
7. The conduit is exteriorized with a double-barreled Roux-en-Y approach (Figure 25-21, *D*).
8. A liver biopsy is then performed.
9. A drain is placed, and the incision is closed in layers.

The procedure just described is one approach of many. Others include exteriorization of the jejunal conduit as a cutaneous jejunostomy and use of double Roux-en-Y loops, avoiding any need for an enterostomy. If none of these procedures is successful, the child may be a candidate for liver transplantation.

Repair of Congenital Diaphragmatic Hernia

A congenital diaphragmatic hernia (CDH) is repaired by replacement of the displaced viscera into the abdominal cavity with surgical correction of the diaphragm defect (Figure 25-22). The conventional surgical repair is through the abdomen, though some cases of CDH can be repaired using a thoracic approach. The concurrence of intraabdominal abnormalities is somewhat high in infants with diaphragmatic hernia; therefore treatment is facilitated with an abdominal approach. It is technically easier to extract the viscera from below than to push them out of the thorax. The abnormal intrathoracic intrusion of the abdominal viscera usually causes severe compromise of intrathoracic pulmonary and vascular activities. Therefore urgent restoration of more normal intrathoracic and intraabdominal relationships is the rule in these newborns. The lung may be hypoplastic because of prolonged compression in utero by the displaced abdominal viscera. A residual intrapleural space usually remains for a few days after surgery.

Procedural Considerations. Direct suturing of the margins of the defect is usually possible. Insertion of prosthetic Silastic sheeting is occasionally required and should be available. The major instrument set is required. The infant is positioned supine.

Operative Procedure

1. The surgeon makes a subcostal incision on the side of the defect, going through all muscle layers.
2. The abdominal viscera are withdrawn from the chest and held downward through the abdominal wound. Because abnormalities of abdominal viscera, such as malrotation, are

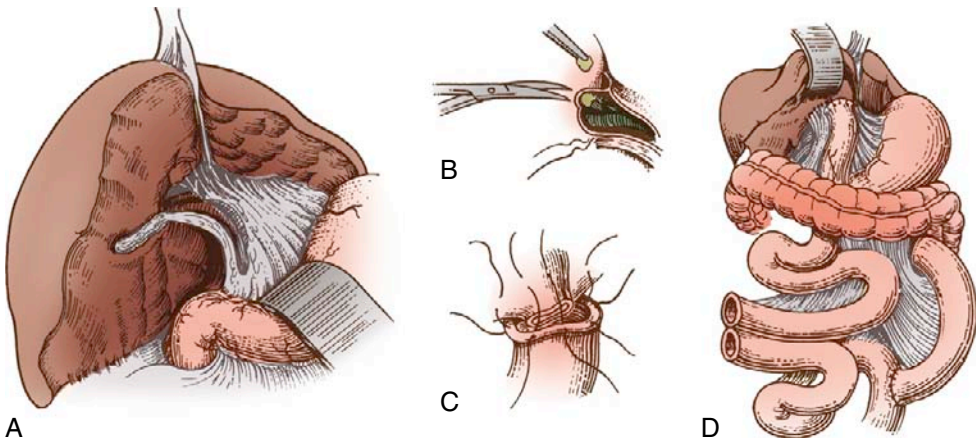


FIGURE 25-21 Kasai procedure. **A**, Exploration of hepatoduodenal ligament and ligation of drainage structures. **B**, Transection of hepatic duct remnant using frozen-section biopsy specimens as a guide. **C**, Anastomosis of jejunal conduit at porta hepatis. **D**, Exteriorization of conduit using double-barreled Roux-en-Y approach.

associated with diaphragmatic hernia, the organs are carefully inspected at this time. If a malrotation is found, the surgeon may repair it if the clinical condition of the infant is amenable to the procedure.

3. The defect is then carefully inspected, including a search for a hernia sac, which is present in fewer than 5% of cases. If a sac is identified, it is excised.
4. The posterior and anterior rims of the diaphragm are identified, and primary closure is performed with mattress sutures of nonabsorbable material. If the rim of tissue is too small for mattress sutures, ample nonabsorbable sutures are used. Occasionally, reinforced Silastic sheeting may be needed if sufficient diaphragm is not available for primary closure.
5. The abdominal wall is then closed, followed by subcutaneous tissue and skin closure. If the musculature cannot accommodate the abdominal viscera, it is left open and the skin is closed to leave a ventral hernia. In severe cases, the patient may be given extracorporeal membrane oxygenation (ECMO) for several days before repair of the defect. The infant is returned to the OR within 7 days for repair of the ventral hernia.

Pancreatectomy

Pancreatectomy is the treatment for several disorders, including congenital hyperinsulinism (HI) and pancreatitis. A pancreatectomy may be total, meaning that the entire pancreas is removed. In some cases, the common bile duct, spleen, gallbladder, and portions of the small intestine and stomach may be removed along with it. Pancreatectomies may also be partial—only the body and tail of the pancreas are removed. Pancreatectomy for congenital hyperinsulinism is described in the following Operative Procedure. Congenital hyperinsulinism is a condition in which the release of insulin is not properly regulated and insulin (beta) cells of the pancreas secrete too much insulin at the wrong time (Children's Hospital of Philadelphia [CHOP], 2009). Treatment of HI is focused on regulating blood glucose level to reduce the risk of brain damage. Surgical intervention is recommended when medical management of HI proves unsuccessful. The procedure for a total pancreatectomy for congenital hyperinsulinism is described in the following section.

Procedural Considerations. Multiple specimens are sent to the pathology laboratory for frozen-section analysis throughout the procedure in order to confirm the extent of the disease. The child is positioned supine with the hips elevated.

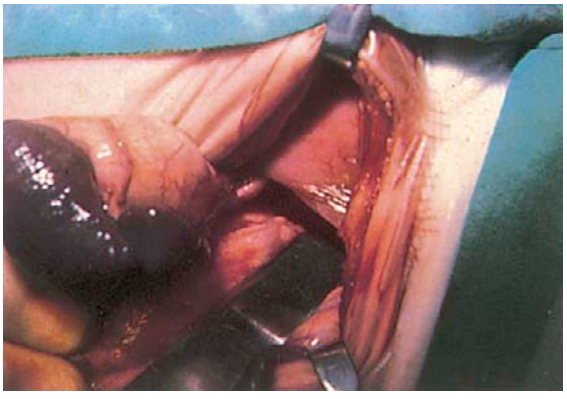


FIGURE 25-22 Defect in the posterolateral aspect of the left diaphragm (diaphragmatic hernia).

Operative Procedure

1. The surgeon makes a transverse supraumbilical incision using a #15 blade. The Denis Brown retractor is placed.
2. The body and tail of the pancreas are exposed for biopsy for analysis by frozen section.
3. The hepatic flexure of the colon and the duodenum are exposed for additional biopsy and frozen section.
4. If results indicate the need for total pancreatectomy (large nuclei in islet cells), the dissection is begun at the pancreatic tail, and then extended to the body and head.
5. A vessel loop is used to isolate the common bile duct and care is taken to preserve duodenal blood supply to the pancreatic head during dissection. Once the uncinate process is mobilized from behind the superior mesenteric vessels and the common bile duct is dissected away from its entry point into the duodenum, the pancreatic head is freed.
6. A pancreatectomy is performed and blood supply to the duodenum is evaluated. In the event that a pancreatic remnant remains, it is ligated using nonabsorbable interrupted horizontal mattress sutures. Omentum is tacked down to the dissected area, and the gallbladder is milked to evaluate patency and test for bile leak.
7. In certain cases, a gastrostomy tube may be placed.
8. The abdominal incision is closed in layers using nonabsorbable suture for fascia and absorbable sutures for subcutaneous and subcuticular tissue. The incision is dressed with Mastisol adhesive and wound closure strips.

GENERAL SURGERY—RESECTION OF TUMORS

Nearly two thirds of childhood cancers occur as solid tumor malignancies. As is always the case, the therapy administered depends on the type of tumor. Examination and judicious investigation of all unusual masses are imperative. Thorough diagnostic workup and prompt definitive treatment may result in cure, even if the tumor is malignant. Chemotherapy and radiation therapy are adjuncts to surgical excision of tumors.

Wilms' Tumor

Wilms' tumor, also known as *nephroblastoma,* is the most common intraabdominal childhood tumor. It presents as a painless mass whose enlargement may laterally distend the abdomen (Figure 25-23). The child may be asymptomatic or may have weight loss, malaise, or abdominal pain. Nephroblastomas may cause obstruction of the vena cava, hepatic veins, or renal veins.

Procedural Considerations. The child is positioned supine with a roll under the affected side. Both chest and abdomen are prepped. Infrequently the tumor extends into the inferior vena cava as well as the right atrium of the heart, and in such cases cardiopulmonary bypass (CPB) should be readily available. Lines are placed into the arms and neck to facilitate clamping of the inferior vena cava if needed. Separate sterile gloves and instruments should be available for inspection of the contralateral kidney. Careful attention should be given when handling tumor and lymph nodes to avoid tumor spillage.

Operative Procedure

If the tumor is operable, the following aspects are important:

1. The transabdominal approach, which may be extended to a combined transabdominal-transthoracic approach, is used to inspect abdominal contents and clamp the vessels of the renal pedicle before tumor dissection.
2. All suspicious lymph nodes are removed, placed into separate containers, and labeled. If no suspicious nodes are present, biopsy specimens are obtained of those in adjacent areas.
3. The opposite kidney is explored before dissection of the tumor.
4. The extent of the tumor can be marked with hemostatic clips to facilitate radiation therapy.
5. The entire primary tumor is removed if doing so does not place the patient in jeopardy.
6. Any residual tumor is marked with clips.
7. Because of its proximity to the kidney, the adrenal gland is usually removed.
8. The abdominal cavity and viscera are thoroughly inspected for evidence of tumor extension or metastases. Extensive surgery may include partial colectomy or partial resection of the diaphragm.

Neuroblastoma

Neuroblastoma is responsible for 6.9% of all childhood cancers and is the third most common childhood cancer after leukemia and brain and nervous system cancers (American Cancer Society [ACS], 2009). It arises from neural crest tissue and can develop anywhere sympathetic nerve tissue is found; the most common sites are the retroperitoneum and adrenal medulla. The mass is usually firm, irregular, and nontender. It is a silent tumor in its early stages and metastasizes rapidly, often to the lymphatics, liver, skin, bone marrow, lung, brain, or orbits. Treatment includes an operation to ligate the tumor's blood supply and remove as much of the tumor as possible, as well as chemotherapy and radiation.

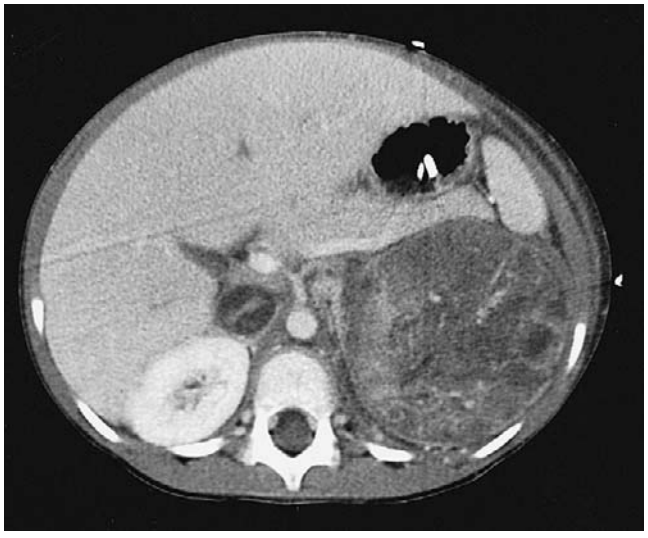


FIGURE 25-23 Computerized tomographic scan showing left-sided Wilms' tumor with compression of the inferior vena cava.

Sacrococcygeal Teratoma

A sacrococcygeal teratoma is a tumor that originates early in embryonic cell division. The tumor consists of cell types from more than one embryonic germ layer. Teratomas range from benign, well-differentiated cystic lesions to solid, malignant lesions. They are the most common tumor in newborns, occurring in 1:35,000 to 1:40,000 births (Laberge et al, 2005). The sacrococcygeal area is the most common extragonadal site of teratoma, usually presenting as a large protuberance rising from that site (Figure 25-24). It may be irregular or symmetric, may vary in size, and may be pedunculated.

A sacrococcygeal teratoma is usually resectable but may undergo malignant changes if not removed early in life. Sacrococcygeal teratomas can be resected prenatally using fetal surgery techniques (see Chapter 13) or postnatally. Tumors resected in the newborn period show microscopic evidence of malignant cells, but surgical cures have been achieved. Early surgical resection is important because these tumors are not sensitive to irradiation and are only temporarily responsive to chemotherapy.

The tumor is in the area of the sacrum and coccyx but may extend into the pelvis or abdomen. Resection is usually feasible by placing the patient in the jackknife position and excising

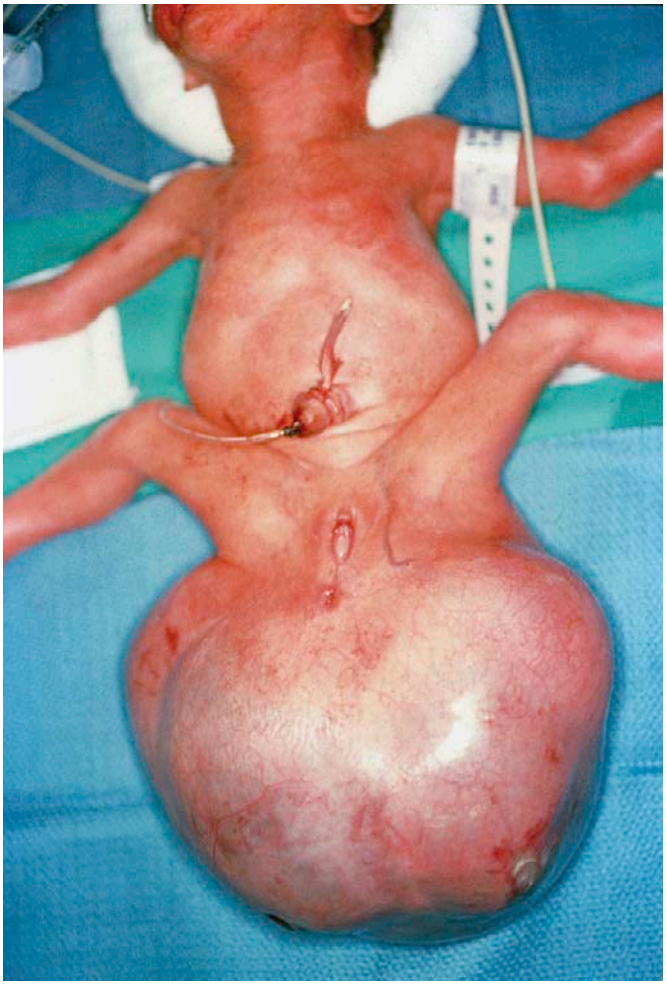


FIGURE 25-24 Infant with large sacrococcygeal teratoma.

the tumor mass and coccyx en bloc. In cases where the tumor extends high into the pelvis, an abdominal incision may also be required.

GENITOURINARY SURGERY

Pediatric Cystoscopy

Pediatric cystoscopy is endoscopic examination of the lower urinary tract of pediatric patients. The major difference between adult and pediatric cystoscopy is the size of the instruments used and consideration of the small, delicate orifices of the pediatric patient. Indications for pediatric cystoscopy include urinary tract infections, enuresis, urethral valves, vesicoureteral reflux, diverticula, bladder neck contractures, bladder tumors, and urinary tract obstructions. Pediatric cystoscopy may also be used in conjunction with Deflux injection for minimally invasive treatment of vesicoureteral reflux.

Procedural Considerations. The cystoscopy setup will have the same type of components as those for the adult cystoscopy patient, except that the size of the cystourethroscope system will be specific to the pediatric patient's needs.

Each pediatric cystourethroscope is designed to fit specific component parts and is very delicate. Therefore the perioperative nurse must be familiar with the proper use of the system and handle the components carefully. The resectoscope loop is commonly used to resect urethral valves and occasionally bladder tumors. The cold knife may be used with the resectoscope to cut urethral strictures and occasionally to resect a urethral valve.

The most common type of anesthesia used for the pediatric patient is general anesthesia. After induction of anesthesia, the child is placed in a lithotomy or frog-leg position and prepped and draped according to established procedure.

Operative Procedure. The pediatric cystourethroscope is lubricated and inserted through the urethra into the bladder. The light cord and irrigation tubing are attached to the telescope and cystoscope, and the examination is performed. Most commonly the interior of the bladder is viewed on a video monitor by means of a camera attached to the cystoscope.

Circumcision

Circumcision is the excision of the foreskin (prepuce) of the glans penis. Circumcision may be done for therapeutic reasons or for perceived prophylactic benefits; it may also be done for religious reasons, as is required in specific faiths. Provision should be made to observe the religious needs and preferences of the parents.

Therapeutic indications include correction of phimosis or paraphimosis or treatment of balanoposthitis. Phimosis is a condition in which the orifice of the prepuce is stenosed or too narrow to permit easy retraction behind the glans. Balanoposthitis is characterized by an inflamed glans and mucous membrane with purulent discharge and may require circumcision. Paraphimosis is a recurrent condition in which the prepuce cannot be reduced easily from a retracted position.

Procedural Considerations. Newborns are generally positioned on a specially constructed board that facilitates restraint by immobilizing the limbs and exposing the genitalia. Although it was once thought that circumcision caused infants little pain, the neonatal foreskin contains mature nerve endings that allow for the transmission of pain. Measures to ameliorate the pain of the procedure include local dorsal penile nerve block, a ring block with buffered lidocaine and bupivacaine, or the topical application of a eutectic mixture of local anesthesia (EMLA) cream. Older children require general anesthesia.

For infants, the setup includes fine plastic surgery instruments. A Gomco clamp of the appropriate size, a Plastibell, or the Hollister disposable circumcision device may be employed. The Hollister device includes sutures that are sealed in a sterile packet ready for use. The Plastibell technique uses a plastic ring and suture tied around the foreskin like a tourniquet. The excess tissue is trimmed, and in about 5 to 8 days the ring falls off. For older patients, the circumcision clamp is not needed, and only a plastic surgery instrument set is used. Petrolatum gauze for dressing should be available.

Operative Procedure *(Figure 25-25)*

1. If the prepuce is adherent, the surgeon may use a probe or hemostat to break up adhesions. The prepuce is clamped in the dorsal midline and incised toward the coronal mucosa margin, leaving about 5 cm of coronal mucosa intact. A similar procedure is performed ventrally. The two incisions are then joined circumferentially. Alternatively, a superficial circumferential incision is made in the skin with a scalpel at the level of the coronal sulcus and mucosa at the base of the glans. The redundant skin is undermined between the circumferential incisions and removed as a complete cuff.
2. Bleeding vessels are coagulated or clamped with mosquito hemostats and tied with fine absorbable ligatures. Before closure, the area may be cleansed with an appropriate antiseptic solution.
3. The raw edges of the skin incision are approximated to a coronal cuff of mucosal prepuce, generally with interrupted 4-0 or 5-0 absorbable sutures on fine plastic cutting or GI needles. The wound is usually dressed with petrolatum gauze or an antibiotic ointment. A penile block with bupivacaine is often done for immediate postoperative pain, thus providing a more comfortable emergence from anesthesia.

Hypospadias Repair

Hypospadias is a developmental anomaly characterized by a urethral meatus that opens onto the ventral surface of the penis proximal to the end of the glans (Figure 25-26). There are varying degrees of hypospadias. The meatus may be on the ventral surface of the glans, on the corona, anywhere along the shaft, in the scrotum, or even in the perineum. The more proximal the opening, the greater the degree of chordee (downward curvature of the penis). Chordee is caused by fibrous bands that extend from the hypospadiac urethral meatus to the tip of the glans and represent the abnormally developed urethra and its investing layer of Buck's fascia, dartos, and skin. In some cases of clinical curvature, however, these fibrous bands may not be present. Although these curvatures are still termed *chordee,* they are not true fibrous chordee.

The principal methods of hypospadias repair are meatoplasty and glanuloplasty, orthoplasty (release of chordee, thereby straightening the penis), urethroplasty (reconstruction of the urethra), skin cover, and scrotoplasty. These may be done in one- or two-stage repairs depending on the extent of the condition.

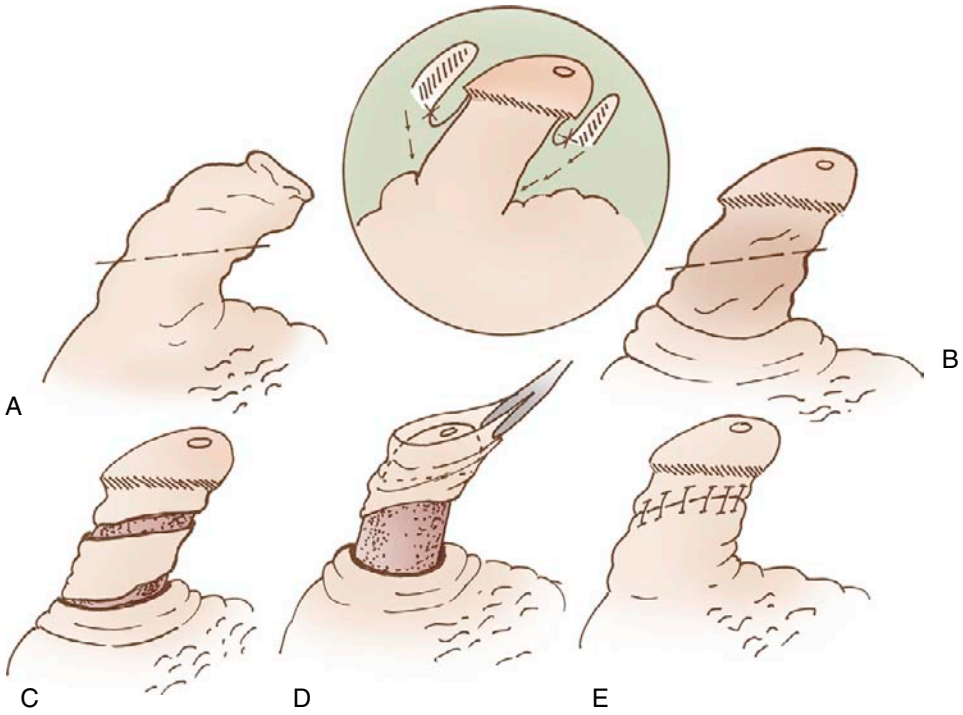


FIGURE 25-25 Circumcision. **A**, Initial incision made in the shaft. **B**, Second incision made in subcoronal sulcus. **C**, Amount of tissue to be removed. **D**, Removal of tissue. **E**, Shaft skin sutured to subcoronal skin.

FIGURE 25-26 Hypospadias.

Recently efforts have increased to relocate the meatus to the apex of the glans, especially in the more extensive one-stage repair.

One complication of hypospadias repair is urethral fistula formation, which can be repaired without much difficulty. Correction of strictures is more troublesome.

Procedural Considerations. The patient (the majority are infants and young children) is placed in the supine position with legs apart. The urine may be diverted with a urethral catheter intraoperatively. The instrument setup varies according to the surgeon's preference. However, a minor set with fine plastic surgery instruments is generally required. Owens gauze, Elastomull, Coban, and Elastoplast, as well as adhesive tape, are generally required for the dressing, which is an important part of the hypospadias repair.

Meatoplasty and Glanuloplasty Incorporated (MAGPI) Procedure

OPERATIVE PROCEDURE

1. The surgeon makes a subcoronal circumferential incision about 8 mm proximal to the meatus and corona. The skin is stripped back from the phallus by subcutaneous dissection (Figure 25-27).
2. A bridge of tissue between the meatus and glanular groove is made, with a transverse closure of the dorsal (upper) meatal edge to the distal glanular groove.
3. Three traction sutures are placed where the foreskin stops, at the apex of the ventral meatus (on the lower side) and lateral areas of the glans.
4. The edges of the glans are sutured together ventrally in a V configuration, and the redundant edges are excised. Vertical mattress sutures are used to approximate the glans beneath the meatus.
5. If foreskin is excessive, it may be trimmed, followed by a sleeve style of reapproximation of the penile skin. If a ventral skin defect is present, a rotational skin flap closure is used.
6. An indwelling catheter is placed, and the wound is dressed.

Orthoplasty. *Orthoplasty* is the proper designation for the plastic procedure performed to straighten the penis. *Chordee repair* is the more common term employed. In true fibrous chordee the penis is curved downward, with the meatus and glans in proximity to one another.

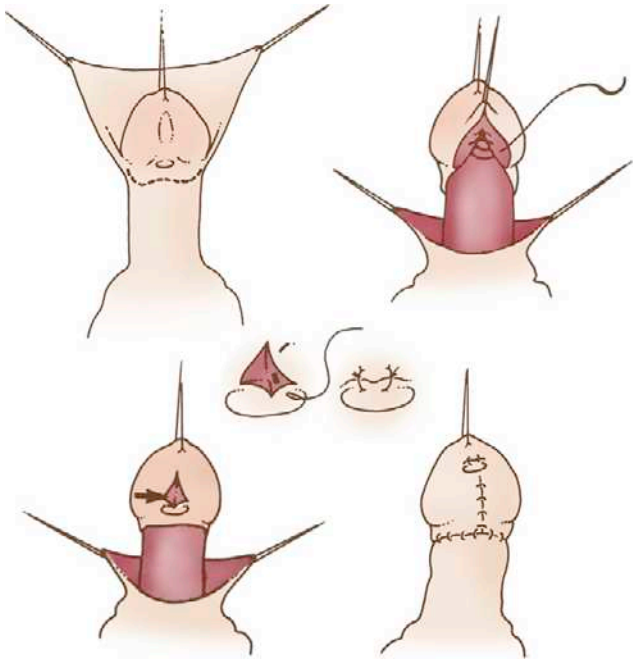


FIGURE 25-27 Meatal advancement and granuloplasty.

Artificial erection is achieved by injecting 0.9% preservative-free, injectable saline solution into the corpus cavernosum. Both corporal bodies fill, making it possible to determine the degree of curvature before and after the resection of the fibrous bands.

OPERATIVE PROCEDURE

1. The surgeon makes a circumferential incision around the corona and carries it distally to the urethral meatus and well below the glans cap (Figure 25-28, *A*). Dissection continues to the level of the tunica albuginea of the corpora cavernosa.
2. With proximal dissection the adherent fibrous plaque is freed, working in a side-to-side fashion. The urethra is elevated from the corpora during this process (Figure 25-28, *B*).
3. The chordee generally surrounds the urethral meatus and often extends for some distance. It is important to free it completely along the entire penile shaft to the penoscrotal junction or, in severe cases, into the scrotum or perineum.
4. After release of the chordee, the glans penis is closed with 4-0 absorbable sutures in a circular manner (Figure 25-28, *C*).
5. If urethroplasty is either delayed or unnecessary, excess dorsal skin is excised (Figure 25-28, *D*) and the incision is closed along the dorsal midline with interrupted absorbable mattress sutures (Figure 25-28, *E*). The wound is dressed according to established protocol.

Urethroplasty. Many procedures are described for reconstruction of a urethra. They may be divided into three general groups: adjacent skin flaps, free skin grafts, and mobilized vascular flaps. There are also many combinations of these procedures. In all the procedures, some type of temporary urinary diversion, such as a perineal urethrostomy, may be used.

The procedural considerations are the same as those for chordee repair.

Adjacent Skin Flap. It is possible to tubularize skin adjacent to the meatus to create a neourethra in a one-stage repair. Transfer of dorsal skin to the ventrum will also provide graft material close to the meatus. However, this is generally done in two stages, and the vascularity of this thin rotational flap is less than optimum, with results that are prone to complication.

OPERATIVE PROCEDURE

1. The surgeon places traction sutures in the tip of the penis and in the glans wings for stabilization and exposure.
2. The distance between the glans tip and the lower edge of the meatus is measured. An outline of the proposed incision is drawn on the penile shaft (Figure 25-29, *A*). In a one-stage approach the distal length must be increased to compensate for the added penile length after chordee release.
3. An incision is made around the outlined flap and carried proximally to a point on the shaft that corresponds to the distance required to reach the glans tip. A flap width of 14 to 16 mm is usually sufficient to ensure good circumference of the neourethra.
4. Once incised, the tube is rolled over an 8F or 10F catheter (Figure 25-29, *B*) with an inverted running stitch of 4-0 or 5-0 absorbable suture.
5. The glans penis is incised, and the glans wings are undermined and freed. The neourethra is carried to the distal portion of the glans and sutured in place (Figure 25-29, *C*).
6. The glans wings are sutured around the neourethra with absorbable interrupted mattress sutures. The redundant foreskin is split down the midline, and the flaps are transposed in a Z-plasty manner (Figure 25-29, *D*).
7. A dry, sterile pressure dressing is applied. The patient can often be discharged on the same day, without the need for an indwelling catheter.

Free Skin Graft. Free skin grafts should be of full thickness. Because the free graft must be revascularized, it is important that it have a perfect skin cover of dorsal preputial penile skin that is well vascularized. This type of graft is generally used with a one-stage hypospadias repair.

OPERATIVE PROCEDURE

1. A V-shaped incision is made on the glans, and the penile skin is mobilized after the chordee is released (Figure 25-30, *A*).
2. Glans wings are developed in a triangular fashion, and ventral preputial skin is used for the full-thickness free graft (Figure 25-30, *B*).
3. The graft is formed into a neourethra over a stenting catheter (Figure 25-30, *C*).
4. The graft is anastomosed proximal to the urethra with the suture line of the graft next to the corpora. The middle glans dart is fixed to the corpora (Figure 25-30, *D*).
5. A meatoplasty with the dorsal glans dart is accomplished.
6. Fine absorbable interrupted sutures are placed around the meatus and glans and along the dorsal penile shaft (Figure 25-30, *E*).
7. The wound is dressed according to established protocol.

Mobilized Vascularized Flaps. Vascularized flaps of preputial penile skin may be mobilized to the ventrum by leaving them attached to the outer surface of the prepuce or as an island flap. One modification is the transverse preputial island-flap neourethra with glans-channel positioning for the meatus. Preputial skin seems to be preferred because of its rich, reliable blood supply.

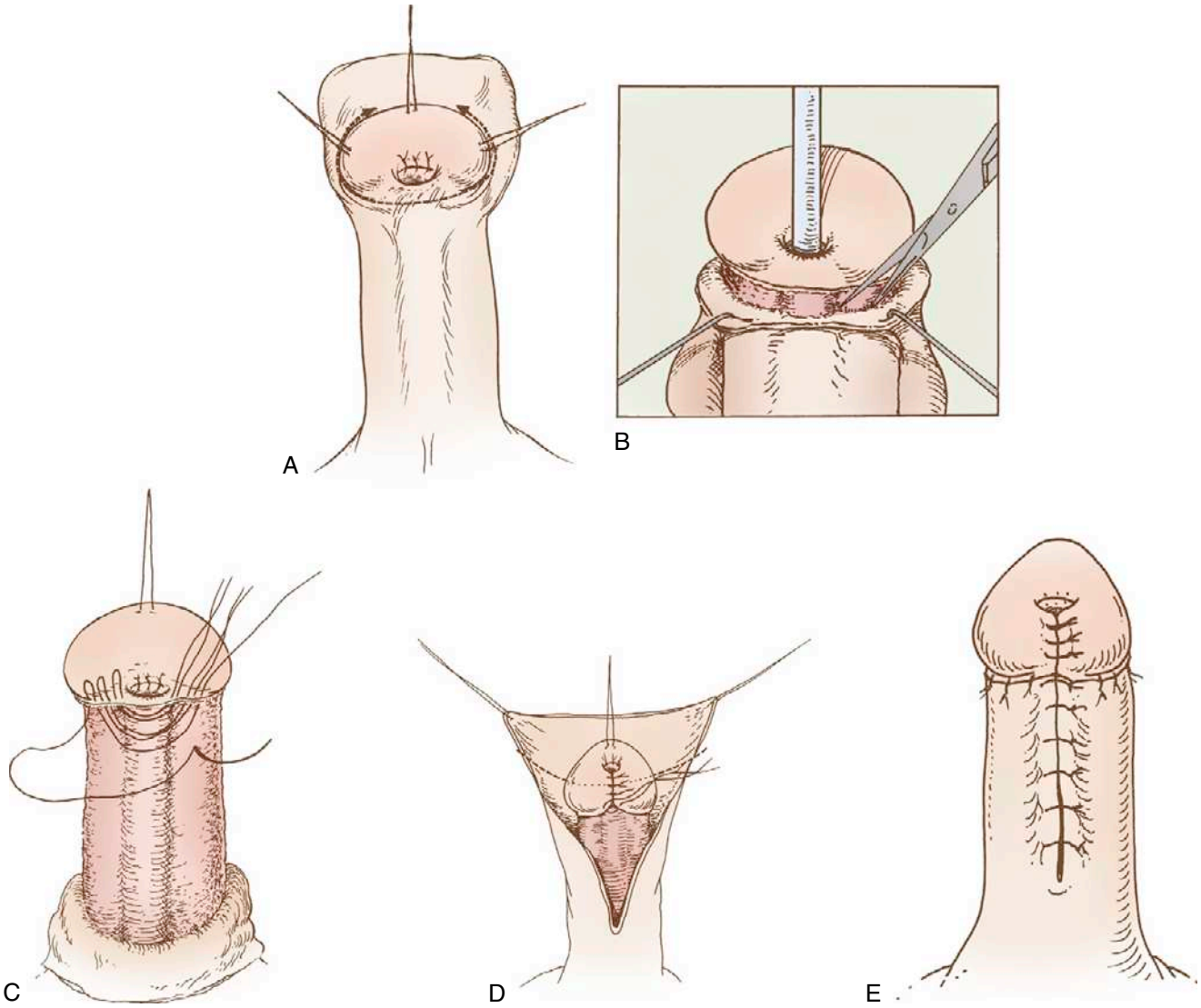


FIGURE 25-28 Orthoplasty.

OPERATIVE PROCEDURE

1. The chordee is released (Figure 25-31, *A*).
2. Ventral preputial skin is dissected free and fanned out (Figure 25-31, *B*).
3. The rectangle of skin is rolled into the neourethra and measured (Figure 25-31, *C*).
4. The island flap is developed by dissection of the subcutaneous tissue from the dorsal penile skin (Figure 25-31, *D* and *E*).
5. A glans channel is created with fine scissors in a plane just above the corpora. The glans tissue is removed with the 14F channel, and the island-flap urethra is spiraled to the ventrum (Figure 25-31, *F*).
6. The neourethra is anastomosed proximal to the urethra (Figure 25-31, *G*).
7. The neourethra is carried to the tip of the glans (Figure 25-31, *H*).
8. The dorsal penile flaps are transposed laterally to the midline, and excess skin is excised. Closure is with fine absorbable interrupted mattress sutures around the glans and down the penile shaft (Figure 25-31, *I*).
9. Dressings are applied according to established protocol.

Skin Cover. After orthoplasty and urethroplasty, the penis must be resurfaced with skin. Abundant excess dorsal foreskin is usually adequate to achieve the desired results.

OPERATIVE PROCEDURE

1. Preputial tissue is transposed through a small buttonhole opening in the midline (Figure 25-32, *A*).
2. The vasculature is spread laterally, and the glans penis is delivered through the hole (Figure 25-32, *B*).
3. The skin flap is then sutured with fine absorbable interrupted mattress sutures (Figure 25-32, *C*).

Epispadias Repair

An epispadias is a congenital anomaly characterized by a urethral opening on the dorsum of the penis. The surgical procedures employed in the correction of epispadias depend on the extent of the deformity. In mild, incomplete defects the repair is the same as a simple hypospadias repair. Complete deformity is always associated with urinary incontinence because of little or no development of the bladder neck; thus the operation is much more involved. The least severe forms of the exstrophy-epispadias complex are (1) balanic epispadias, in which the urethra

opens on the dorsum of the glans, and (2) penile epispadias, in which the urethra opens on the shaft of the penis. The more severe variety, which occurs when the urethra opens on the proximal end of the shaft or in the penopubic position, is generally associated with severe dorsal chordee and urinary incontinence.

Procedural Considerations. The setup for an epispadias repair is the same as that described for hypospadias repair.

Operative Procedures

FIRST-STAGE EPISPADIAS REPAIR

1. The surgeon makes a vertical incision distal to the epispadial meatus and extends it circumferentially to the dorsal coronal margin.

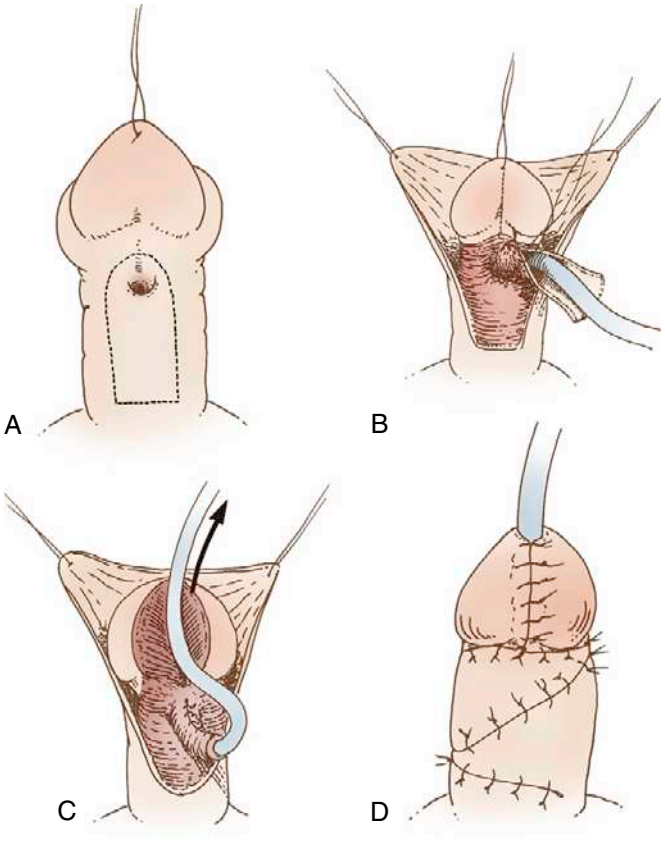


FIGURE 25-29 Urethroplasty with adjacent skin flap.

2. The foreshortened dorsal urethral strip is lifted off the corpora cavernosa, and the ventral prepuce (foreskin) is rotated dorsally to cover the dorsal skin defect created by penile straightening.

SECOND-STAGE EPISPADIAS REPAIR

1. A vertical suprapubic incision is made to expose the anterior bladder wall and widened vesical neck. A wedge section of the anterolateral prostatic urethra is removed on either side so that when it is reconstructed, a more normal-caliber prostatic urethra is formed.
2. The roof of the membranous urethra is removed.
3. The prostatic urethra is closed, including muscle that is sutured together in the midline, with absorbable sutures. The bladder is closed so that an indwelling suprapubic catheter is left. The abdomen is closed in layers.
4. The anterior urethra is closed after an appropriate size of octagonal strip of dorsal penile skin is outlined.
5. The remainder of the repair—the creation of the urethra and its coverage with lateral penile skin—is the reverse procedure of a second-stage hypospadias repair.

Bladder Exstrophy Repair

Bladder exstrophy repair corrects a more severe form of epispadias, in which the anterior bladder wall as well as the roof of the urethra is absent. Bladder exstrophy is always accompanied by wide separation of the rectus muscles of the lower abdominal wall and by diastasis of the pubic bone with anterior displacement of the anus. Repair of bladder exstrophy requires an adequate size of bladder for ultimate continence to be achieved. It is preferable to perform this procedure in the neonatal period.

Procedural Considerations. The infant is placed in a supine position, and the abdomen and thighs are prepped and draped. Instruments are the same as those required for hypospadias repair.

Operative Procedure

1. The surgeon makes an incision around the exposed bladder medial to the paravesical neck mucosa. The incision is carried distally across the epispadial urethra distal to the verumontanum. The paravesical mucosa is preserved for urethral lengthening. The bladder is then freed from the rectus fascia and the peritoneum. The dorsal chordee is released, and the mobilized paravesical mucosa is apposed in the midline and sutured to the proximal end of the urethra just distal to the verumontanum.

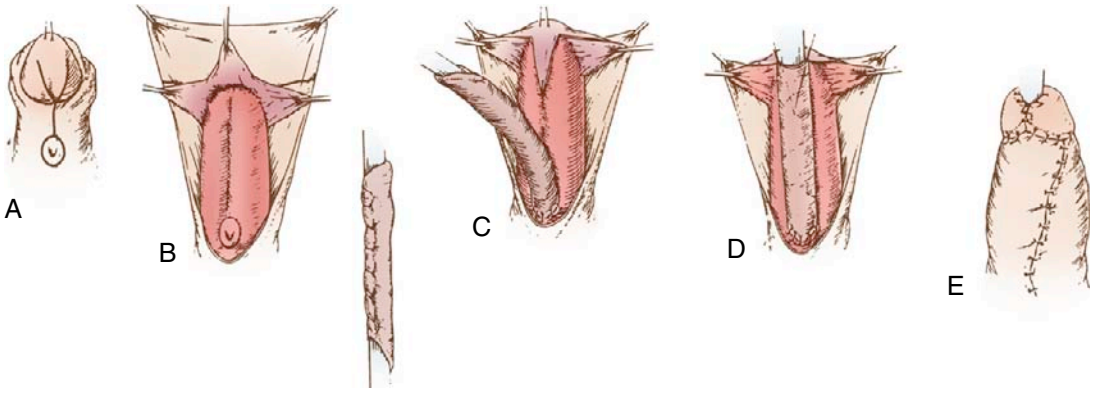


FIGURE 25-30 Urethroplasty with free graft.

2. The bladder wall is closed vertically in two layers with 3-0 absorbable sutures; a suprapubic tube is inserted for drainage.
3. The bladder neck is loosely reconstructed by approximating the interpubic ligament, which extends between the proximal end of the phallus and the pubic bone.
4. The symphysis pubis is approximated with a heavy nonabsorbable suture. During this step the assistant rotates the iliac bones anteriorly.

Hydrocelectomy

A hydrocele is an abnormal accumulation of fluid within the scrotum. The fluid is contained within the tunica vaginalis. Excessive secretion or accumulation of hydrocele fluid may be the result of infection or trauma. A hydrocelectomy is the excision of the tunica vaginalis of the testis to remove the enlarged, fluid-filled sac. In older patients, the procedure is performed through a scrotal incision.

Procedural Considerations. The patient is placed in the supine position. Preparation and draping of the patient include routine cleansing of the external genitalia and draping of the patient with a fenestrated sheet. A minor instrument set is required, plus a small drain; a 30-ml syringe with a 20-gauge, 2-inch aspirating needle; and a suspensory dressing.

Operative Procedure

1. The surgeon makes an anterolateral incision in the skin of the scrotum over the hydrocele mass with a #10 or #15 blade (Figure 25-33, *A*). Bleeding is controlled with the electrosurgical unit (ESU).
2. Small retractors may be placed, after which the fascial layers are incised to expose the tunica vaginalis (Figure 25-33, *B*). With fine scissors, forceps, and blunt dissection, the hydrocele is dissected free and delivered (Figure 25-33, *C*). The sac is opened, and the fluid contents are aspirated.
3. The sac is inverted so that it surrounds the testis, epididymis, and distal cord. Excess tunica vaginalis is excised, and the edges of the tunica are sutured with a continuous 4-0 absorbable suture behind the testicle (Figure 25-33, *D*). The testicle is "bottled" by the inverted tunica vaginalis, and this may then be returned to the sac.

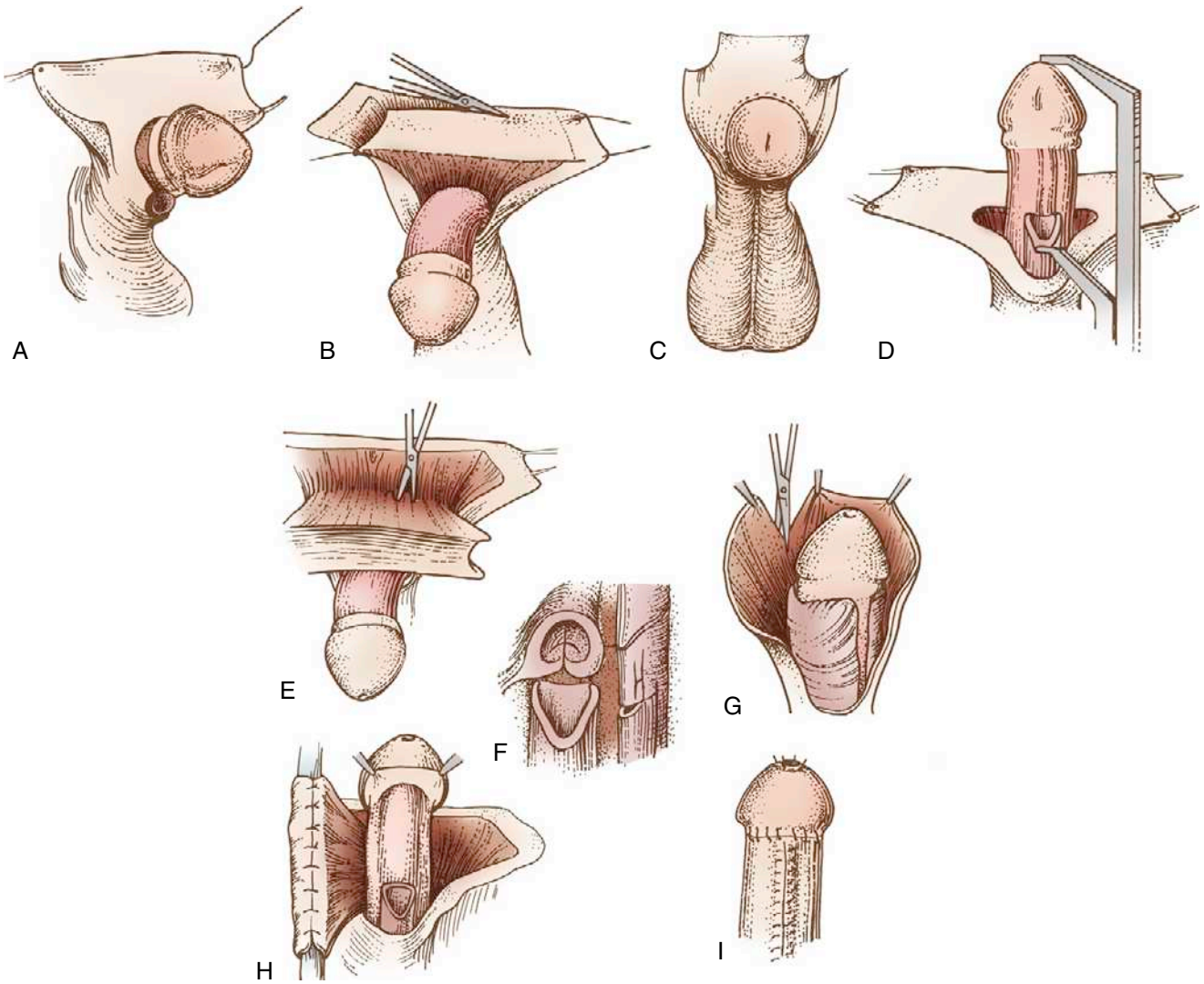


FIGURE 25-31 Urethroplasty, island flap.

4. A drain is placed within the scrotum and exteriorized through a stab wound in the most dependent portion of the scrotum. The scrotal incision is closed in layers with 3-0 and 4-0 absorbable sutures. A fluff compression dressing contained in a scrotal support (suspensory) helps reduce postoperative scrotal edema.

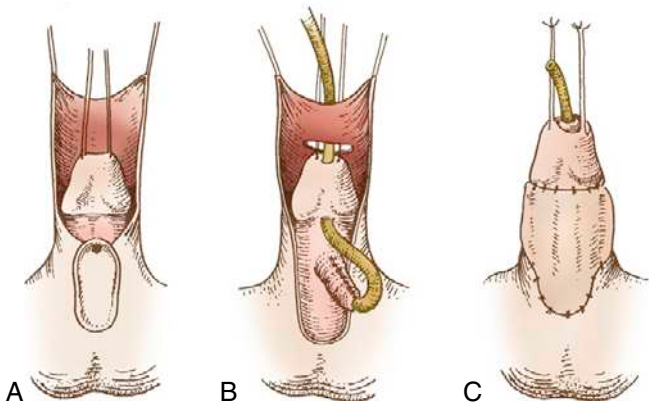


FIGURE 25-32 Skin cover procedure.

Orchiopexy

An orchiopexy is the surgical placement and fixation of the testicle in a normal anatomic position in the scrotal sac. If the testis fails to descend into the scrotum during gestation, it is considered undescended. An undescended testis becomes arrested somewhere along its normal path of descent. If it is palpable in a position other than its normal path of descent, its position is considered to be ectopic.

A retractile testis has fully descended into the scrotum but retracts out of the scrotum as a result of contraction of the cremaster muscle. Gentle manipulation allows replacement of the testis in the most dependent portion of the scrotum. Retractile testes require no surgical or hormonal treatment.

All testes that are undescended after 1 year, including those that are unresponsive to hormone injections, require surgical placement in the scrotum for optimum maturation. Laparoscopic exploration may also be used to determine position, existence, or size of a "hidden" testis.

Procedural Considerations. The setup is the same as that described for hydrocelectomy. Prepping and draping include the lower abdomen, genitalia, and thighs. Because this operation is

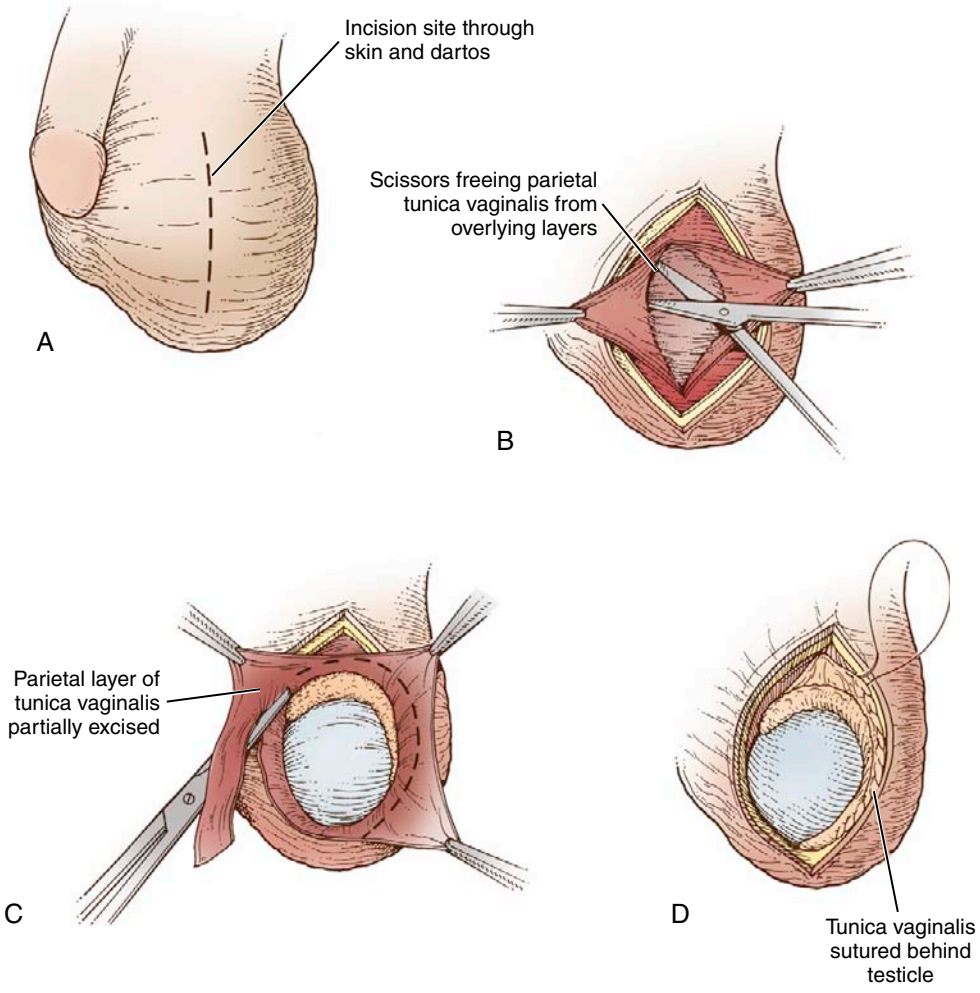


FIGURE 25-33 Hydrocelectomy.

usually performed on children, a setup containing small, delicate instruments and sutures is required.

Operative Procedure

1. An inguinal incision is generally employed for exploration of undescended testes (Figure 25-34, *A*). Most undescended testes are located in the superficial inguinal pouch or inguinal canal.
2. The external oblique aponeurosis is opened through the external inguinal ring to expose the inguinal canal; the gubernacular attachments of the undescended testis are dissected free as high as the internal inguinal ring or into the abdominal cavity (Figure 25-34, *B*).
3. All adhesions and the associated inguinal hernia sac are freed to lengthen the cord so that the testis is allowed to reach the scrotal cavity (Figure 25-34, *C*). The hernia sac is transected, twisted, and ligated with sutures.
4. To draw vessels into the inguinal canal, more proximal to the scrotum, the floor of the inguinal canal may have to be divided at the internal ring (Figure 25-34, *D*).
5. The lateral portion of the internal ring is closed to prevent herniation. A scrotal pocket is created, and the testis is anchored in a normal anatomic position within the scrotum with absorbable sutures (Figure 25-34, *E* to *K*).

Orchiopexy may be accomplished by several surgical methods. The dependent portion of the undescended testis may be sutured to the base of the scrotum with absorbable or nonabsorbable sutures exteriorized through the scrotal wall and tied over a peanut dissector or pledget. The most popular method is to anchor the testis into a dissected subdartos pouch. In this procedure, a small midtransverse scrotal incision is made and the skin and dartos muscle are dissected to create a pouch. The testis is then moved through a small hole in the dartos into the subdartos pouch and anchored in position by the traction suture. The overlying skin of the subdartos pouch is closed with fine absorbable suture material. The inguinal incision is repaired in layers with 3-0 absorbable sutures. The skin is closed with a subcuticular suture, and cyanoacrylate glue is used for dressing.

Vesicoureteral Reflux

Vesicoureteral reflux (VUR) is defined as the retrograde flow of urine from the bladder to the ureter and even to the kidney pelvis. Children are usually initially diagnosed with the occurrence of a febrile urinary tract infection (UTI). The workup for reflux will include a renal bladder ultrasound with prevoid and postvoid views as well as a voiding cystourethrogram (VCUG). The VCUG is used to grade the reflux, with grade I being the least and grade V being the most extensive reflux. Children with VUR are given prophylactic antibiotics and checked yearly. Children with unresolved reflux or breakthrough infections will probably require repair of the reflux. Currently there are two types of repair. For lower-grade reflux the most common approach is the minimally invasive approach of cystoscopy with injection of Deflux at the ureteral orifice into the bladder wall (Research Highlight). If the reflux is more severe, the child may require reimplantation of the ureter into the bladder wall.

Procedural Considerations—Deflux. The setup for Deflux injection includes the same basic instrument setup as described for cystoscopy including a 10F offset cystoscope, light cord with a light source, cystoscopy fluid delivery tubing, Deflux needle, syringe of Deflux, and camera and monitor for the surgeon to view the procedure. The offset scope is the key to a good injection because the lens is offset at approximately a 45-degree angle and the port to insert the needle through the scope comes straight off the end of the scope. The patient is placed in dorsal lithotomy position for the procedure.

Operative Procedure

1. The pediatric offset cystourethroscope is lubricated and inserted through the urethra into the bladder. The light cord, camera, and irrigation tubing are attached to the cystoscope, a urine specimen for culture is obtained, and then an examination is performed.
2. The bladder is partially filled, to allow for visualization.
3. The irrigation fluid is jetted into the ureteral orifice, opening it wide (hydrodistention), and then the needle is introduced under the mucosa of the midureteral tunnel at the 6-o'clock position. The needle tip is positioned just under the urothelium and is advanced 4 to 5 mm in the submucosal plane of the ureter. Deflux is then injected until a prominent bulge appears, and the orifice has assumed a volcano-like shape.
4. The needle is kept in position for 15 to 30 seconds after the injection to prevent extravasation of Deflux.

RESEARCH HIGHLIGHT

The Deflux Procedure Reduces the Incidence of Urinary Tract Infections in Patients with Vesicoureteral Reflux

A prospective review of 100 charts between June 2003 and June 2005 was conducted to evaluate the effectiveness of a single application of dextranomer/hyaluronic acid co-polymer (Deflux) in reducing the incidence of urinary tract infections (UTIs) in children with vesicoureteral reflux (VUR). The mean age of the study population was 3.8 years, and 76% were female. Study demographics included the number of UTIs preoperatively and postoperatively, a radiographic grade of VUR on a voiding cystourethrogram (VCUG), and the presence of VUR on a radionuclide VCUG 3 three months following the procedure. The t-test was used to analyze data.

A total of 155 ureters were graded and treated with a single injection of Deflux; 10 ureters had grade I reflux, 42 had grade II, 76 had grade III, 25 had grade IV, and 2 had grade V. After the initial injection, 77.4% of the study population reported grade 0 reflux at 3 months. A second injection was needed in 22 ureters. After the second injection, the success rate of the procedure was 83.9% overall. The success rates for each grade of reflux were as follows: grade I reflux experienced a 100% success rate; grade II reflux experienced an 88.1% success rate; grade III reflux experienced an 86.8% success rate; grade IV reflux experienced a 64% success rate; grade V reflux experienced a 50% success rate. Of the 100 patients, 75 had a UTI before the Deflux procedure and 13 had a UTI after the Deflux procedure. These results contributed to a decrease in the incidence of annual UTIs from a mean of 0.68 to 0.12 ($p = 0.001$). These results indicate that Deflux is effective in eliminating VUR and reducing the incidence of UTIs and antibiotic use in children with VUR.

Modified from Wadie GM et al: The Deflux procedure reduces the incidence of urinary tract infections in patients with vesicoureteral reflux, *J Laparoendosc Adv Surg Tech A*, 17(3):353-359, 2007.

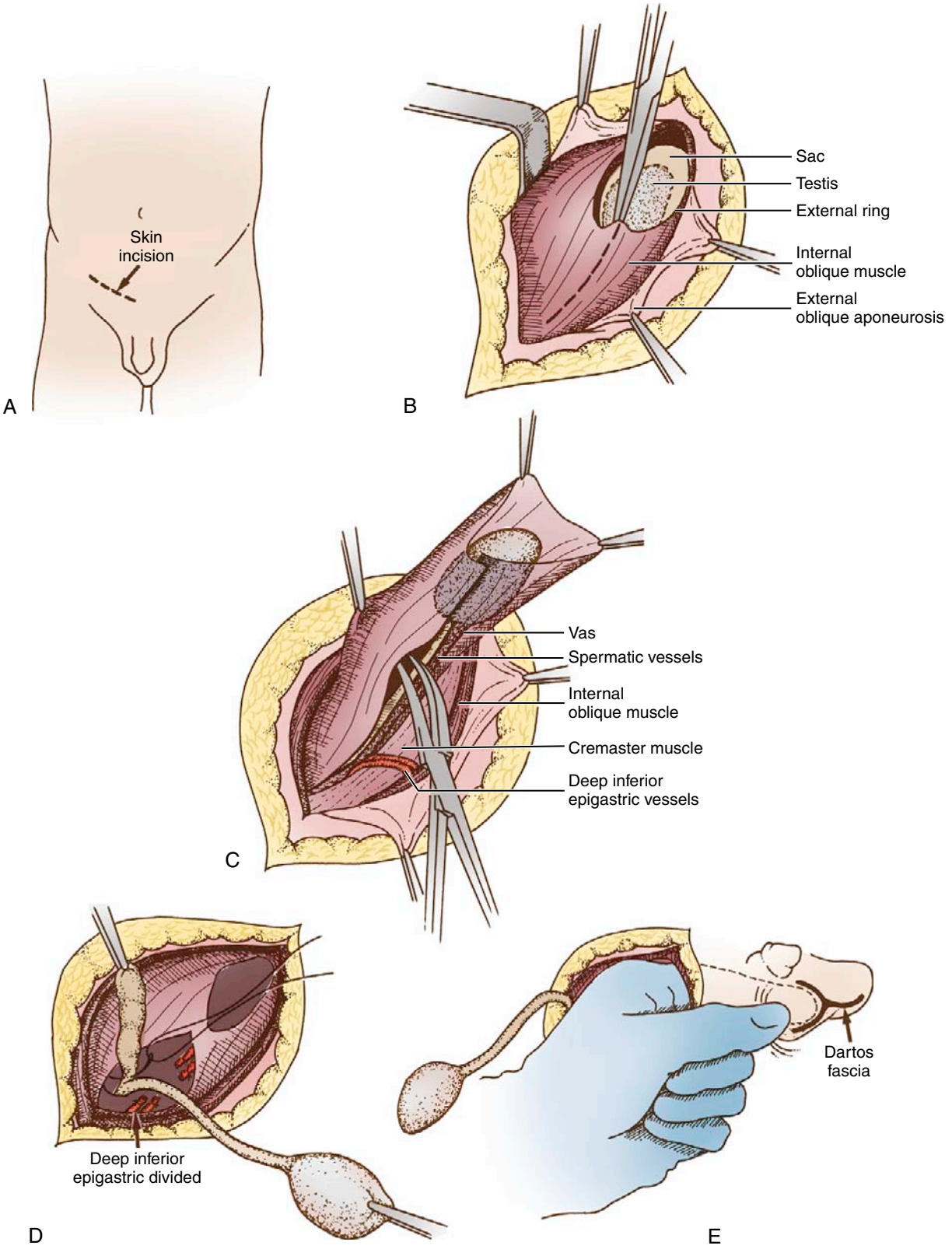


FIGURE 25-34 Orchiopexy.

Continued

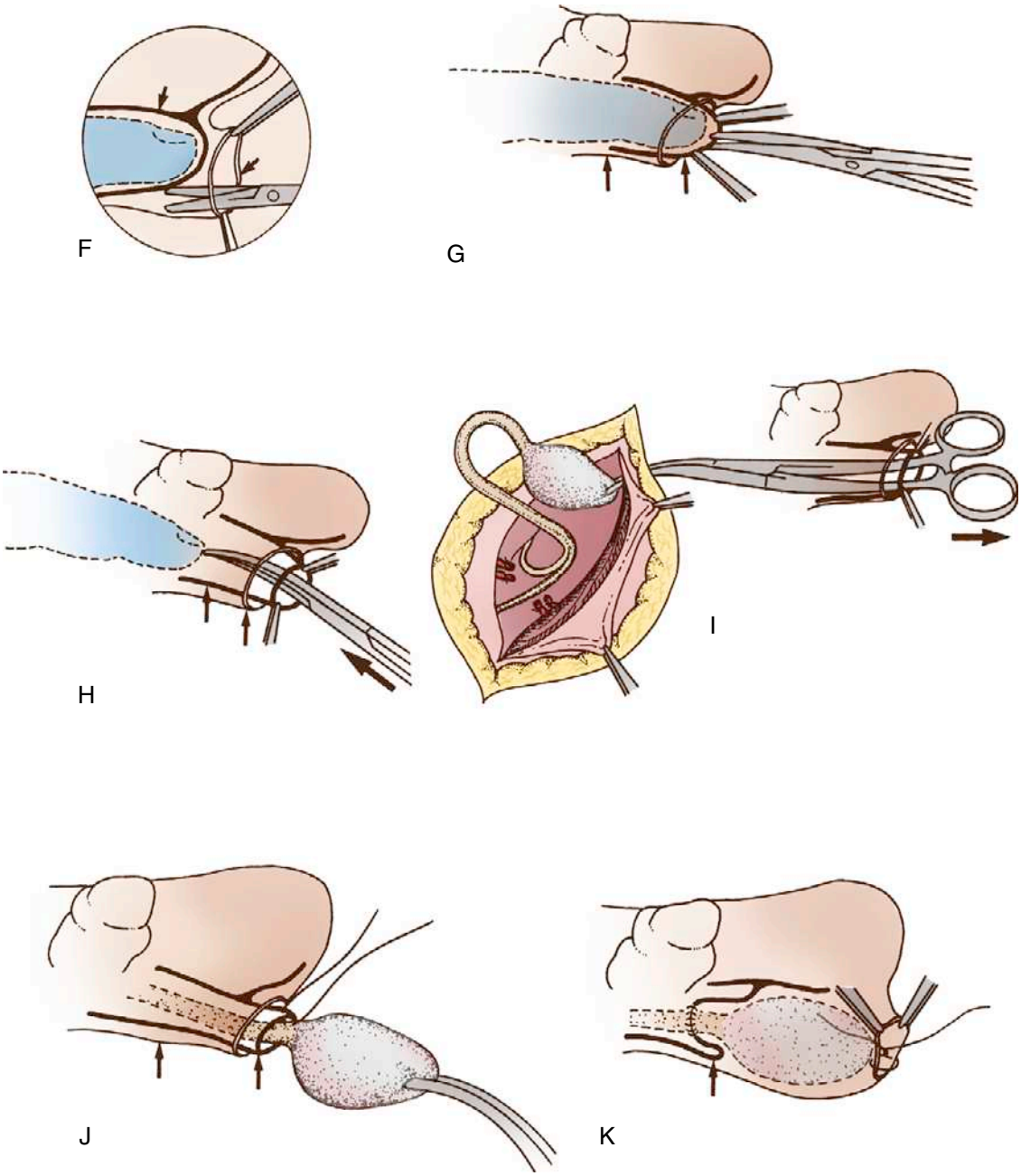


FIGURE 25-34, cont'd Orchiopexy.

5. The needle is removed, the bladder is decompressed, the scope is removed, and the patient is returned to the supine position.

Procedural Considerations—Reimplantation of the Ureter. Reimplantation of the ureter is indicated in children with high-grade VUR. The patient rarely requires a cystoscopy before the operative procedure. A Foley catheter will be placed intraoperatively. The patient is placed in the supine position.

Operative Procedure

1. The surgeon makes a Pfannenstiel incision.
2. The anterior rectus fascia is opened transversely, and then flaps are developed superiorly and inferiorly above the muscle using blunt dissection.
3. The rectus muscle is separated at the midline along the linea alba.
4. The bladder is exposed and then opened in the midline approximately 2 cm above the bladder neck. The bladder is decompressed and then packed with radiopaque sponges.
5. A Denis-Brown retractor is placed, and the trigone is exposed.
6. The ureter is identified, and a 6F or 8F feeding tube is placed; then the ureter is dissected with minimal tissue handling and an absorbable stitch is used to tag the orifice. The ureter is then further dissected sharply with tenotomy scissors, completely freeing it from the bladder wall and allowing it to move freely.

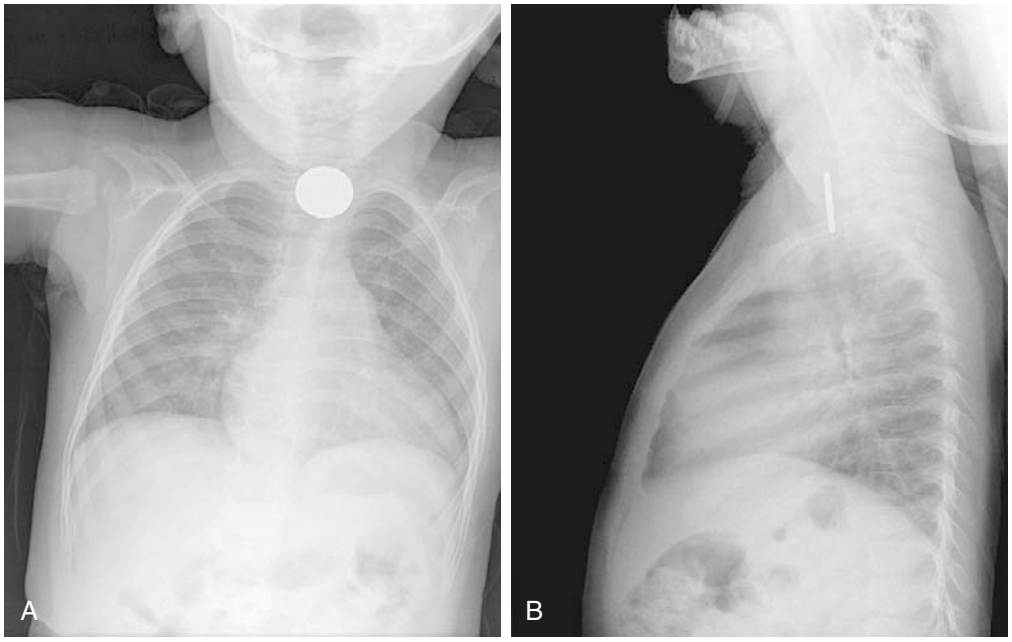


FIGURE 25-35 **A**, Anteroposterior view of coin trapped in esophagus. **B**, Lateral view.

7. The original ureteral orifice is then used to begin the dissection for a tunnel leading to the new outlet between the bladder mucosa and the detrusor muscle.
8. The suture tag is then passed through the tunnel, bringing the ureter to its new outlet.
9. The ureter is sutured in place with interrupted absorbable stitches circumferentially, and the feeding tube is removed from the ureter. If ureteral catheters are left in place, they are exteriorized through the bladder and skin and sutured in place.
10. The sponges are removed from the bladder.
11. The Denis-Brown retractor is removed from the field.
12. The bladder is closed with a running absorbable suture (a suprapubic tube may be placed during the closure). A Penrose drain may be inserted and stitched in place with a nylon suture.
13. The fascia is closed with a running absorbable suture, and the skin is approximated with a running subcuticular closure. Cyanoacrylate glue is applied. If a drain is used, an absorbent wound dressing is applied and Montgomery straps are used in order to make dressing changes easier for the child, using twill tape to string in shoelace-like fashion to close the dressing.

OTORHINOLARYNGOLOGIC PROCEDURES

Foreign-Body Removal

In the normal course of exploration and play, children often ingest foreign objects or place objects in their noses or ears. Most foreign bodies that are ingested pass safely through the digestive tract without incident and do not need to be removed. If the foreign body is sharp, is caustic (i.e., batteries), or becomes lodged (Figure 25-35), it may need to be removed by esophagoscopy (see Chapter 18) or through an open procedure.

The external ear canal and nose are other areas of interest to curious children. Common objects placed in the nares and external ear canal are dried beans, buttons, plastic objects, metals, food, erasers, nuts, seeds, and button batteries. Items placed in the ear can cause bleeding and difficulty with hearing. A high index of suspicion should be raised in the child with unilateral rhinorrhea, nasal crusting, and air outflow obstruction because these symptoms are often caused by a nasal foreign body. Foreign bodies in the nose and ear may require removal in the OR setting with conscious sedation or a general anesthetic.

The most significant risk of foreign-body ingestion is aspiration. Children are more prone to aspiration than adults because their laryngeal sphincters are immature, they do not have molars to chew all foods adequately, and they often run, shout, and play with objects in their mouths. A study conducted at the Johns Hopkins Hospital tracked common aspirated items between 1939 and 1991 (History box). Today, children continue to present with the similar trends in terms of commonly aspirated food items—candy/gum, peanuts and other nuts, seeds, popcorn, hot dogs, vegetable matter, meat matter, and fish bones. The most commonly aspirated nonfood items are coins, toy parts, crayons, pen tops, tacks, nails, needles, pins, beads, and screws. Aspiration may produce a complete or partial airway obstruction (Figure 25-36). Foreign objects in the respiratory tree are removed by means of rigid or flexible bronchoscopy (see Chapter 22).

Tonsillectomy and Adenoidectomy

A tonsillectomy and adenoidectomy is indicated primarily either for relief of pharyngeal obstruction or for recurrent pharyngitis or tonsillitis.

Pharyngeal obstruction is revealed by a history of sleep-disordered breathing. Mouth breathing, snoring, pauses in breathing, restless sleep, waking at night, and enuresis may be related to obstruction. Daytime somnolence and an inability to concentrate may also be indicators of poor sleep quality. Tonsil size is graded on a scale of 1 to 4, with 1 being contained within the tonsillar fossa and 4 with the tonsils touching each

HISTORY

Pediatric Tracheobronchial Foreign Bodies

Direct laryngoscopy and bronchoscopy date as far back as 1895, and the first successful bronchoscopy in the United States took place in 1898. At that time, the death rate for patients with tracheobronchial foreign bodies was 50%. Chevalier Jackson is renowned for developing the diagnostic and therapeutic principles that are the cornerstone of foreign-body evaluation as well as for advancing pediatric foreign-body aspiration treatment. These techniques, in conjunction with improvements in instrumentation and anesthetic management, have resulted in a death rate that is less than 1% today.

A historical review of 167 pediatric tracheobronchial foreign bodies between 1939 and 1991 indicated that 60% were of the vegetable origin, with peanuts accounting for 39.9% overall. Other popular foreign bodies included plastic toys, safety pins/tacks, edible seeds, small hardware (nails, screws), and miscellaneous food items. Foreign-body aspiration occurs most commonly in children ages 6 months to 4 years and is a serious and potentially fatal occurrence. Although foreign-body aspiration is classically diagnosed by a triad of sudden onset of paroxysmal coughing, wheezing, and decreased breath sounds on the affected side, these symptoms may not present in all cases. Furthermore, chest radiographs may show no obstruction, which supports the practice of bronchoscopy as a method to rule out foreign-body aspiration when it is clinically suspected.

Modified from Hughes CA et al: Pediatric tracheobronchial foreign bodies: historical review from the Johns Hopkins Hospital, *Ann Otol Rhinol Laryngol* 105(7):555-561, 1996.

other in the middle of the pharynx. Adenoids are not able to be visualized through the mouth, but symptoms of adenoid enlargement can include mouth breathing, nasal congestion, rhinorrhea, and hyponasal speech. Flexible nasolaryngoscopy and lateral neck radiography can aid in diagnosis of nasopharyngeal obstruction.

Recurrent episodes of pharyngitis sufficient enough to warrant surgical removal should take into consideration the amount of time a child is absent from school, the amount of work time the parent misses, the number of days a child requires antibiotics, and the child's risk for poststreptococccal complications such as glomerulonephritis or mitral valve damage. Three episodes of β-hemolytic streptococcus pharyngitis or more than five episodes of streptococcal/non-streptococcal pharyngitis in the course of a 1-year period would generally merit surgical removal.

An additional reason for tonsillectomy would be a marked difference in tonsil size. Lymphoma on rare occasion may present in this fashion. Unusually enlarged tonsils in an immunosuppressed transplant recipient may also be indicative of post-transplant lymphoproliferative disorder.

Other indications include dysphagia from obstructing tonsils, halitosis from tonsilloliths, and recurrent adenoiditis contributing to sinusitis or otitis media.

A variety of surgical techniques are currently used for tonsillectomy and adenoidectomy. The technique most commonly used is electrosurgery for both (hot) dissection and hemostasis. Other techniques include cold dissection (adenoid curettage and #12 blade for tonsillectomy), radiofrequency, coblation, and laser.

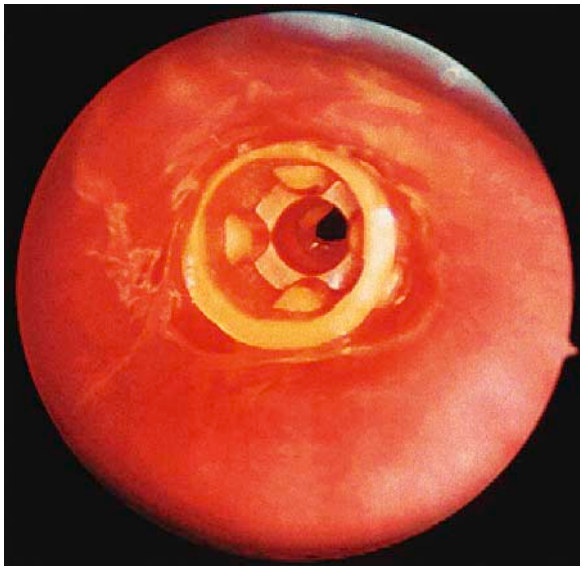


FIGURE 25-36 Foreign body causing partial airway obstruction.

Procedural Considerations. The patient is positioned supine. An oral endotracheal tube with a preformed bend, such as the Ring, Adair, or Elwin (RAE), is used to facilitate visualization of the surgical field. The neck is extended by placing a small roll under the shoulders. Typical draping includes a head drape and an impervious sheet over the patient; no prep is used. The following description is of a hot (electrocoagulation) dissection tonsillectomy with microdebrider dissection adenoidectomy.

Operative Procedure

1. The surgeon inserts a mouth gag retractor with a size-appropriate tongue blade, taking care to keep the tongue in midline position with the endotracheal tube protected by the blade.
2. The posterior and lateral walls of the pharynx are carefully inspected and palpated to detect abnormally positioned vessels.
3. The soft palate is palpated to detect a submucous cleft palate. A bifid uvula is often associated with this anomaly. If this is the case, complete removal of the adenoids can cause velopharyngeal insufficiency.
4. The tip of a 12F red rubber catheter is advanced through one of the nares, into the nasopharynx and out through the mouth. The catheter is gently stretched and the two ends are clamped snugly with a Kelly clamp near the upper lip to retract the soft palate forward.
5. The adenoids are visualized with a laryngeal mirror and removed under direct visualization using either a microdebrider or a suction electrocoagulator. Care is taken to preserve the torus tubarius surrounding the eustachian tube opening. If a microdebrider is used, the nasopharynx is then packed firmly with thoroughly moistened radiopaque tonsil sponges.
6. The superior pole of the first tonsil is grasped with an Allis clamp. A monopolar electrosurgery pencil with a guarded spatula tip is used to make mucosal cuts along the anterior tonsil pillar and superior edge of the fossa.
7. The tonsil is carefully dissected out, following the plane of the tonsillar capsule, while retracting the tonsil medially with the Allis clamp.

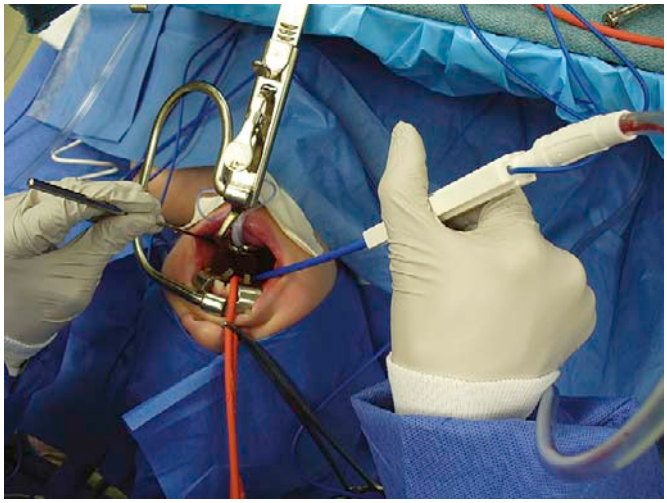


FIGURE 25-37 Electrocoagulation of bleeding in the adenoid bed.

8. The final attachment of the inferior portion of the pharyngeal tonsil to the lingual tonsil is transected with the electrocoagulator. Any vessels encountered during the dissection are electrocoagulated.
9. Monopolar suction electrocoagulation is used to attend to any residual bleeding or prominent bleeding vessels. A Hurd dissector is used to retract the anterior tonsillar pillar and improve exposure of the tonsillar fossa during hemostasis. The laryngeal mirror is used to help visualize the recessed superior pole of the tonsillar fossa.
10. This procedure is repeated for removal of the left tonsil.
11. The sponges packing the nasopharynx are then removed. Any areas of bleeding in the adenoid bed are electrocoagulated using the suction electrocoagulator and laryngeal mirror (Figure 25-37).
12. At this point, the mouth gag is released for a brief period, and then reopened. The nasopharynx and oropharynx are reinspected to ensure that there is no further bleeding from vessels that may have been compressed by the opened mouth gag.
13. The oropharynx may be irrigated with 50 to 60 ml of normal saline solution to evaluate for any additional signs of bleeding. The endotracheal tube cuff should be inflated or the anesthesia provider should maintain positive-pressure inflation during the irrigation to prevent inadvertent passage of the irrigation into the trachea.
14. The red rubber catheter is removed. The mouth gag retractor is carefully removed from the oral cavity to prevent inadvertent extubation of the patient.
15. Dentition, temporomandibular joint mobility, and perioral skin are reinspected for inadvertent surgical complications

Excision of Branchial Cleft Cyst/Remnant/Sinus Tract

Congenital branchial cleft anomalies are remnants of the branchial arch apparatus that failed to disappear during early embryologic development. At approximately 5 weeks' gestation, the branchial arches are associated with an external cleft of ectodermal origin and an internal pouch of endodermal origin. Anomalies that remain from incomplete resolution can be in the form of a branchial cleft cyst, a sinus, or a fistula. The location of branchial cleft anomalies ranges from the preauricular area (type 1) to the lateral neck along the sternocleidomastoid muscle (types 2, 3, and 4). A cyst may not become apparent until later in childhood, typically during times of acute infection or possible abscess formation, and can occur anywhere along the course of a branchial sinus tract or fistulous tract. A sinus tract usually has an external opening to the neck, generally along the anterior border of the sternocleidomastoid muscle. A fistula has both an external opening and an internal opening; the internal opening is usually in the area of the pyriform sinus near the tonsil on that side. Excision of the branchial cleft anomaly is indicated if it is cystic in nature or if it has become infected. The infection must be treated before surgical excision; if an abscess is present an incision and drainage may be needed.

Procedural Considerations. Imaging studies (computed tomography [CT], magnetic resonance imaging [MRI]) are helpful to determine the presence of an associated tract. The patient will be positioned supine with a roll under the shoulders to slightly extend the neck. A surgical drain, such as a rubber band, is frequently placed. Antibiotics are usually given intraoperatively before surgical incision. Description of a branchial cyst (type 2) excision follows.

Operative Procedure

1. A transverse skin crease overlying the lesion and 1.5 cm below the margin of the mandible is selected. The surgeon injects the proposed incision line with 1% lidocaine with 1:100,000 epinephrine.
2. The surgeon makes the skin incision with a #15 blade through the skin and subcutaneous tissues.
3. The platysma muscle is divided with the ESU.
4. The tissues overlying the cyst are gently dissected with fine forceps and small scissors or a small gauze peanut.
5. The cyst is gently grasped with a Babcock clamp. Surrounding tissue is dissected free from the cyst using small scissors to spread between the cyst capsule and surrounding tissue and then to cut through fibrous attachments.
6. If a pedicle or fibrous tract is identified, it is followed as far cephalic as possible before it is clamped, cut, and tied with 3-0 absorbable suture.
7. A small rubber band drain is usually placed to prevent accumulation of fluid or blood in the dissected cavity. A safety pin or suture is attached to the distal end of the drain; the drain is removed within 24 hours.
8. The wound is closed in layers. The skin is closed with subcuticular sutures, and adhesive strips are applied to keep the wound edges approximated.

NEUROSURGICAL PROCEDURES

Neuropathologic conditions requiring surgical intervention can be found in any age group. The most common problems requiring neurosurgical procedures in infants and children include meningocele, myelomeningocele, encephalocele, craniosynostosis, hydrocephalus, brain tumors, and trauma. The surgical approach, instruments, and equipment required for brain tumors and trauma are relatively similar to those required for adults; consequently, the majority of these procedures are as described in Chapter 20.

Myelomeningocele/Meningocele

Myelomeningocele (Figure 25-38) is a form of spina bifida and is always associated with Chiari type II malformations. It occurs because of a congenital flaw in neural tube closure at approximately 8 to 12 days after conception. The failure of the neural tube to close correctly causes a defect in the posterior elements of the lumbar vertebrae, fascia, and dura, allowing the meninges, spinal cord, and nerve roots to protrude out in a sac or cyst through the skin. The exposed spinal cord is called the neural placode and is not properly developed; there is always some degree of paralysis and loss of sensation below the defect. The amount of disability depends on the vertebral level of the spina bifida and frequently includes loss of bladder and bowel function and hydrocephalus. Meningoceles are similar to myelomeningoceles but not as neurologically devastating: meninges and cerebrospinal fluid (CSF) protrude into the defect but not the spinal cord.

Procedural Considerations. Infants born with either of these defects need to be given broad-spectrum antibiotics immediately after birth and taken to the OR within 24 hours for closure of the defect. Nursing care includes ensuring the area of the defect is covered with sterile gauze kept moistened with normal saline solution; positioning the infant so that the defect is not compressed; and maintaining the infant's body temperature, a more difficult task because of the need to keep the exposed defect moist. A very high percentage of children with this defect develop an allergy to latex; surgical closure and all subsequent surgical procedures should be performed in a latex-free environment.

Operative Procedure

1. The surgeon makes an elliptical incision around the defect with a #15 blade.
2. Metzenbaum scissors are used to remove the pearly epithelial tissue around the neural placode. Retention of the epithelial tissue can lead to formation of a postoperative epidermoid.
3. Using the Metzenbaum scissors, the surgeon performs blunt dissection following the nerve tissue on the ventral side of the placode down to the spinal canal.
4. The dura is then separated from the fascia with the Metzenbaum scissors.
5. Using 4-0 braided nylon suture, the surgeon closes the dura over the neural placode.

FIGURE 25-38 Examples of meningocele and myelomeningoceles. **A**, Meningocele. Lesion is covered by skin and meninges. **B**, Myelomeningocele. Neural component evident at central strip of lesion. **C**, Thoracolumbar myelomeningocele. **D**, Severe myelomeningocele. Neural tissue in center represents the open spinal canal.

6. A #11 blade and Metzenbaum scissors are used to free the fascia from the muscle layer.
7. Braided nylon suture is used to close the fascial layer over the dura.
8. The muscle layer is then closed, followed by skin closure.

Craniectomy for Craniosynostosis

Craniosynostosis is the premature fusion of one or more cranial sutures. The condition can occur as part of a syndrome or as an isolated process. Craniosynostosis is characterized as "simple" when only one suture line is involved and "compound" when two or more suture lines are involved. The defect occurs in utero, and the exact etiology remains unknown. The purpose of the cranial sutures is to allow the calvaria to bend during the birth process and to allow the skull to expand to accommodate normal brain growth during infancy. The normal brain is finished growing by 2 years of age; at this time fusion of the cranial sutures normally begins. The fusion process is complete by 8 years of age.

Sagittal synostosis accounts for approximately 50% to 58% of all the synostoses with equal distribution between males and females (Sheth et al, 2008). The sagittal suture runs in the midline of the skull, connecting the anterior fontanelle to the posterior fontanelle. Premature closure of this fontanelle produces an elongation of the skull in the anteroposterior plane. Surgical intervention involves a linear strip craniectomy to excise the sagittal suture line from the anterior fontanelle to the lambdoidal suture line. Surgery is generally performed on the infant between 6 weeks and 6 months of age, with the best cosmetic results coming from the earlier repair. A craniectomy for sagittal synostosis is described.

Procedural Considerations. The infant is positioned supine using a cerebellar headrest. Additional measures need to be taken to maintain the infant's normal body temperature; room temperature should be elevated, and a forced air–warming blanket should be used. An overbed warmer should be used during anesthesia induction and IV placement.

Operative Procedure

1. A sinusoidal incision is made midway between the anterior and posterior fontanelles from ear to ear, just posterior to the pinna.
2. The scalp is elevated off the skull anteriorly and posteriorly to expose the anterior fontanelle, posterior fontanelle, and asterion. Care is used to leave the pericranium attached to the skull to minimize bleeding.
3. A burr hole is made on each side of the sagittal suture on the lambdoidal suture.
4. A craniotome is used to cut anteriorly to the anterior fontanelle on each side of the sagittal suture. A Leksell or Lempert rongeur is used to cut across the sagittal suture and connect the burr holes.
5. A Cobb periosteal elevator is used to carefully dissect the sagittal suture off the underlying dura.
6. A burr hole is placed at the asterion on each side. The craniotome is used to make a curvilinear cut just posterior to the coronal suture.
7. The parietal bone is then "greensticked" (fractured but leaving the periosteum intact) laterally.
8. The skin is then closed with 3-0 and 4-0 absorbable sutures.

Ventriculoatrial and Ventriculoperitoneal Shunts

Hydrocephalus is characterized by excess production of CSF or is associated with a blockage in the ventricular drainage system. Early intervention is indicated in infants to prevent cranial distortion caused by the increasing size of the ventricles (Figure 25-39).

The two most widely used pediatric surgical procedures to divert excessive CSF from the ventricles to other body cavities from which it can be absorbed are ventriculoatrial (ventriculocardiac) (Figure 25-40) and ventriculoperitoneal shunts. See Chapter 20 for complete information related to these two procedures.

ORTHOPEDIC PROCEDURES

Pediatric orthopedic surgery may encompass the following areas: spine disorders, sports medicine, cerebral palsy, musculoskeletal tumors and injuries, foot and ankle disorders,

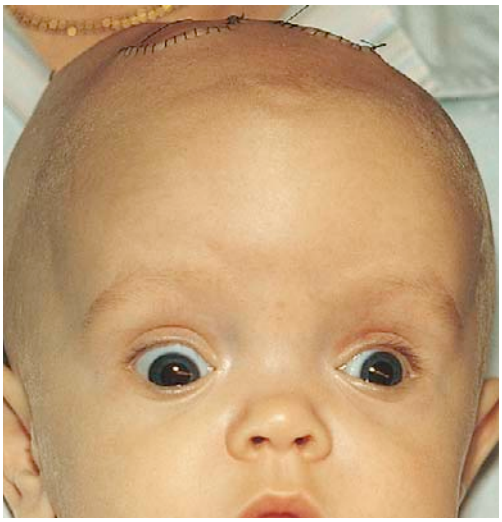


FIGURE 25-39 Infant with hydrocephalus.

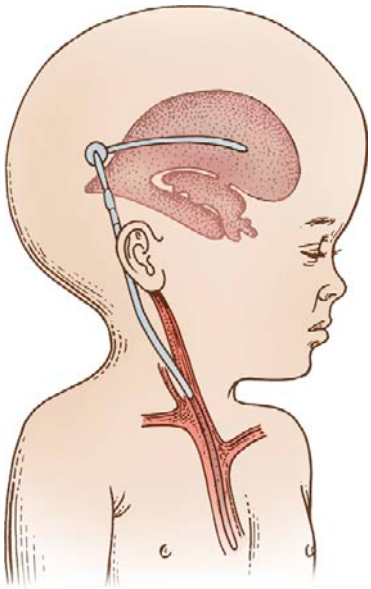


FIGURE 25-40 Placement of ventriculoatrial shunt.

limb length discrepancy, hip disorders, hand surgery, limb deficiency (amputations), thoracic insufficiency, and trauma. The majority of instrumentation, equipment, and procedural considerations are similar to those described in Chapter 19, Orthopedic Surgery. Nonetheless, there are treatment modalities and procedures that are more commonly performed in the pediatric population than in the adult population. Procedures for developmental dysplasia of the hip, abductor and adductor tenotomy, and variations of clubfoot will be described in this section.

Developmental Hip Dysplasia

Until recently, dislocation of the hip seen in newborns was referred to as "congenital dislocation of the hip" (CDH). The term *developmental dysplasia of the hip (DDH)* has replaced the former name to reflect the evolutionary nature of hip problems in the first few months of life. DDH is a progressive condition in which the hip structures fail to develop adequately. Because the pathologic process leading to hip dysplasia may not be present or identifiable at birth, periodic exams of every infant's hips are essential at each routine baby exam until the child is 1 year old. About 1% of infants have dislocated, dislocatable, or subluxatable hips. Sixty percent of DDH cases occur in females, and 60% of all cases involve only the left hip (Wilson et al, 2008). DDH encompasses the entire spectrum of abnormalities involving the growing hip, ranging from simple dysplasia to dysplasia with subluxation or dislocation of the hip joint. The goal of DDH management is to achieve and maintain a concentric reduction of the femoral head within the acetabulum, in order to provide the optimal environment for the normal development of both structures. When proper alignment is disrupted, soft tissue and bony changes cause contractures of the hip muscles, a shallow acetabulum, and possibly a deformed femoral head. Treatment of congenital dislocation of the hip varies depending on the age of the patient and the stability of the hip. A Pavlik harness is the most commonly used nonoperative device in infants. If the Pavlik harness fails, the infant is brought to the OR and anesthetized for a closed reduction of the hip (proper positioning of the femur head within the acetabulum) confirmed by intraoperative arthrogram and fluoroscopy, with application of a spica cast. Failure of closed reduction and immobilization necessitates an open reduction with an adductor tenotomy to allow adequate abduction to reduce the femoral head; after surgery, children younger than 2 years are then placed in a postreduction spica cast. For children older than 3 years the surgeon may need to perform a shortening varus femoral osteotomy (derotational osteotomy) to facilitate reduction of the femoral head into the acetabulum. In addition, if the acetabulum coverage is inadequate, a pelvic realignment (pelvic osteotomy) procedure may be necessary. Many of the pediatric orthopedic plating systems offer congenital dysplastic hip implants, which can be used in the reconstruction.

Procedural Considerations. The patient most often is in the lateral position for these procedures. An anterior incision is usually made for open reduction, whereas a lateral incision is made for the subtrochanteric femoral osteotomy. A soft tissue set and bone set (appropriate for age) are required as well as an oscillating saw, a wire driver, Steinmann pins, blade plate implants, and instrumentation.

Operative Procedure

DDH OPEN REDUCTION (Figure 25-41)

1. The hip joint is opened, and the soft tissue in the acetabulum is excised.
2. The femoral head is then reduced into the acetabulum and held by suturing of the capsule.

DEROTATIONAL OSTEOTOMY. A derotational osteotomy is performed when the femoral head is improperly seated in the acetabulum.

1. The femur is placed in internal rotation and divided.
2. The distal fragment is rotated externally to place the knee and foot straight ahead.
3. If the patient is a young child, the osteotomy is frequently performed in the supracondylar region, and the patient is immobilized in a plaster spica cast.

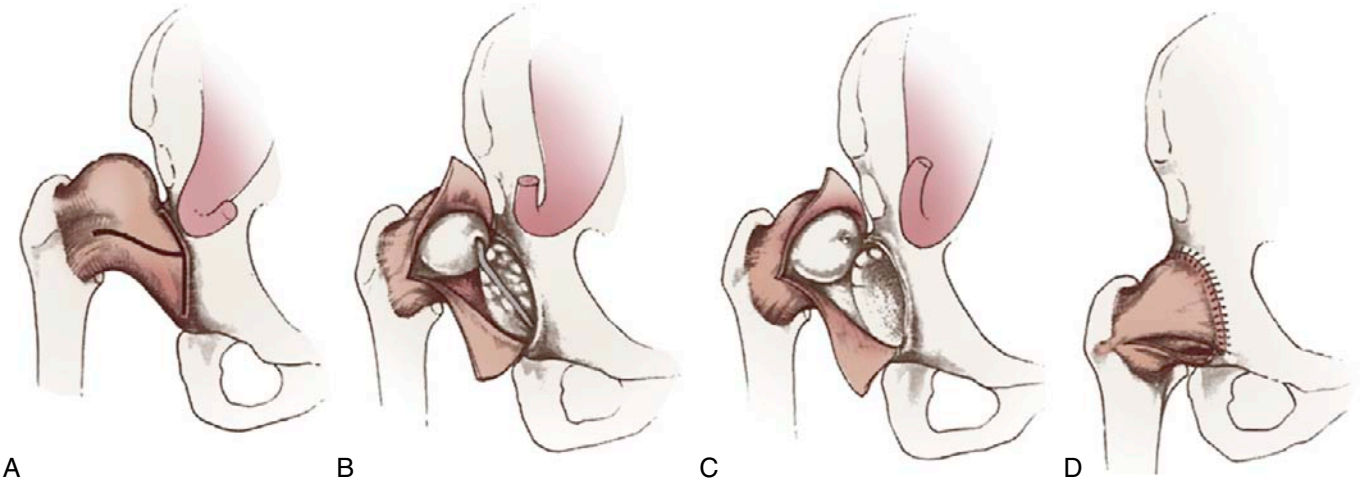


FIGURE 25-41 Repair of congenital hip disorder using open reduction. **A**, T-shaped incision of capsule. **B**, Capsulotomy of the hip and locating the true acetabulum. **C**, Removal of tissue from the depth of the acetabulum. **D**, Capsulorrhaphy.

4. For an older child, the osteotomy is frequently done in the subtrochanteric region and the osteotomized fragments are held with an osteotomy blade plate or an intermediate compression screw. Immobilization may not be necessary.

PELVIC OSTEOTOMY

1. A complete division of the wing of the ilium is made by an osteotomy from the sciatic notch to the anterior margin of the ilium, superior to the acetabulum.
2. The ilium is then wedged down to increase the depth of the acetabulum when the osteotomy site is opened and a bone graft is inserted.
3. Heavy suture is used to close the capsule, and a spica cast is applied for postoperative immobilization.

Tenotomy/Lengthening Procedures

Tenotomies and lengthening procedures are commonly recommended for children with cerebral palsy to treat contractures or because the spasticity of these muscles makes mobility and abduction and adduction of the extremities difficult (Wilson, 2008). These procedures may also be recommended as treatment for groin injuries where traditional medical treatment has failed. Once the tendons are cut, the affected extremity may be immobilized in a cast, brace, or splint to allow for healing and promote normal growth patterns. In other cases, a dressing may be applied without immobilization. The procedure may be performed open (as described here) or using percutaneous techniques.

Procedural Considerations. The patient is positioned supine for the procedure with the affected extremity or extremities draped free for prepping and draping.

Operative Procedure

1. The adductor longus, gracilis, and adductor brevis are lengthened through a medial groin incision to improve hip abduction.
2. The pectineus adductor brevis interval is exposed to locate the iliopsoas tendon. The iliopsoas tendon is divided to correct hip flexion contractures.
3. Wounds are irrigated and closed using absorbable suture. Cyanoacrylate glue dressing is applied to each incision line.

Clubfoot

Clubfoot is a complex deformity that is diagnosed prenatally through ultrasound or at birth. According to the American Academy of Orthopedic Surgeons (AAOS), clubfoot may occur unilaterally or bilaterally and may be idiopathic or one in a combination of other syndromes with associated anomalies (AAOS, 2007). The general characteristic for all cases includes inversion of the foot such that the anterior foot is located in the typical position of the posterior foot. Often, there is a deep crease in the midfoot. Each case of clubfoot differs in severity, but all require treatment. Treatment options include nonsurgical methods such as taping, bracing, physical therapy, or continuous passive motion exercise using a machine. When clubfoot is treated surgically, the following procedures are required: release of soft tissue and joint contractures, tendon lengthening, and temporary pin fixation of the joints in the foot. Many variations of surgical intervention exist, and one method is described in the following Operative Procedure.

Procedural Considerations. The patient is positioned supine for induction of anesthesia and surgical repair. A tourniquet is applied to the affected leg. The leg is prepped and draped free.

Operative Procedure

1. The surgeon makes an incision through the skin, subcutaneous tissue, and scar tissue posteriorly and medially on the affected foot with a #15 blade and dissects the tissue to locate the Achilles' tendon.
2. The Achilles' tendon is lengthened by tenotomy and scar tissue is removed.
3. The peroneal tendons are identified and lengthened by tenotomy, and dissection is carried around to the medial aspect of the foot.
4. The posterior subtalar capsule is identified and divided, and scar tissue is removed.
5. The posterior aspect of the ankle is identified, divided, and debrided of scar tissue. Dissection is carried around medially to the posterior tibialis tendon, taking care to isolate and protect the neurovascular bundle. The posterior tibialis tendon is released.
6. The medial aspect of the talonavicular joint is released. Foot flexion and rotation are verified and the surgical incision is irrigated and closed using absorbable dressings.
7. A bulky dressing and cast are applied to the affected foot and the tourniquet is deflated.

PLASTIC AND RECONSTRUCTIVE SURGERY

Cleft Lip Repair

The normal upper lip is composed of skin, underlying orbicularis oris muscle, and mucosa. Two skin ridges are situated near the midline of the central philtrum of the lip. The vermilion (red portion of the lip) peaks at the philtral ridge on each side and gently curves downward as it reaches the midline to form the Cupid's bow. A deficiency in tissue (skin, muscle, and mucosa) along one or both sides of the upper lip or, rarely, in the midline results in a cleft at the site of this deficiency. The deficiency of tissue present with a cleft lip results in distortion of the Cupid's bow, absence of one or both philtral ridges, and distortion of the lower portion of the nose. Cleft lip is usually associated with a notch or cleft of the underlying alveolus and a cleft of the palate.

Cleft lip repair is most often performed when the infant is about 3 months of age. Timing of the repair follows the "rule of 10": the infant is 10 weeks of age, weighs 10 pounds, and has a hemoglobin level of 10 g/dl. Early surgical correction aids in feeding and infant-parent bonding. Lip repair is directed toward rearrangement of existing tissues to approximate the normal lip as closely as possible. Some considerations may also be given to correcting the nasal deformity at the time of the cleft lip repair.

Procedural Considerations. A plastic surgery local instrument set is required, plus the following special instruments: Brown lip clamps; calipers; a Foment retractor; Beaver blades, #64 and #65; and a Logan bow. The OR bed is usually reversed

to create more knee room if the surgeon prefers to sit during the surgery. The patient is placed in the supine position, with the head at the edge of the OR bed. The face is prepped, and the head drape is used. The surgeon may stand or sit at the patient's side or just above the patient's head during the operation.

Operative Procedure

Many types of cleft lip repair are in common use, one of which is illustrated in Figure 25-42. The following steps are applicable to all lip repairs:

1. Normal landmarks are identified and marked or tattooed. Precise measurements, taken with calipers and a ruler, are made so that corresponding points can be marked along the cleft.
2. The lip may be infiltrated with epinephrine 1:200,000, or lip clamps may be used to aid hemostasis.
3. Incisions are made along the markings for the repair.
4. The abnormal musculature is dissected.
5. Additional dissection along the maxilla and nose may be performed.
6. Closure is done in three layers: muscle, skin, and mucosa. Adhesive strips may be used. A Logan bow is applied to the cheeks with tape strips, and elbow restraints are placed.

Cleft Palate Repair

The palate is composed of the bony or hard palate anteriorly and the soft palate posteriorly. The alveolus borders the hard palate. A separation or cleft of the palate occurs in the midline and may involve only the soft palate or both hard and soft palates. The alveolus may be cleft on one or both sides.

The major function of the soft palate is to aid in the production of normal speech sounds. An intact hard palate is necessary to prevent escape of air through the nose during speech and to prevent the egress of liquid and food from the nose.

Cleft palate repair is usually performed when the child is 6 months of age and should be achieved before the beginning of speech. Variable factors, including the child's weight and the possibility of other disease processes, can affect the timing of the surgery. The various operations used to achieve surgical closure of the palate all employ tissue adjacent to the cleft (in the form of flaps), which is shifted centrally to close the defect.

Procedural Considerations. A basic plastic surgery instrument set is required, plus the following special instruments: Dingman mouth gag with assorted blades; Blair palate hook; palate knives; Blair palate elevators; and Fomon lower lateral scissors, short and long. The patient is placed in the supine position, with the head at the edge of the OR bed. The head drape is used. Many surgeons sit just above the patient's head and cradle the head on their lap (with the patient's neck hyperextended).

Operative Procedure

One of the most frequently used cleft palate repairs is illustrated in Figure 25-43. The following steps are common to all palate repairs:

1. The Dingman mouth gag is inserted. Maintenance of the position of the endotracheal tube is crucial at this point. The surgeon may also insert a throat pack to absorb blood that may drain into the throat.

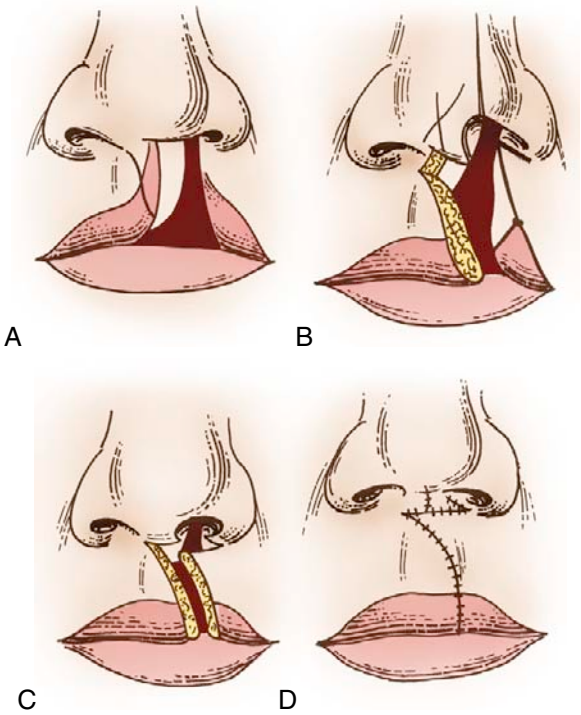


FIGURE 25-42 Rotation-advancement method to correct complete unilateral cleft of lip. **A**, Rotation incision marked so that Cupid's bow–philtral dimple component will rotate down into normal position; flap advances into columella to form nostril sill. **B**, Dimple component has dropped down; second flap has advanced into columella. **C**, Flap is being advanced into rotation gap, while skin-roll flap is interdigitated at mucocutaneous junction line. **D**, Scar is maneuvered into strategic position where it is hidden at nasal base and floor and at philtrum column; then it is interdigitated at mucocutaneous junction.

2. The outlines of the palatal flaps are marked.
3. The palate is injected with 1% lidocaine with epinephrine 1:100,000 for hemostasis.
4. The flaps are incised and elevated.
5. Closure is in three layers: nasal mucosa, muscle, and palatal mucosa.
6. A large horizontal mattress traction suture is placed through the body of the tongue. If the patient experiences upper airway obstruction after extubation, traction is placed on this suture to pull the tongue forward, rather than insert an airway that might harm the palate repair. The throat pack is removed.

Pharyngeal Flap

When abnormal speech (velopharyngeal insufficiency) results despite a cleft palate repair, a secondary surgical procedure may be necessary to improve speech. Primarily an excess of air escaping through the nose during speech characterizes typical "cleft palate speech." This hypernasality often results from insufficient bulk or movement of the muscles of the soft palate. To decrease or eliminate this problem, tissue from the pharynx, in the form of a pharyngeal flap, is added to the soft palate. This flap also reduces the size of the opening between the oropharynx and nasopharynx, thus decreasing or eliminating the nasal escape of air during speech.

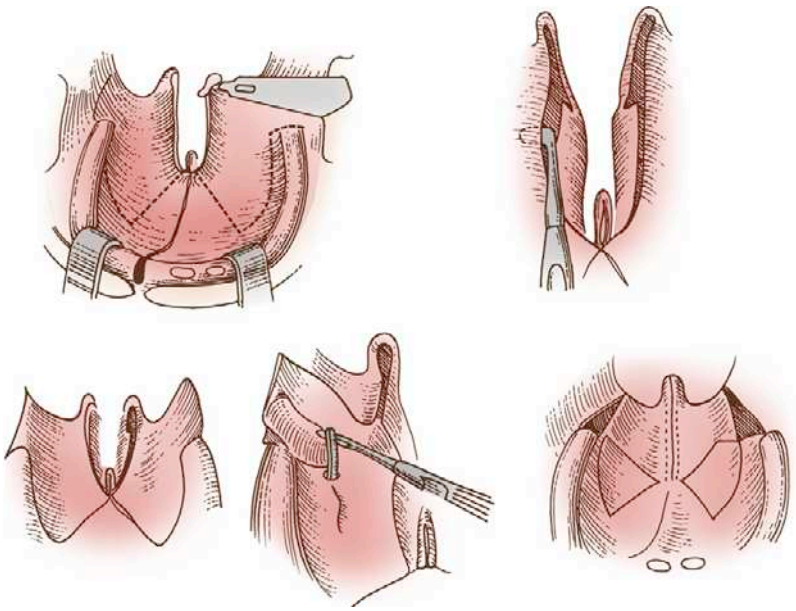


FIGURE 25-43 Closure of cleft of soft palate by V-Y (Wardill-Kilner) palatoplasty. A V-shaped incision is made on oral side of palate; mucoperiosteal flaps are elevated on oral and nasal sides, with preservation of blood vessels; Y-shaped closure (in three layers) closes cleft and lengthens palate.

A pharyngeal flap repair may be done at any age, but most are done before the patient is 14 years old. A pharyngeal flap also may be part of primary cleft palate repair.

Procedural Considerations. Positioning, draping, and instruments are the same as those described for cleft palate repair, with the addition of two 12F red rubber catheters.

Operative Procedure

1. The Dingman mouth gag is inserted. A throat pack may be inserted.
2. The surgeon injects the palate and posterior wall of the pharynx with 1% lidocaine with epinephrine 1:100,000 for hemostasis.
3. The palate is incised, and the pharyngeal flap is incised and elevated.
4. The pharyngeal wall donor site may be sutured or left open.
5. The pharyngeal flap is sutured to the palate, and the palate is closed.
6. A traction suture is placed through the body of the tongue. The throat pack is removed.

Total Ear Reconstruction

An absent external ear presents the surgical team with the objective of developing or restoring a part of the appearance that will help with self-esteem and confidence in daily interactions as well as enhance hearing, since the external ear funnels sound waves from the environment into the inner ear. Emotional support is a key aspect of the plan of care for these patients.

The external ear consists of skin, subcutaneous tissue, and cartilage. The surgical procedure to create an external ear involves the retrieval of rib cartilage, carving the cartilage, placing the newly fashioned ear on the side of the patient's head, and skin grafting and dressing of the operative sites, with continual assessment and reassessment of the preoperative sketches made of the patient's ear with relation to facial structure. This can be accomplished as a one-stage procedure or as a sequence of surgeries. For congenital defects, the ideal time for initiating the procedure is between 6 and 10 years of age. In the case of traumatic loss of the external ear (as from burns), the time is individually determined. The use of tissue expanders may be considered in some cases to stretch the skin surface required to cover the ear.

Procedural Considerations. A basic plastic surgery instrument set is required, with the addition of rib graft instrumentation for autologous rib cartilage retrieval in total ear reconstruction. A sterile Doppler probe with sterile conduction gel should be available for intraoperative use. Preoperative sketches of the ear are done with the use of unexposed x-ray film. Symmetric and anatomic landmarks are vital considerations in the patterns developed for the reconstruction. When the sketches are complete, the films are sterilized with care not to remove the markings made by the surgeon. The patient is supine with the arms tucked securely at the sides. Appropriate padding and protection of vulnerable neurovascular bundles and pressure sites are critical. Use of a sequential compression device and a forced air–warming unit over the lower half of the patient's body should be considered because of the anticipated length of the procedure. Before the skin prep, the surgeon will assess the vascular integrity of the temporoparietal flap with an unsterile Doppler probe and conduction gel and will mark the incision sites. Infiltration of the operative sites with local anesthetic with epinephrine 1:200,000 can be used for hemostasis. Epinephrine in higher concentrations (e.g., 1:100,000) is not recommended for use in the area of the flap because of the possible obliteration of the vascular complexes present. The perioperative nurse preps the patient's face, torso, and an

additional site if a skin graft is anticipated. A standard head drape and a split drape (or U drape) for the patient's torso allow the team access to the auricular area and chest, respectively. Usually two instrument tables are used, with one designated for carving the rib cartilage. Because the procedure is lengthy (6 to 8 hours on average), rolling sitting stools should be provided for the team. Periodic progress of the procedure should be relayed to the patient's family members in the surgical waiting room.

Operative Procedure

1. The temporoparietal fascia flap is lifted, and a sterile Doppler probe and sterile conduction gel are used to assess the vascular integrity of the flap.
2. The chest wall is incised, and the rib cartilage segments are removed with care to preserve the perichondrium. This will encourage bone growth and help to prevent a chest wall defect. The assessment of intact pleura is critical before closure of the chest. Instillation of saline into the wound is done; if bubbles appear, the pleura is not intact; a chest tube is then inserted and attached to a chest drainage system. If the integrity of the pleura is in question, an intraoperative chest x-ray film may be taken to assess for a pneumothorax. If the pleura is intact, closure of the wound is performed and injection of 0.25% bupivacaine to the intercostal incision area is performed.
3. While one team closes the chest, another team begins the process of carving the rib cartilage for the ear reconstruction. The previously marked radiographs are crucial aids for the artistic abilities of the surgeon, providing a blueprint for the sculpting phase of the procedure. Surgical wire is used to connect the carved pieces of rib cartilage as it is shaped to resemble the external ear.
4. A skin graft is taken, and the donor site is covered with a dressing of choice.
5. Hemostasis is maintained with the ESU, topical thrombin, and infiltration of local anesthetic with epinephrine.
6. The flap covers the sculpted ear, and the skin graft is used to cover any exposed areas (this is a technique used especially with burn patients who have less available skin for coverage).
7. Drains are placed and attached to closed-wound suction, or gauze stents wrapped with nonadherent gauze are sutured in place behind the ear. Soft, bulky dressings are applied to the ear and secured with a head wrap of rolled gauze. Standard dressings are applied to the chest wall.

Otoplasty

A congenital deformity in which the ear protrudes abnormally from the side of the head is generally the result of an absent or insufficiently pronounced antihelical fold of the external ear. The various methods of otoplasty are an attempt at correction by creating an antihelical fold that positions the ear more normally (Figure 25-44). Protruding ears may be unilateral or bilateral. An otoplasty is generally performed for children who are uncomfortable or self-conscious about the deformity, usually in the elementary school–age years.

Procedural Considerations. A plastic surgery instrument set is needed. The patient is placed supine on the OR bed, and a head drape is used, leaving both ears well exposed. The patient's head is turned with the affected ear up and with the lower ear well padded to avoid pressure injury.

Operative Procedure

1. The antihelical fold is created when the external ear is bent backward. The position of the antihelical fold is marked by placing 25-gauge or straight needles through the ear from anterior to posterior, applying methylene blue to the tips of the needles, and withdrawing them to mark the cartilage within.
2. An ellipse of skin is excised from the posterior surface of the ear after it has been infiltrated with 1% lidocaine with epinephrine 1:100,000.
3. The ear cartilage is usually incised near the antihelical fold, and the anterior surface of the cartilage is scored to allow it to bend backward.
4. Sutures are usually placed to hold the cartilage in its new position.
5. The skin incision is closed.
6. A drain may be placed to aid in the skin's adherence to the cartilage framework beneath.
7. A nonadherent dressing, such as petroleum gauze or cotton coated with Polysporin antibiotic ointment, is usually placed in front of and behind the ear, followed by fluffed gauze and a bulky dressing made of rolled gauze to exert moderate compression on the ear.

Repair of Syndactyly

Syndactyly refers to a congenital webbing of the digits of the hands or feet. It is occasionally seen in association with other abnormalities, such as extra fingers or toes (polydactyly), or with bony abnormalities. In syndactyly with normal digits, most

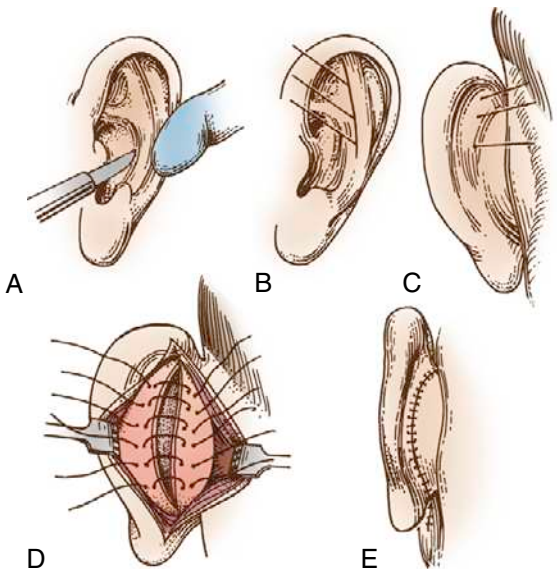


FIGURE 25-44 Otoplasty for correction of protruding ears. **A**, Antihelix defined by application of pressure to ear. **B**, Position of antihelical fold marked by the passage of straight needles through ear. **C**, Needle points visible along posterior surface of ear with ellipse of skin to be excised marked. **D**, Section of ear cartilage incised and scored or excised with sutures placed to hold cartilage back. **E**, Posterior ear incision sutured.

commonly seen, a web of skin joins adjacent fingers (Figure 25-45) but each finger has its own tendons, vessels, nerves, and bony phalanges. Although the skin web may appear loose, a deficiency in skin is always present when surgical separation is performed. Plans for taking a skin graft (usually full thickness) should always be made. Surgical separation of syndactyly is performed at any time, usually after approximately 12 months of age.

Toe syndactyly is less often treated surgically than finger syndactyly because proper function of the foot does not require fine movements of individual toes. Although the setup and description that follow are for the repair of finger syndactyly, they can also be applied to the repair of toe syndactyly.

Procedural Considerations. A plastic surgery local instrument set is required, plus a sterile marking pen, sterilized unexposed x-ray film, a pediatric pneumatic tourniquet, and an Esmarch bandage. The patient is placed supine on the OR bed with the affected arm extended on a hand table. A hand drape is used, and the affected hand and wrist are prepped and draped as well as both inguinal areas (donor sites for full-thickness skin grafts). Some surgeons prefer to use the wrist or forearm as donor sites.

Operative Procedure

1. The skin is incised and small flaps at the sides of fingers and in the web are elevated.
2. After the flaps have been sutured into position, patterns of areas of absent skin on the sides of fingers are made and transferred to the skin-graft donor site.
3. The skin graft is taken; if a full-thickness skin graft is used, it must be defatted before the graft is sutured in place.
4. Skin grafts are sutured to fingers.
5. Stent dressings are placed over the skin grafts. The entire hand is immobilized in a bulky dressing or in a long arm cast.

FIGURE 25-45 Syndactyly involving third and fourth fingers.

Orbital-Craniofacial Surgery

Some congenital anomalies involve the orbital-craniofacial skeleton. These include hypertelorism, in which the distance between the orbits is increased as seen in Crouzon's disease and Apert's syndrome. Crouzon's disease (Figure 25-46) is characterized by premature closure of the cranial sutures, resulting in an abnormally shaped skull, exophthalmos and hypertelorism, parrot's beak nose, and maxillary hypoplasia. Apert's syndrome (Figure 25-47) includes the same craniofacial deformities as Crouzon's disease and also syndactyly or other hand anomalies. Recent advances in plastic surgery make surgical correction of some of these deformities possible.

Binocular vision is normal in humans. It involves the coordinated use of both eyes to obtain a single mental impression of objects. Binocular vision is usually absent in craniofacial anomalies because of the increased distance between the orbits. The purposes of orbital-craniofacial surgery are to provide the patient with binocular vision by moving the orbits closer together and to provide the patient with a more acceptable appearance by moving the bones of the orbital-craniofacial skeleton into a more normal position. Correction of the

FIGURE 25-46 Crouzon's disease.

FIGURE 25-47 Apert's syndrome.

deformity seen in Crouzon's disease and Apert's syndrome involves a surgically created Le Fort III maxillary fracture.

Although an extracranial approach may be used, an intracranial approach is used in most cases; therefore a neurosurgeon and a plastic surgeon perform these operations through a bifrontal (coronal) craniotomy. A tracheostomy may be done before the start of the procedure. Bone grafts from hips or ribs are necessary to augment areas of bone deficit, which result from movement of the craniofacial skeleton.

Procedural Considerations. These operations are usually performed on children. They are very extensive procedures, often lasting 12 to 14 hours. Blood loss is considerable. Postoperative complications, such as cerebral edema or meningitis, can be formidable. The perioperative nurse must pay particular attention to the following important details: (1) insertion of a Foley catheter into the patient's bladder before the operation is started, (2) positioning of the patient on the OR bed so that all bony prominences are well padded, and (3) availability of accurate means for measuring blood loss. Use of a sequential compression device and forced air–warming units should also be anticipated.

A basic plastic surgery instrument set, craniectomy instruments and supplies (see Chapter 20), plastic hand instrumentation, and tracheostomy instruments and supplies are required. A high-speed drill, saws, and general orthopedic instrumentation are also needed. A separate setup is necessary for obtaining the bone graft.

The patient is positioned, prepped, and draped as described for bifrontal craniotomy (see Chapter 20). The entire face is left exposed, however, and may temporarily be covered with a plastic drape until the portion of the operation requiring access to the face is reached. The bone-graft donor site is also prepped and draped so that both iliac crests and the lower ribs are exposed.

Operative Procedure

1. Tracheostomy, if required, is performed first, followed by application of arch bars (when indicated as in Crouzon's disease and Apert's syndrome).
2. The bifrontal craniotomy with craniectomy is performed.
3. Bilateral orbital osteotomies (Figure 25-48, *A*) into the anterior cranial fossa are performed. Bilateral conjunctival (lower eyelid) and labiogingival sulcus incisions (for Crouzon's disease and Apert's syndrome) are made for orbital and maxillary osteotomies.

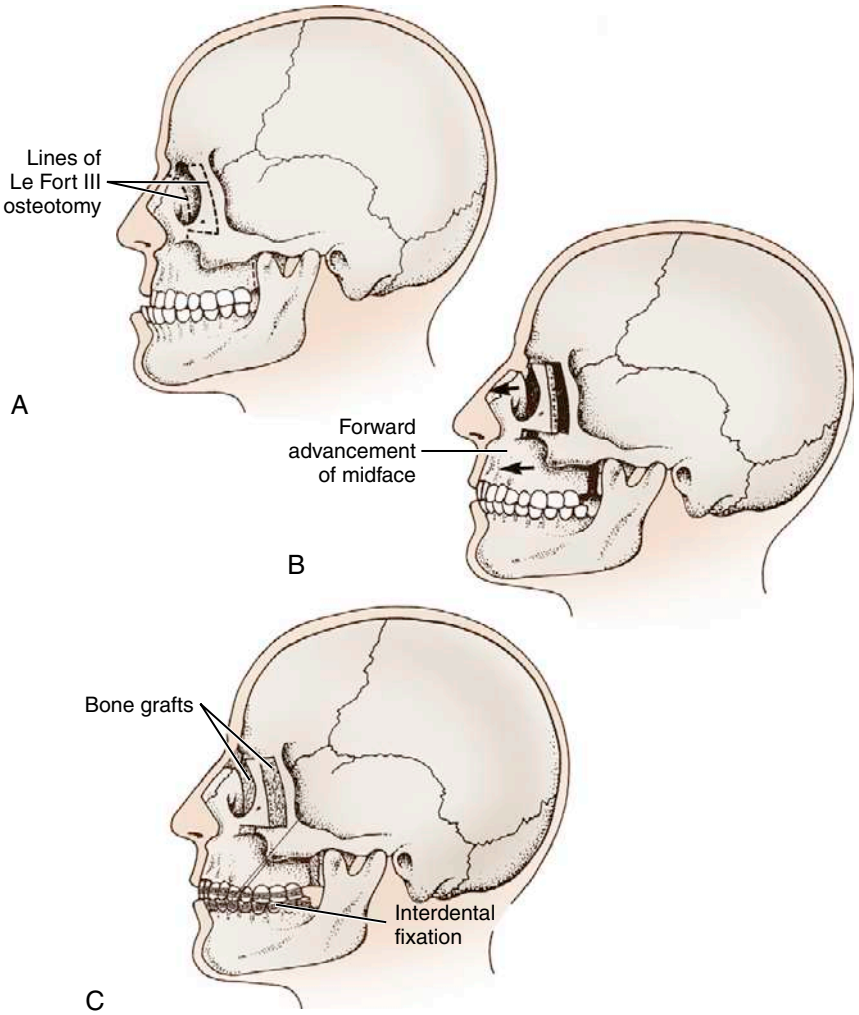


FIGURE 25-48 Steps in surgical correction of Crouzon's disease deformities.

4. The bones of the orbital-craniofacial region are now moved (Figure 25-48, *B*), based on measurement of the intercanthal distance (in hypertelorism) or occlusion of the teeth (in Crouzon's disease and Apert's syndrome).
5. Bone grafts may be taken from the calvaria, ribs, or hips to augment areas of bone deficit, which result from movement of the craniofacial skeleton.
6. Bone grafts are fixed in place with interosseous wires and by means of intermaxillary fixation applied to arch bars (for Crouzon's disease and Apert's syndrome) (Figure 25-48, *C*). Rigid plate-and-screw fixation is another option.
7. The craniotomy, conjunctival, intraoral, and bone-graft donor site incisions are closed and dressings applied.

Pediatric Ophthalmic Surgery

Although the anatomy of the eye remains the same (refer to Chapter 17), children experience different eye conditions from adults that are specifically related to vision development in the brain. Vision develops in the brain until approximately 9 years of age. It is affected by eyes that are not straight or do not focus correctly. Therefore it is imperative that any vision problems are detected and corrected early.

Pediatric ophthalmologists participate in specific programs of study that focus on examination and care of childhood vision problems and structural disorders of the eye. Their scope of practice includes not only examination and treatment, such as vision testing and treatment of eye infections, but also surgical management of disorders such as congenital nasolacrimal duct obstruction, pediatric cataracts, ptosis, strabismus, pediatric glaucoma, and eye injuries (American Association for Pediatric Ophthalmology and Strabismus [AAPOS], 2005). It is not uncommon for pediatric ophthalmology to be subdivided into specialty categories. The field of oculoplastics was first identified in 1966. Oculoplastics encompasses the merging of plastic surgery and ophthalmology in attempt to treat or repair the oculo-orbital region of the face, be it structural (drainage problems) or cosmetic in nature (Whitaker, 2002). Surgeons may also focus their practice on corneal disorders, retinal disorders, or neuro-ophthalmology.

***Eye Muscle Surgery for Strabismus** (Figure 25-49).* Any misalignment of the eyes is called strabismus. Strabismus is further subdivided into the categories listed in Box 25-4. Strabismus occurs as a result of poorly controlled neuromuscular eye movements. Any child can suffer from strabismus, but disorders that affect the brain (cerebral palsy, hydrocephalus, Down syndrome, brain tumors) are associated with an increased prevalence of the disorder. Additionally, strabismus may occur in conjunction with traumatic brain, nerve, or ocular injury.

The goal for treatment of strabismus is to straighten the eyes so that binocular vision functions appropriately. Nonsurgical treatments may include eyeglasses and eye exercises. Surgery may be recommended to change the alignment of the eyes relative to each other by strengthening, weakening, or repositioning the eye muscles. If a child presents with strabismus in addition to another eye disorder (e.g., ambylopia, cataract, or ptosis), the other condition will be treated before corrective surgery.

Skin incisions are not necessary to repair strabismus. Instead, the surgeon will use a lid speculum to retract the eyelid and incise the conjunctiva to expose the muscles. Box 25-5 differentiates between the methods of muscle repair. The repaired muscles are sutured using a standard knot or adjustable suture. Adjustable sutures consist of temporary knots (bow or slip) placed in an accessible position so that eye alignment can be altered approximately 24 hours after surgery. The lateral rectus recession and lateral rectus resection procedures are described below.

PROCEDURAL CONSIDERATIONS. The patient receives a general anesthetic, and the full face above the nose is prepped with half-strength Betadine. Both eyes are prepped so that the repair can be measured against the contralateral eye for symmetry.

OPERATIVE PROCEDURE—LATERAL RECTUS RECESSION

1. A lid speculum is placed in the affected eye and the unaffected eye is taped closed.
2. The infratemporal limbus is grasped using Moody locking forceps and the eye is rotated superonasally.
3. A conjunctival fornix incision is made posterior to the limbus in the infratemporal quadrant.

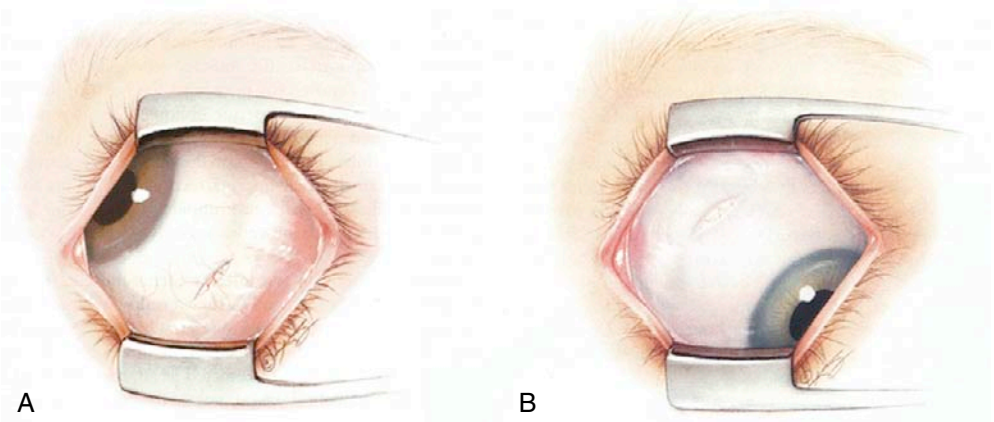


FIGURE 25-49 Forniceal incisions for strabismus surgery. All six muscles can be isolated from these two incisions. **A,** Inferotemporal incision: isolates the lateral rectus, inferior rectus, and inferior oblique muscles. **B,** Superonasal incision: isolates the medial rectus, superior rectus, and superior oblique muscles.

4. Tendons and episclera are dissected until bare sclera is reached, and the lateral rectus is isolated with a Green muscle hook.
5. A suture is passed through the original insertion of the lateral rectus muscle and locked on superior and inferior aspects. The muscle is then cut from its insertion on the globe using Aebli scissors.
6. Calipers are used to mark a location posterior to the insertion point, and suture is passed through the sclera using "crossed swords" technique.
7. The muscle is pulled up firmly to the globe and tied into position. The location is measured again using calipers.
8. Conjunctiva is closed using plain gut suture.
9. The surface of the eye may be covered in neomycin/polymyxin/dexamethasone and tetracaine ointment.

BOX 25-4

Types of Strabismus

- Esotropia: Inward turning of one or both eyes
- Exotropia: Outward turning of one or both eyes
- Hypertropia: One eye higher than the other
- Hypotropia: One eye lower than the other

BOX 25-5

Methods of Muscle Repair

RECESSION
- Is a weakening procedure.
- Alters the attachment site of the eye muscle on the eyeball.
- Muscle is cut from the surface of the eye and reattached at a point further back from the front of the eye.

RESECTION
- Is a strengthening procedure.
- Extraocular muscle is reattached to the eyeball at its original site.
- A section of the muscle is removed and a stitch is placed in the muscle at the intended new attachment site.
- The segment of muscle between the stitch and the eyeball is removed.
- The shortened muscle is reattached to the eye.

OPERATIVE PROCEDURE—LATERAL RECTUS RESECTION

1. A lid speculum is placed in the affected eye and the unaffected eye is taped closed.
2. The infratemporal limbus is grasped using Moody locking forceps and the eye is rotated superonasally.
3. A conjunctival fornix incision is made posterior to the limbus in the infratemporal quadrant.
4. Tendons and episclera are dissected until bare sclera is reached, and the lateral rectus is isolated with a Green muscle hook.
5. A suture is passed through the original insertion of the lateral rectus muscle and locked on superior and inferior aspects. The central sutures are tied together and a resection clamp is placed anteriorly.
6. The muscle is cut anterior to the resection clamp, and the remaining muscle stump is cut from its original insertion point.
7. The suture needles are passed through the original insertion in a perpendicular fashion and tied together.
8. The muscle is pulled up firmly to the globe and tied into position.
9. Conjunctiva is closed using plain gut suture.
10. The surface of the eye may be covered in neomycin/polymyxin/dexamethasone and tetracaine ointment.

Ptosis (Blepharoptosis) Surgery. Defined as a droopy eyelid, ptosis is either congenital or acquired. Congenital ptosis (Figure 25-50) is usually a result of a deficit in the levator palpebri muscle in the upper eyelid. Acquired ptosis occurs as a result of neurologic conditions that affect the nerves of the eye (myasthenia gravis, Horner's syndrome, third nerve paralysis). It can also manifest in conjunction with movement disorders, resulting in double vision. Ptosis may also result from orbital tumors.

Ptosis is treated with corrective lenses if amblyopia with astigmatism is present. Surgery is indicated for cases in which the droopy eyelid is blocking normal vision or causes the child to position their head with the chin up in attempt to compensate for the block in vision. The goal of surgery is to create as perfect of an anatomic result as possible by elevating the position of the lid, creating a lid fold, and preserving the contour and symmetry of both lids (Figure 25-51). The Fasenella-Servat procedure is indicated for mild congenital ptosis (less than 2 mm of lid droop) with good levator function. Variations of this procedure are favored over

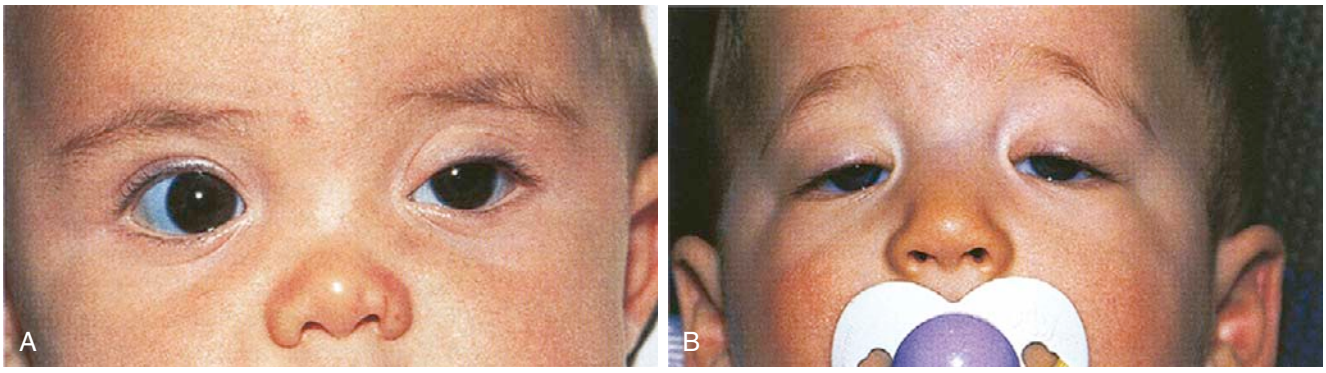


FIGURE 25-50 Simple congenital ptosis. **A**, Unilateral. **B**, Bilateral.

other types of repair, including Werb's procedure (Heher & Katowitz, 2002).

PROCEDURAL CONSIDERATIONS. The patient is positioned supine with the head on a gel ring. The eyes are prepped with half-strength povidone-iodine (1:1 povidone-iodine and normal saline solution). The patient is draped to expose both eyes for comparison during the procedure. Ointment is applied to the contralateral eye, and the eye is taped shut for protective purposes during surgery.

OPERATIVE PROCEDURE

1. A scleral shell is placed into the affected eye to protect the globe.
2. The upper lid is everted and two curved hemostats are placed at the upper tarsal border and adjusted so that the tips are centrally located (Figure 25-52, *A*).
3. Traction sutures are passed through the tissue at the nasal and temporal end, approximately 3 mm below the clamps (Figure 25-52, *B*).

FIGURE 25-51 Modified Fasenella-Servat procedure. **A**, Preoperative. **B**, Six months postoperative.

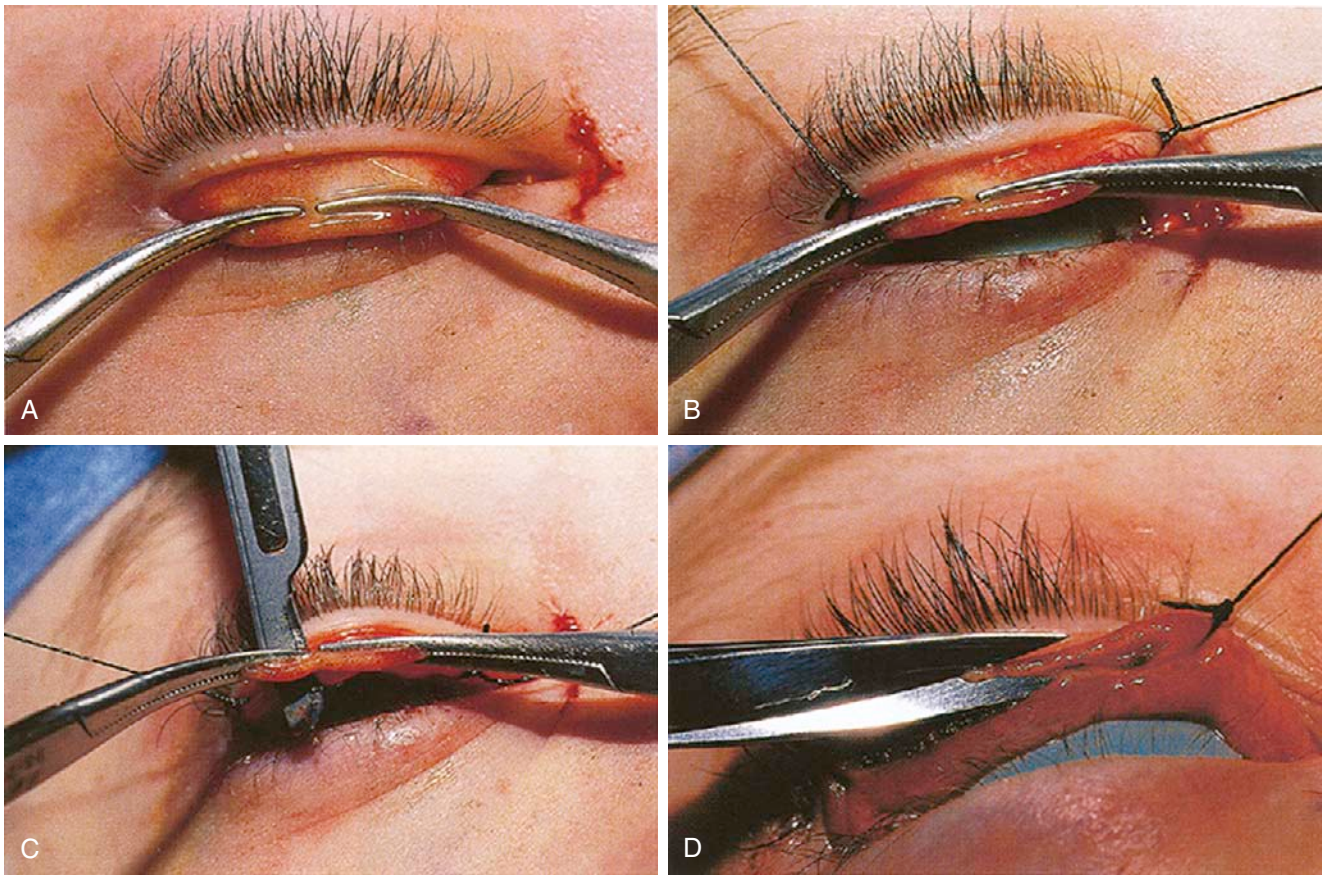


FIGURE 25-52 Modified Fasenella-Servat procedure. **A**, Hemostats at upper tarsal border. **B**, Passage of traction sutures. **C**, Excision of tissue using blade. **D**, Excision of tissue using sharp scissors.

Continued

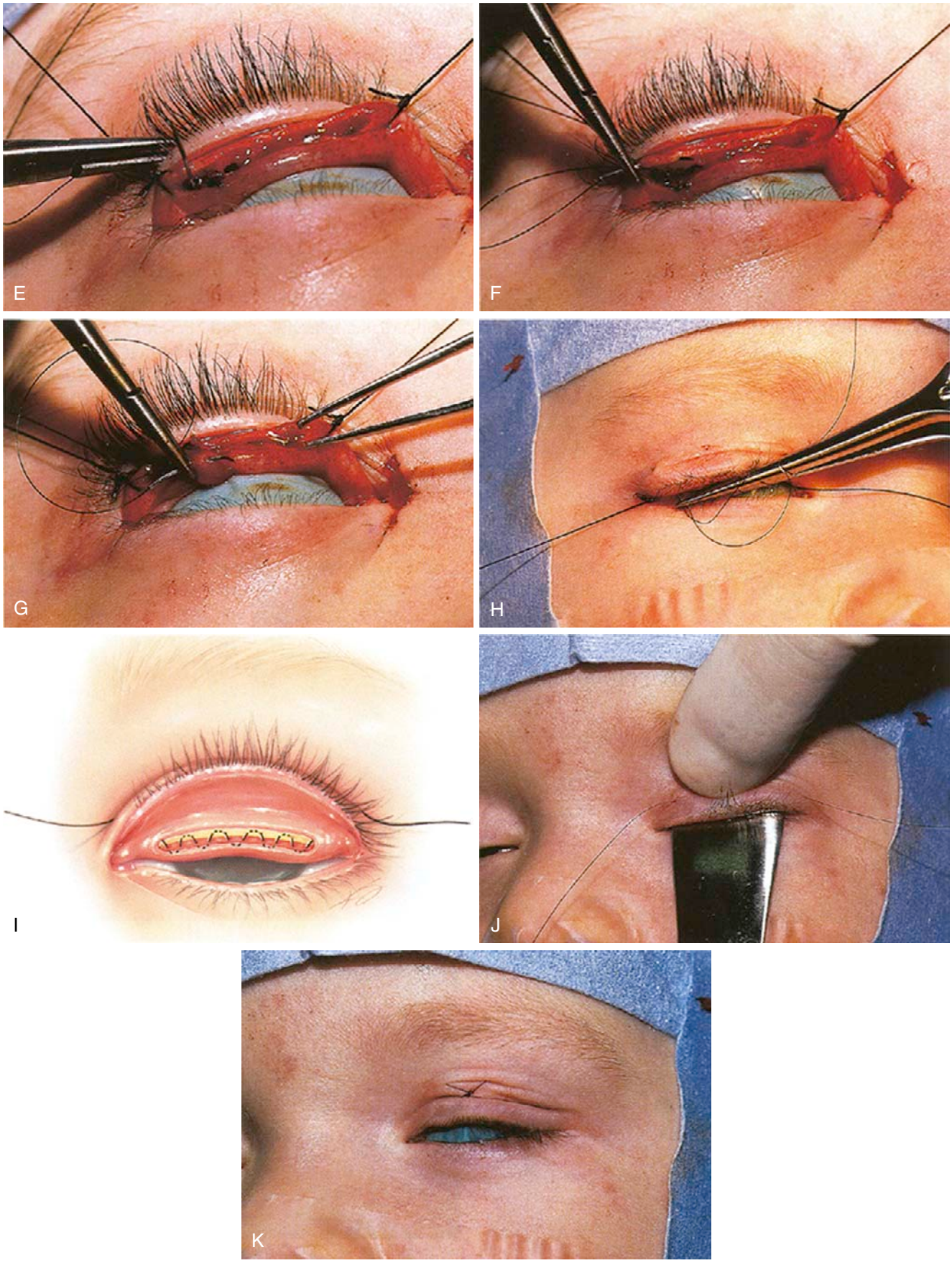


FIGURE 25-52, cont'd **E-G**, Reconnection of conjunctiva and Müller's muscle to edge of tarsus. **H** and **I**, Suture passed through apex of incision and out through crease. **J**, Smoothing incision line with lid plate. **K**, Nylon suture allows for lid adjustment.

4. The tissue between the two clamps and traction sutures is excised using a #15 blade (Figure 25-52, *C*) or sharp scissors (Figure 25-52, *D*).
5. A nylon suture is passed through the end of the lid crease out through the apex of the incision and run in a "serpentine" fashion. The suture reconnects the conjunctiva and Müller's muscle to the cut edge of the tarsus (Figure 25-52, *E* to *G*).
6. At the opposite end of the incision, the suture is passed through the apex of the incision and out through the crease, and then buried beneath the conjunctival surface (Figure 25-52, *H* and *I*).
7. The traction sutures are removed and the lid is returned to its normal position. A lid plate is used to smooth the incision line by pressing directly on the skin surface to flatten the tissues against the plate (Figure 25-52, *J*).
8. The nylon suture is tied snugly over the skin and remains in place approximately 1 week following surgery to allow for lid adjustment (Figure 25-52, *K*).
9. The scleral shell is removed and antibiotic ointment is applied to the eye and suture line. A dressing may be applied to the surgical site.

Cataract Surgery. Cataracts occur in approximately 3 out of 10,000 children and are primarily classified as nuclear, lamellar, or traumatic in nature (AAPOS, 2005) (Box 25-6). If a cataract causes significant vision loss, it must be removed as soon as possible. An intraocular lens may be used in order to replace the focusing power once the natural lens is surgically removed. Criteria for placement of an intraocular lens specify that the child must be 1 year of age or older, as these devices have not been approved by the U.S. Food and Drug Administration for younger populations. In these instances, other options include wearing glasses or contact lenses to correct the deficit.

Corneal Surgery. The cornea is only about 0.5 mm thick, and consists of many layers. The stroma is the thickest part of the cornea. Diseases of the cornea include, but are not limited to, allergies, conjunctivitis (pink eye), corneal infections, dry eye, herpes zoster (shingles), ocular herpes, pterygium, and Stevens-Johnson syndrome. In some cases, corneal surgery or a corneal transplant is necessary, particularly when high pressure from glaucoma allows fluid to accumulate in the stroma. Once this occurs, it may lead to a cloudy cornea.

Trabeculotomy for Glaucoma. The pathophysiology of glaucoma is markedly different for infants and children than in adults, and its occurrence is rare, occurring in approximately 1 in 10,000 births (AAPOS, 2005). Pediatric glaucoma is categorized according to age of onset (Table 25-3). Cases of glaucoma are classified as primary (without specific identifiable cause) or secondary (occurring in conjunction with another disorder, medication use, or eye trauma). Children with glaucoma could have other eye abnormalities in addition to the glaucoma, including opacities of the cornea (Peters' anomaly, for example).

Pediatric glaucoma is treated by a combination of medical and surgical intervention, as the goal of treatment is more than simply lowering intraocular pressure. Children diagnosed with congenital or infantile glaucoma often develop myopia and require glasses. There is also an increased occurrence of strabismus and amblyopia in children with glaucoma. Extreme cases may result in vision loss, supporting the need for early diagnosis and management of the disorder.

Pediatric glaucoma is commonly evaluated by examining the child under anesthesia (EUA). At this time, the ophthalmologist will measure intraocular pressure, corneal length, axial diameter, and refractive error and assess corneal clarity and the optic nerve. If the intraocular pressure is elevated, it can be treated medically or surgically. The majority of primary pediatric glaucoma cases are treated surgically.

The most common surgical approaches are trabeculotomy with goniometry. These procedures open the drainage canal and facilitate aqueous drainage. Other options, such as trabeculotomy with tube placement, create a bypass route to shunt aqueous drainage. Laser procedures are also effective in some cases of glaucoma. Successful management of the disease typically requires multiple examinations and procedures.

BOX 25-6

Types of Cataracts

- Nuclear: Cloudiness in the center part of the lens
- Lamellar: Cloudiness between the nuclear and cortical layers of the lens
- Traumatic: Results from blunt or penetrating force that damages the lens

TABLE 25-3

Categories of Glaucoma

Category	Age at Presentation	Symptoms at Presentation
Congenital	Glaucoma present at birth	Excessive tearing Light sensitivity Large, cloudy cornea Dull-appearing iris
Infantile	Glaucoma presents between 1 and 24 months of age	Excessive tearing Light sensitivity Large, cloudy cornea Dull-appearing iris
Juvenile	Glaucoma presents after 36 months of age	No obvious symptoms; presents similar to adult-onset glaucoma

Retinal Disorders. Retinal diseases include retinopathy of prematurity (ROP). ROP is one of the most common causes of visual loss in childhood and can lead to lifelong vision impairment and blindness. The most effective proven treatments for ROP are laser therapy or cryotherapy. Both laser treatments and cryotherapy are performed only on infants with advanced ROP. Severe cases (stage V) of this disorder are treated with scleral buckle and posterior vitrectomy (see Chapter 17).

TRAUMA

Principles governing surgical care of trauma patients are discussed in Chapter 27. However, when caring for the pediatric trauma patient in surgery, the perioperative nurse must possess additional knowledge in order to develop a detailed plan of

BOX 25-7

Trauma Transfer Criteria for Pediatric Patients Less Than or Equal to Age 14

CONSIDER TRANSFER TO PEDIATRIC TRAUMA CENTER

- Nonoperative management of solid organ injury
- Assessment of any of the following "negative points" on the pediatric trauma scale:
  - Weight less than 10 kg
  - Unstable airway
  - Blood pressure less than 50 mm Hg (systolic)
  - Coma
  - Major open, penetrating wound
  - Open, multiple fractures
- Injury severity score greater than 9
- Victim or nonaccidental injury that requires intervention from child protective team or other resources
- Anticipated complexity of care exceeds the capabilities of local resources at adult trauma center

TRANSFER TO PEDIATRIC TRAUMA CENTER

- Persistent physiologic demise
- Traumatic brain injury
- Intubation and mechanical ventilation with no expectation to wean within 24 hours
- Children with special needs or other co-morbid conditions

Modified from Pennsylvania Trauma Systems Foundation: *Adult trauma center accreditation, Appendix C: Transfer guidelines: adult trauma centers (level I, II, and III) to pediatric trauma centers*, 2009.

action that effectively drives the delivery of safe patient care. During all episodes of patient care, it is necessary for the perioperative nurse to communicate with members of the surgical and interdisciplinary team in a fashion that best supports positive patient outcomes. The urgency of injury will dictate the timeliness of surgical intervention—in some instances, pediatric trauma patients may require transfer to a level I trauma center. The criteria for transfer are outlined in Box 25-7. The perioperative nurse should be prepared to administer care to any type of injury in a safe and effective manner that is appropriate across all age levels.

Trauma is the leading cause of death in children from 1 to 14 years of age. Each year, another 100,000 children experience disability from trauma. Several factors, such as age, gender, behavior, and environment, influence the risk of traumatic injury. For instance, infants and toddlers are more prone to falls resulting in severe injury, which may be related to the pliable nature of their skeletal system. If broken bones are present, a severe force of injury must be assumed. Older children and adolescents are at higher risk for bicycle-related and motor vehicle–related injuries. In this age-group, blunt injuries resulting from motor vehicle accidents or direct blows (as with contact sports or child abuse) along with falls are the most common mechanisms of injury (Cooper, 2005). It is not uncommon for pediatric traumatic injuries to occur in the home environment, stressing the importance of community awareness and education as it relates to trauma prevention. Some of the most significant prevention strategies focus on car seat safety as a means of preventing injury from motor vehicle accidents (Patient Safety).

Throughout the pediatric population, neurologic injuries are the most common cause of traumatic death in children;

PATIENT SAFETY

Child Passenger Safety

The number one killer of children ages 3 to 14 is motor vehicle crashes. Parents and caregivers should be encouraged to follow these steps to reduce the risk of injury or death for children who ride in motor vehicles:

INFANTS

- Ride in rear-facing car seats until 1 year old and 20 pounds.
- Check the weight requirements of the car seat against the infant's height and weight—keep track of these measurements with each visit to the pediatrician.
- Harnesses should be even with or below the infant's shoulders and worn tightly. You should not be able to pinch extra webbing at the shoulder.
- Adjust the chest clip to armpit level.
- Recline the seat no more than 45 degrees.

TODDLERS

- Use a forward-facing seat until the harness no longer fits the child. Most children will outgrow the seat between ages 4 and 5.
- Check the weight requirements of the car seat against the child's height and weight—keep track of these measurements with each visit to the pediatrician.
- Harnesses should be even with or below the child's shoulders and worn tightly. You should not be able to pinch extra webbing at the shoulder.
- Adjust the chest clip to armpit level.
- If possible, use a top tether. Tethers limit the forward motion of the head in a crash.

BOOSTERS

- Booster seats are used in conjunction with the vehicle lap and shoulder belts for children who do not meet the size requirements for standard seat belts. Normal seat belts begin to fit children between the ages of 8 and 12.
- Boosters should be used in the back seat only.
- The weight range for booster seats is between 40 and 100 pounds.
- Use the lap and shoulder belts every time a child is in a booster seat. Never use only the lap belt, and make sure that the seat belt is properly buckled.

SAFETY BELTS

- Safety belts fit properly when the knees bend over the edge of the seat, the lap belt rests on the upper legs or hips, and the shoulder belt rests on the shoulder or collarbone.
- Never put the shoulder belt under a child's arm or behind a child's back.
- Ensure that children sit upright when wearing seat belts. Avoid leaning against windows, slouching, or lying down.

Modified from Safe Kids USA: *Child passenger safety,* 2006, available at www.usa.safekids.org/skbu/cps/index.html. Accessed February 21, 2009.

their head is proportionately larger in relation to their body mass and especially vulnerable to injury. Table 25-4 gives a guideline for using the Glasgow Coma Scale for infants and children. Because children have a much smaller reserve than adults, once a decline in vital functions is noted, demise is rapid. Information about commonly used medications in pediatric resuscitation is noted in the Surgical Pharmacology box.

IV access is often difficult in the pediatric patient, and an intraosseous line may be inserted by emergency rescue personnel before arrival at the hospital or in the emergency department

SURGICAL PHARMACOLOGY

Medications Used in Pediatric Resuscitation

Perioperative nurses must always be prepared in the event of a cardiac event in the pediatric patient. The information contained in this section provides several commonly used medications, their mode of action, and nursing implications for pediatric resuscitation.

Drug	Dosage	Action	Nursing Implications
Epinephrine HCl	Intravenous/intraosseous (IV/IO): 0.01 mg/kg (1:10,000) Endotracheal (ET): 0.1 mg/kg (1:1000) Repeat doses = 0.1 ml/kg (1:1000)	Adrenergic; acts on both alpha- and beta-receptor sites, especially heart and vascular and other smooth muscle	Most useful drug in cardiac arrest Disappears rapidly from bloodstream after injection; instill 2-3 ml of saline following ET administration May produce renal vessel constriction and decreased urine output
Sodium bicarbonate	IV/IO: 1-2 mEq/kg	Alkalinizer, buffers pH	Infuse slowly and only when ventilation is adequate; flush with saline before and after administration Do not mix with catecholamines or calcium Incompatible with epinephrine
Atropine sulfate	20 mcg/kg dose Minimum dose: 100 mcg Maximum single dose: infants and children, 0.5 mg; adolescents, 1.0 mg	Anticholinergic-parasympatholytic; increases cardiac output, heart rate by blocking vagal stimulation in heart	Used to treat bradycardia after ventilatory assessment; always provide adequate ventilation and monitor O_2 saturation Produces pupil dilation, which constricts with light
Calcium chloride	20 mg/kg IV 10.2 mg/kg May repeat dose every 10 min	Electrolyte replacement; needed for maintenance of normal cardiac activity	Used only for hypocalcemia, calcium blocker overdose, hyperkalemia, or hypermagnesemia Administer slowly, very sclerosing; administer in central vein Incompatible with sodium phosphate
Lidocaine HCl	0.5-1 mg/kg dose	Antidysrhythmic, inhibits nerve impulses from sensory nerves	Used for ventricular dysrhythmias only
Amiodarone	IV: 5 mg/kg over 30 min followed by continuous infusion starting at 5 mcg/kg/min; may increase to maximum 10 mcg/kg/min	Antidysrhythmic agent, inhibits adrenergic stimulation; prolongs action potential and refractory period in myocardial tissues; decreases atrioventricular (AV) conduction and sinus node function	Recommended as first choice for shock-refractory ventricular tachycardia Contraindicated in severe sinus node dysfunction, marked sinus bradycardia, second- and third-degree AV block Monitor for hypotension
Adenosine	First dose: 100 mcg/kg (maximum dose 6 mg) Second dose: 200 mcg/kg (maximum dose 12 mg) Follow with 2- to 3-ml normal saline flush	Antidysrhythmic, for supraventricular tachycardia (SVT) Causes temporary block through AV node and interrupts reentry circuits	Administer rapid IV push, followed by saline flush May cause transient bradycardia
Naloxone (Narcan)	0.01-0.1 mg/kg/dose (<5 years/20 kg) (>5 years/20 kg = 2 mg)	Reverses respiratory arrest caused by excessive opiate administration	Evaluate level of pain after administration because analgesic effects of opioids are reversed with large dose of naloxone
Magnesium sulfate	IV/IO: 25-50 mg/kg	Inhibits calcium channels and causes smooth muscle relaxation	Given as rapid IV infusion for suspected hypomagnesemia Have calcium gluconate (IV) available as antidote
IV INFUSIONS			
Epinephrine HCl infusion	0.1-1 mcg/kg/min	Adrenergic—see above	Titrate to desired hemodynamic effect
Dopamine HCl infusion	1-20 mcg/kg/min (maximum dose 50 mcg/min)	Agonist; acts on alpha receptors, causing vasoconstriction Increases cardiac output	Titrate to desired hemodynamic effect
Dobutamine HCl infusion	2.5-15 mcg/kg/min	Adrenergic direct-acting beta$_1$-agonist Increases contractility and heart rate	Titrate to desired hemodynamic effect Little vasoconstriction, even at high rates
Lidocaine HCl infusion	20-50 mcg/kg/min	Antidysrhythmic Increases electrical stimulation threshold of heart	See above Lower infusion dose used in shock Used for ventricular tachycardia

Modified from Lexi-Comp ONLINE™, available at www.crlonline.com/crlsql/servlet/crlonline. Accessed May 21, 2009.

TABLE 25-4

Pediatric Modification of Glasgow Coma Scale

Glasgow Coma Scale	Pediatric Modification	
EYE OPENING		
Birth to 1 year	12 months or older	
4 Spontaneously	4 Spontaneously	
3 To shout	3 To verbal command	
2 To pain	2 To pain	
1 No response	1 No response	
BEST MOTOR RESPONSE		
Birth to 1 year	12 months or older	
5 Localizes pain	6 Obeys command	
4 Flexion, withdrawal	5 Localizes pain	
3 Flexion, abnormal	4 Flexion, withdrawal	
2 Extension, rigidity	3 Flexion, abnormal	
1 No response	2 Extension, rigidity	
	1 No response	
BEST VERBAL RESPONSE		
Birth to 2 years	2-5 years	Older than 5 years
5 Cries appropriately, coos	5 Appropriate words, phrases	5 Oriented and converses
4 Cries	4 Inappropriate words	4 Disoriented, converses
3 Inappropriate crying	3 Cries, screams	3 Inappropriate words
2 Grunts	2 Grunts	2 Incomprehensible sounds
1 No response	1 No response	1 No response

Modified from Emergency Nurses Association (ENA): *Trauma nursing core course,* ed 6, Des Plaines, Ill, 2007.

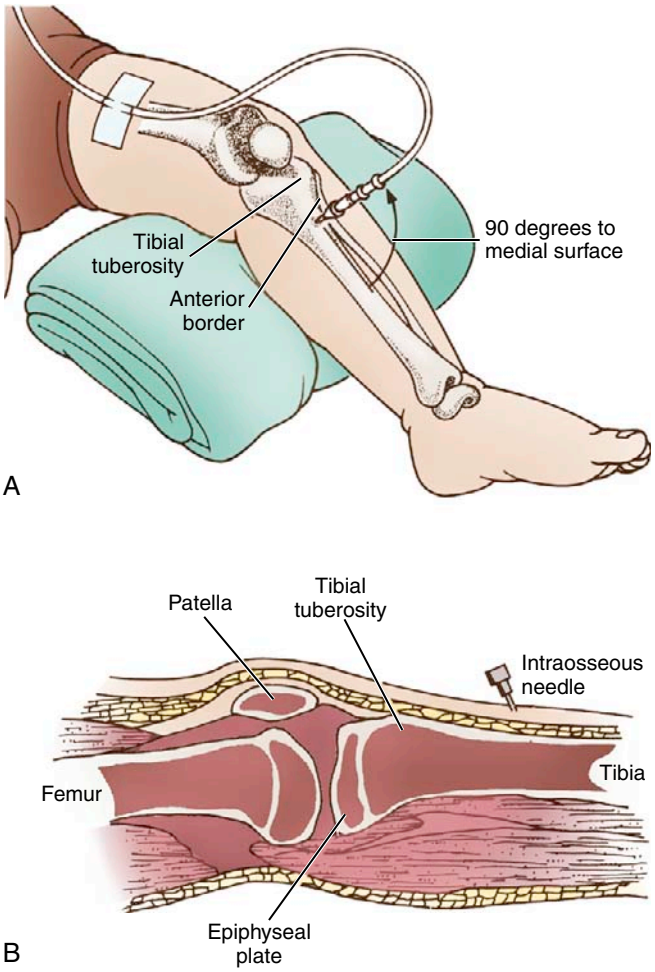


FIGURE 25-53 A, Intraosseous infusion technique. B, Insertion.

(ED). These lines are inserted by use of an intraosseous needle or bone marrow aspiration needle and are placed slightly below the knee on the anterior aspect of the tibia at a 90-degree angle (Figure 25-53). Stabilization of the line may be difficult, but the line can remain for up to 24 hours and provides rapid access when other routes are too time-consuming or difficult to access. Fluid resuscitation levels for children experiencing hemorrhage, as well as types and dosages of medications, are based on body weight, since weight provides a better mechanism of accuracy when calculating dosage.

Because of the nature of the trauma, exact body weight may be unable to be obtained. In these instances, body weight can be estimated using Broselow tapes or palmar methods. The body size of the patient determines the type of instrumentation required. Pediatric trauma instrument sets, including vascular clamps and retractors, and suture supplies should be available and organized in a fashion that promotes easy and timely access when urgent situations arise. Creative problem solving may be required of the perioperative nurse in adaptation of feeding tubes, drains, and other equipment.

Maintenance of body temperature is of utmost concern in the pediatric population, and undue skin exposure should be avoided. Fluids for irrigation and IV infusion may be warmed, depending on the preferences of the surgeon and the status of the child. Whenever possible, room temperature is elevated. Warming blankets and head coverings (stockinettes) may be used to prevent heat loss; this is especially critical with children who have sustained burns.

Traumas are graded based on the severity of injury (Table 25-5). The perioperative nurse should attempt to obtain a trauma history from ED personnel or the family if the patient comes directly to the OR. Initial vitals signs should be obtained and compared with those obtained during prehospital care or in the ED; Table 25-6 presents normal vital sign ranges for infants and children. Box 25-8 gives a formula for blood pressure estimation. As the perioperative nurse obtains the initial assessment, it is important to use a developmental approach to pediatric trauma patients, who respond differently from adults. During traumatic events, it is also imperative to consider the well-being of patients, families, and caregivers. The perioperative nurse plays an integral role in preparing those associated with the child for outcomes associated with trauma surgery and may help facilitate consults from the departments of child life, social work, and clergy.

Airway and breathing are part of the primary survey for pediatric trauma victims. Anatomic variations of the upper airway related to age must be considered. Airway patency must be assessed and secured. Initial assessment for all pediatric

TABLE 25-5

Trauma Grading

	Physiologic Considerations	Anatomic Considerations
Level I: Life-threatening injuries, unstable vital signs	Respiratory distress Intubated before transport Unstable airway Cardiac arrest Glasgow Coma Score (GCS) ≤8 Unstable vital signs Lateralizing neurologic signs or worsening neurologic exam Any signs of shock Severe uncontrolled hemorrhage Systolic blood pressure <80 mm Hg that does not respond to fluid resuscitation	Airway compromise Major vascular injury Crush injury Above-elbow or above-knee amputation with high probability of surgical intervention Penetrating injury to abdomen, chest, head, neck, or groin Burns >25% total body surface area Spinal cord injury with neurologic signs or symptoms and unstable vertebral fractures
Level II: Potentially life-threatening injuries, vital signs stable at present	GCS ≥9 and ≤13 Hypotension before transport, resolved during transport	Blunt abdominal trauma with abnormal exam Blunt chest trauma with ≥2 rib fractures Significant penetrating trauma to upper extremities or distal to groin Significant crush or amputation distal to elbow or knee with high probability of operative intervention

Modified from Children's Hospital of Philadelphia: *2008-2009 Trauma program resident/fellow manual.*

TABLE 25-6

Pediatric Vital Signs

Age	Heart Rate (beats/min)	Respirations (breaths/min)	Systolic Blood Pressure (mm Hg)
Newborn	100-150	30-55	50-70
Infants to 2 years	80-120	25-40	70-88
2-6 years	70-110	20-30	88-94
6-10 years	60-95	16-22	94-102
10-16 years	60-85	12-20	80-111

From Ball JW, Bindler RC: *2008 Pediatric nursing: caring for children,* Upper Saddle River, NJ, 2008, Pearson Prentice Hall.

BOX 25-8

Estimating Blood Pressure for the Pediatric Patient

Systolic BP (mm Hg) = (2 × age in years) + 80
Diastolic BP (mm Hg) = ⅔ Systolic BP

trauma patients may best be obtained by application of the head tilt–chin lift or jaw-thrust method, depending on the age of the child and the nature of the injury. When the integrity of the spinal cord is questionable, in-line cervical traction should be applied. Collars and stabilizing devices must remain in place until cervical fracture has been ruled out and the spine "cleared," or declared free of injury by a radiologist. Airway equipment sizes may be selected based on age as well as whether the child is breathing spontaneously and whether the child is unconscious. An assessment of relevant systems will be performed on stabilization of the pediatric airway, and surgery will progress as planned.

SURGERY FOR CONGENITAL HEART DISEASE

Congenital heart disease (CHD) occurs in approximately 5 to 8 of every 1000 live births. Structural abnormalities of the heart and great vessels result in an embryologic failure in septation, malalignment, failure to develop, and/or failure to progress.

The etiology of CHD varies, although certain factors are associated with increased prevalence. For example, risk of CHD is increased secondary to environmental factors: rubella during the first 8 weeks of gestation may result in patent ductus arteriosus and pulmonary artery stenosis (along with other syndromes). Other risk factors include maternal chronic illnesses such as diabetes or poorly controlled phenylketonuria (PKU), alcohol consumption, and exposure to environmental toxins. The incidence of CHD is increased also in certain chromosomal defects; for example, atrial septal defects are seen in children with trisomy 21 (Down syndrome). In addition, an increased prevalence is seen in small-for-gestational-age (SGA) babies and in children who have a positive family history of CHD (that is, those families with a sibling or parent who has CHD).

Congenital cardiac abnormalities are classified as cyanotic or acyanotic as well as by their effect on pulmonary blood flow (Box 25-9). Of the acyanotic lesions, there are those that increase pulmonary blood flow, such as patent ductus arteriosus (PDA), atrial septal defect (ASD), ventricular septal defect (VSD), and atrioventricular canal defects (AVCs). With these abnormalities, blood flows from the high-pressure left side of the heart to the low-pressure right side of the heart because of an abnormal connection either between the septum or in the great arteries. The resultant increase in pulmonary blood flow causes the right side of the heart and lungs to become overloaded. Congestive heart failure (CHF) may develop, pulmonary vascular resistance may increase, and the pulmonary vessel walls may thicken; and if left untreated, the condition may become irreversible.

BOX 25-9

Classification of Congenital Cardiac Defects

ACYANOTIC WITH INCREASED PULMONARY BLOOD FLOW
- Patent ductus arteriosus
- Atrial septal defect
- Ventricular septal defect
- Atrioventricular septal defect

ACYANOTIC OBSTRUCTIVE LESIONS
- Coarctation of the aorta
- Aortic stenosis
- Pulmonary stenosis

CYANOTIC WITH DECREASED PULMONARY BLOOD FLOW
- Tricuspid atresia
- Tetralogy of Fallot
- Pulmonary atresia with intact ventricular septum

CYANOTIC WITH INCREASED PULMONARY BLOOD FLOW
- Total anomalous pulmonary venous connection (return)
- Truncus arteriosus
- Hypoplastic left heart syndrome

CYANOTIC WITH VARIABLE PULMONARY BLOOD FLOW
- Transposition of the great arteries
- Double-outlet right ventricle
- Double-outlet left ventricle
- Single ventricle

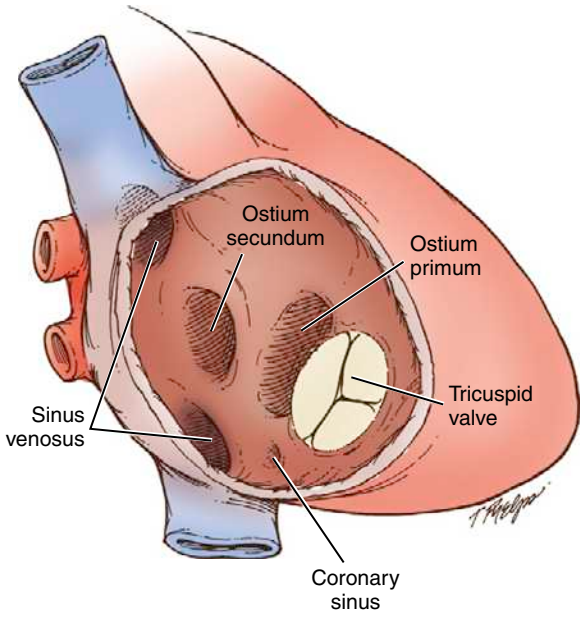


FIGURE 25-54 Various types of atrial septal defects (ASDs) viewed through the right atrium (ostium secundum, ostium primum, sinus venosus). An unroofed coronary sinus may also act as an ASD.

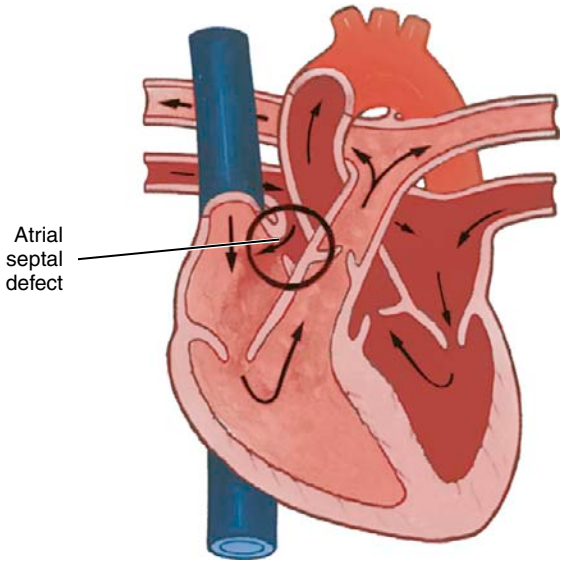


FIGURE 25-55 Atrial septal defect.

Acyanotic obstructive lesions, such as aortic stenosis, pulmonary stenosis, or coarctation of the aorta, increase the workload of the chamber that pumps against the obstruction (increases afterload). Cardiomegaly and ventricular hypertrophy may be seen in response to the increased workload, and if the obstruction is severe, heart failure may ensue.

The presence of cyanosis implies that one of the following conditions is present: right-sided heart obstruction with blood traveling right to left without passing through the lungs; mixing of venous and arterial blood within the heart or great vessels; or incorrect positioning of the great vessels. The degree of cyanosis depends on pulmonary blood flow and intracardiac mixing of blood through a shunt. This classification of lesions includes, but is not limited to, tetralogy of Fallot (TOF), pulmonary atresia with intact ventricular septum (PA/IVS), tricuspid atresia (TA), transposition of the great arteries (TGA), total anomalous pulmonary venous return (TAPVR), and hypoplastic left heart syndrome (HLHS). Treatment goals for these lesions include managing pulmonary blood flow and/or arterial oxygen saturation.

Repair of Atrial Septal Defect

Congenital defects in the atrial septum occur in approximately 10% of CHD cases (Melek, 2006). The classification within this group of defects is based on anatomic location and associated abnormalities (Figure 25-54). The ostium secundum defect is located in the superior and central portions of the septum. The ostium primum defect is located in the lower portion of the atrial septum and is associated with other defects in the atrioventricular canal, usually with a cleft of the mitral valve or occasionally of the tricuspid valve. An accompanying VSD may also be present. The sinus venosus defect is located at the right atrium–superior vena cava junction and is associated with partial anomalous pulmonary venous return.

An ASD results in a left-to-right atrial shunt whose direction and magnitude are determined by the size of the defect and relative resistance to flow into the ventricles and great vessels (Figure 25-55). ASDs are often tolerated well with no symptoms during childhood, especially if the defect is small. However, if the defect is large or of the ostium primum type, with a pronounced shunting of blood, the workload of the right side of the heart is increased. On assessment, there is a characteristic systolic pulmonary murmur at the second intercostal space at the left sternal border, and a fixed splitting of the second heart sound may also be heard. The right side of

the heart and the pulmonary artery and its branches become enlarged. The vascularity of the lung field is increased, with resulting pulmonary hypertension and subsequent failure of the right side of the heart. At this point the shunt may reverse. The initial symptoms may include fatigue, retardation of normal weight gain, and increased susceptibility to respiratory tract infections. Later signs and symptoms include those of failure of the right side of the heart and cyanosis with a reverse shunt. Asymptomatic children whose ASD is left unrepaired until adulthood may develop right atrial and right ventricular hypertrophy, atrial dysrhythmias, CHF, embolic events, and pulmonary vascular disease. The defect is common in children with Down syndrome.

Procedural Considerations. ASDs are closed, under direct vision, by a simple suture technique (primary closure) or by insertion of a synthetic prosthetic patch or pericardial patch.

The child is placed in the supine position for a median sternotomy or in a right anterior oblique position for an anterolateral thoracotomy. The instrument setup is the same as that described for basic open-heart surgery (see Chapter 24), with consideration given to the age and size of the child; intracardiac patch material, 2 × 2 inches or larger, may also be required.

Operative Procedure (Figure 25-56)

1. A median sternotomy incision is performed, and cardiopulmonary bypass (CPB) is instituted. (Infrequently, a right anterolateral incision is performed.) Many bypass strategies can be employed. With bicaval cannulation, the child remains on bypass during the repair and blood is directed away from the right atrium through cannulae in the superior and inferior venae cavae. Occasionally, with this method the cannulae may obstruct the view of the ASD. With single venous cannulation, a cannula is placed into the right atrium and the child remains on bypass during the repair. With this technique, the venous line is clamped immediately before the right atrium is incised and pump suctions are placed into the inferior and superior venae cavae during ASD closure. Deep hypothermic circulatory arrest is sometimes used in more complicated repairs, such as ostium primum ASD or sinus venosus defects associated with anomalous pulmonary venous return.
2. The right atrium is incised, and the pathologic defect is determined.
3. The defect is closed with a continuous suture, or a patch of pericardium or prosthetic material may be used. By filling the atrium with blood before the atriotomy is completely closed, the surgeon can express air from the atrium. For the ostium primum defect with a cleft mitral valve, repair of the cleft is accomplished by approximation, with use of interrupted (possibly pledgetted) sutures.

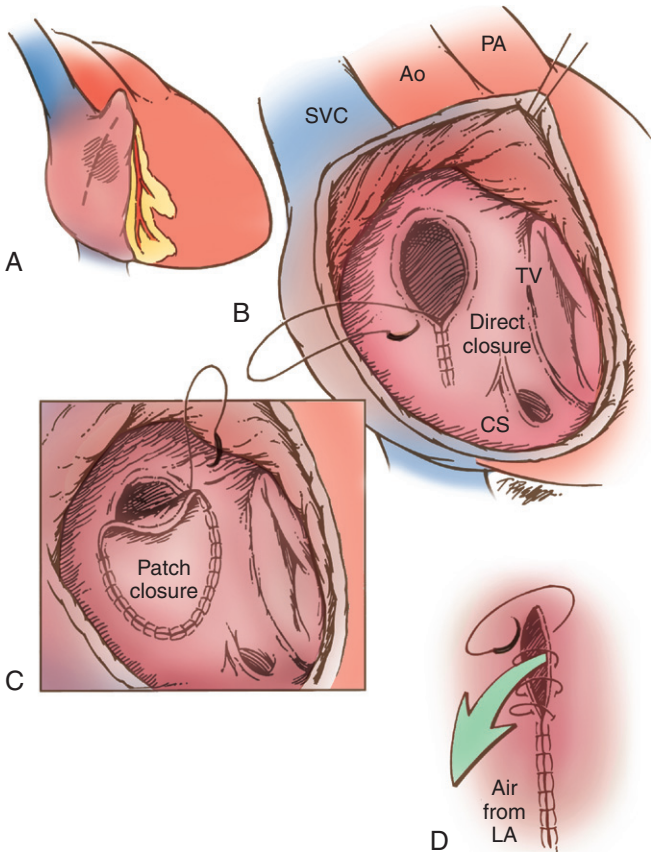


FIGURE 25-56 Surgical procedure for atrial septal defect (ASD) closure. **A**, Incision through right atriotomy. Direct suture closure, **B**, and patch closure, **C**, of secundum ASD. **D**, Deairing of the left atrium. *Ao,* Aorta; *CS,* conduction system; *LA,* left atrium; *PA,* pulmonary artery; *SVC,* superior vena cava; *TV,* tricuspid valve.

Repair of Ventricular Septal Defect

One of the most common congenital cardiac anomalies, VSDs (Figure 25-57) occur in approximately 2% to 7% of live births, with as many as 60% closing spontaneously (Ramaswamy et al, 2009). Most VSDs are small with little physiologic importance. As with ASDs, the classification of VSDs depends on location and associated lesions (Figure 25-58). Perimembranous VSDs (also called *conoventricular, subaortic, infracristal,* or *membranous*) are most commonly found. These defects occur directly

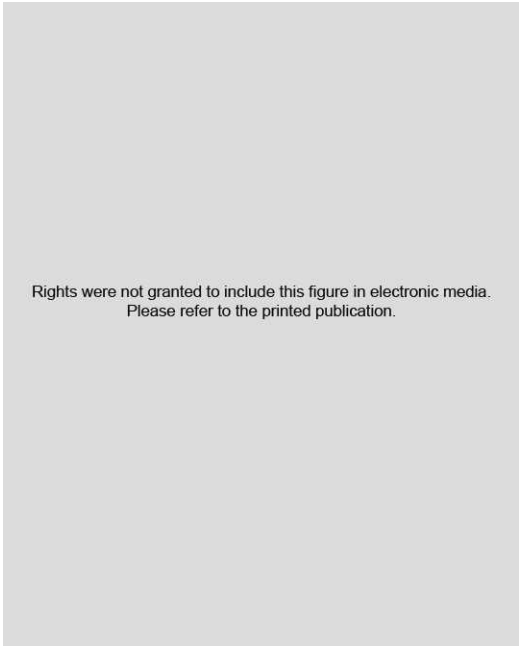


FIGURE 25-57 Ventricular septal defects: anatomic classification.

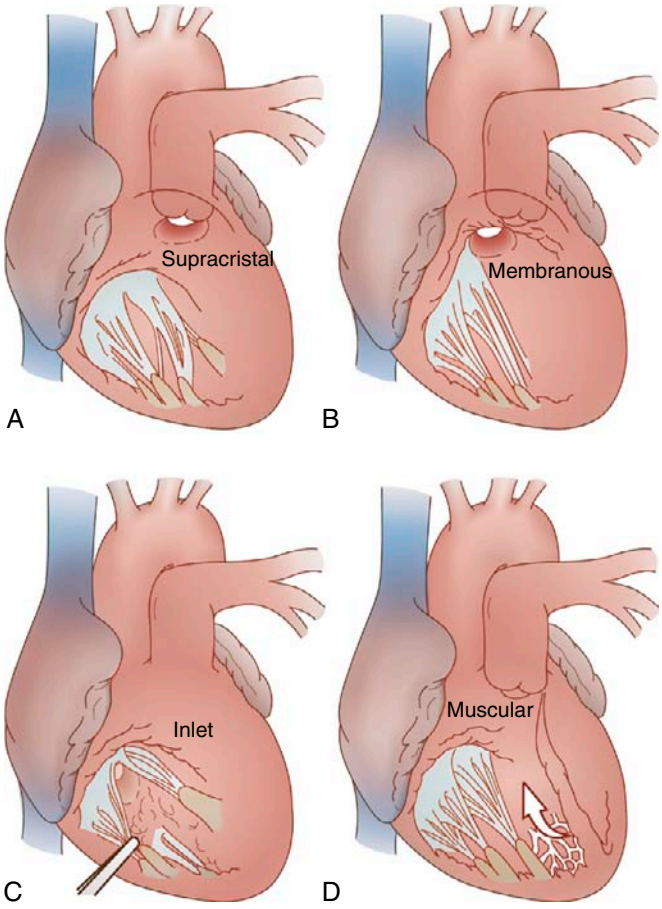


FIGURE 25-58 Various types of ventricular septal defects viewed within the right ventricle. **A**, Infundibular (supracristal). **B**, Membranous. **C**, Inlet (AV canal). **D**, Muscular (trabecular).

adjacent to the membranous septum and the fibrous trigone of the heart where the aortic, mitral, and tricuspid valves are in fibrous continuity. The tricuspid valve tissue sometimes forms an aneurysm of the membranous septum, which may be a mechanism of defect closure for this type of defect. Subpulmonary VSDs (also referred to as *supracristal, infundibular, intracristal, outlet, conoseptal,* or *conal*) are located above the crista supraventricularis within the outlet septum and border the semilunar valves. Muscular-type VSDs can be located anywhere in the muscular septum, including apical, anterior, or posterior, or in the midseptum inlet and outlet. Malalignment-type VSDs are created by a malalignment between the infundibular septum and the trabecular muscular septum. Canal-type or inlet defects are located posteriorly within the area confined by the tricuspid valve septal leaflet papillary muscles. The defect borders the tricuspid valve annulus.

The hemodynamics depend on the size and location of the defect as well as the pulmonary vascular resistance (PVR) and systemic vascular resistance (SVR). Newborns are often asymptomatic until the PVR decreases—then a left-to-right shunt occurs, and the corresponding murmur is auscultated. Small defects with moderate shunt and increased pulmonary blood flow but not increased pulmonary pressure may not produce any symptoms. A large VSD, however, may produce high pulmonary flow under high pressure and contribute to CHF. In

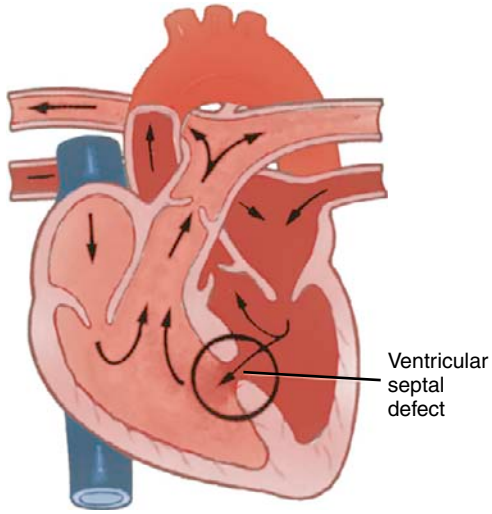


FIGURE 25-59 Ventricular septal defect.

this case the patient is at risk of developing pulmonary hypertension (Figure 25-59). Surgical closure of the defect should be performed to prevent increased pulmonary hypertension. If PVR further increases and rises above SVR, shunt reversal (Eisenmenger's syndrome, or shunting from right to left) and cyanosis may occur.

Operative Procedure. Under direct vision, a congenital defect in the ventricular septum (Figure 25-60) is closed by a simple suture technique or, in most instances, by insertion of a synthetic prosthetic or pericardial patch.

1. A median sternotomy is performed, and CPB is instituted.
2. The location of the defect determines the location of the incision. For membranous and canal defects, an incision is usually made in the right atrium, the atrium is retracted, and the VSD is identified by use of a pump suction through the tricuspid valve into the right ventricle. For supracristal VSDs, an incision is usually made in the pulmonary artery and may be extended into the right ventricle. A muscular VSD may require a ventriculotomy.
3. A patch is most frequently used to close the defect. To place the patch, a continuous 6-0 or 5-0 nonabsorbable suture on a small needle or an interrupted suture with or without pledgets may be used. Rarely is the defect closed primarily.
4. CPB is discontinued, and the sternum is closed.

Correction of Tetralogy of Fallot

TOF, described initially in the early nineteenth century, includes the association of four anatomic findings: VSD, subpulmonic stenosis, aortic override of the ventricular septum, and right ventricular hypertrophy (RVH) (Figure 25-61). Occurring in approximately 10% of congenital heart defects, TOF is actually the result of a single anatomic abnormality: anterior malalignment of the infundibular septum with the muscular septum (Davis, 2007).

The preoperative hemodynamics or physiology depends mainly on the degree of pulmonary stenosis. In patients with minimal obstruction to pulmonary blood flow, the physiology is similar to that of a VSD with left-to-right shunting. These patients will have pulmonary overcirculation and symptoms of

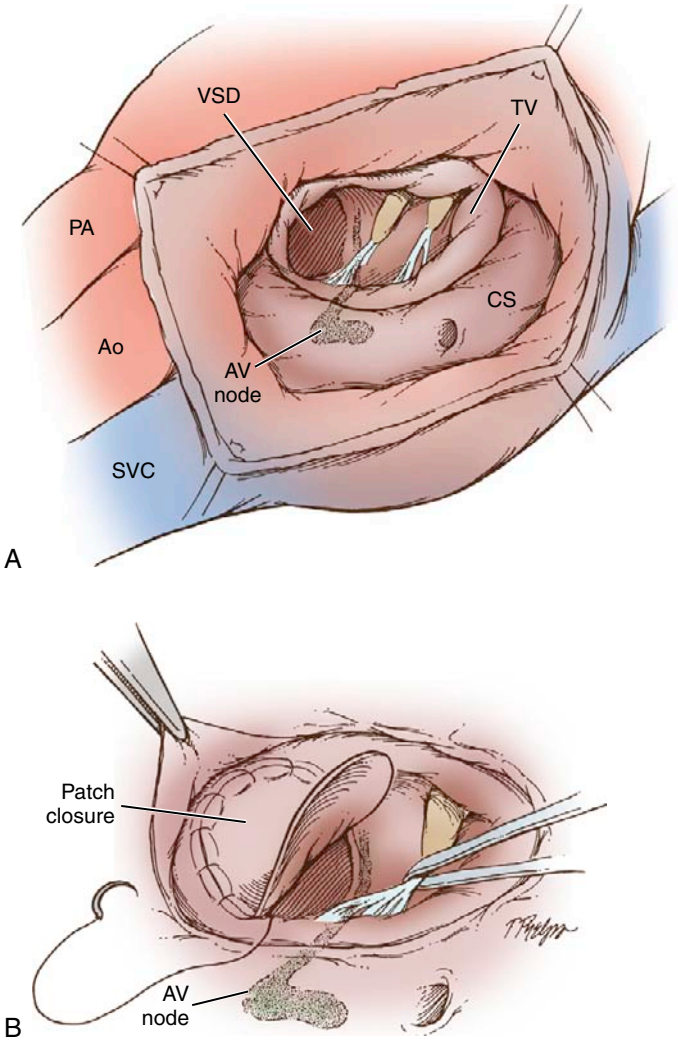


FIGURE 25-60 Ventricular septal defect *(VSD)* closure through the tricuspid valve *(TV)*. **A**, Open site. **B**, Partial closure. *Ao,* Aorta; *AV,* atrioventricular; *CS,* conduction system; *PA,* pulmonary artery; *SVC*, superior vena cava.

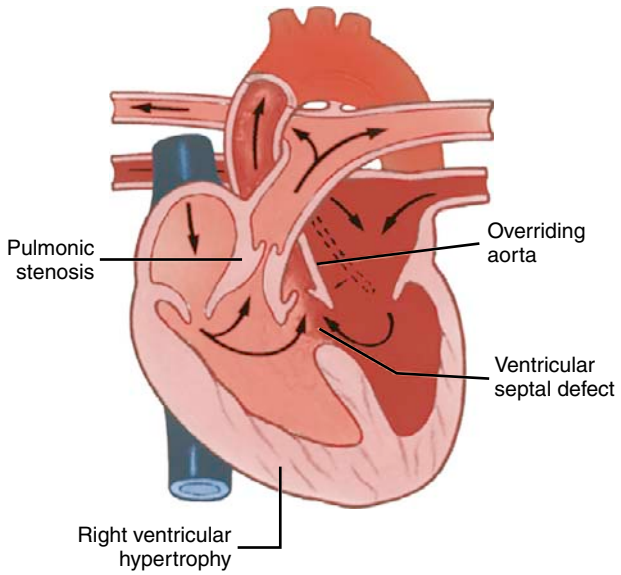


FIGURE 25-61 Tetralogy of Fallot.

CHF. Occasionally labeled as "pink tets," these patients have little to no right-to-left shunting and do not exhibit cyanosis.

At the other end of the spectrum of this particular type of heart defect are children with severe pulmonary stenosis, who may have significant right-to-left shunting at the VSD level and exhibit hypoxemia with oxygen saturations in the 60% to 80% range. Cyanosis, as seen in the superficial vessels of the skin, is the result of shunting unoxygenated blood into the systemic circulation. Other clinical manifestations may include episodes of acute dyspnea with cyanosis, retarded growth, clubbing of extremities, reduced exercise tolerance, and increased prevalence of "tet," or hypercyanotic spells. A systolic murmur and secondary polycythemia are usually present in the cyanotic child. Echocardiography is performed to confirm the diagnosis of TOF; occasionally a cardiac catheterization and angiography may be necessary in delineating other anatomic abnormalities, such as with the coronary arteries, before surgical repair.

The selection of a palliative or corrective procedure is based on the age and general condition of the child and the severity of the pulmonary stenosis. The treatment of choice is primary repair; contraindications for primary repair include anomalous origin of the anterior descending coronary artery and presence of pulmonary atresia. Complete or primary repair consists of closure of the VSD and repair of the pulmonic stenosis under direct vision.

Procedural Considerations. The child is placed on the OR bed in a supine position. The setup is the same as that described for open-heart surgery, with consideration given to the child's age and size. Additional items to be added to the basic open-heart setup include the following: intracardiac patch, 2 × 2 inch; outflow cardiac patch, 2 × 2 inch; and a felt or Gortex patch, 4 × 4 inch.

Operative Procedure

1. A median sternotomy is performed, and CPB with hypothermia is instituted.
2. A vertical ventriculotomy over the infundibular area may be performed (Figure 25-62, *A*).
3. The VSD is identified. Closure requires an intracardiac patch in almost all instances. This can be of a synthetic material or a piece of pericardium.
4. Interrupted or continuous cardiovascular sutures are placed in the septum with caution because of the danger of suturing a branch of the neuroconductive system.
5. The hypertrophied infundibular muscle is excised, as completely as possible, from the right ventricular outflow tract. If the pulmonic valve is stenosed, the fused commissures are incised.
6. An estimate is made about whether the right ventricle can be closed primarily or if a patch is necessary. If the pulmonic stenosis cannot be relieved adequately by valvulotomy and infundibulectomy, an outflow patch of synthetic material or pulmonary homograft tissue may be needed to enlarge the outflow tract (Figure 25-62, *B*). If the pulmonary artery or valve annulus is quite small, it may be necessary to extend the patch across the valve ring to the proximal portion of the pulmonary artery (Figure 25-62, *C*).
7. CPB is discontinued, and the sternum is closed.

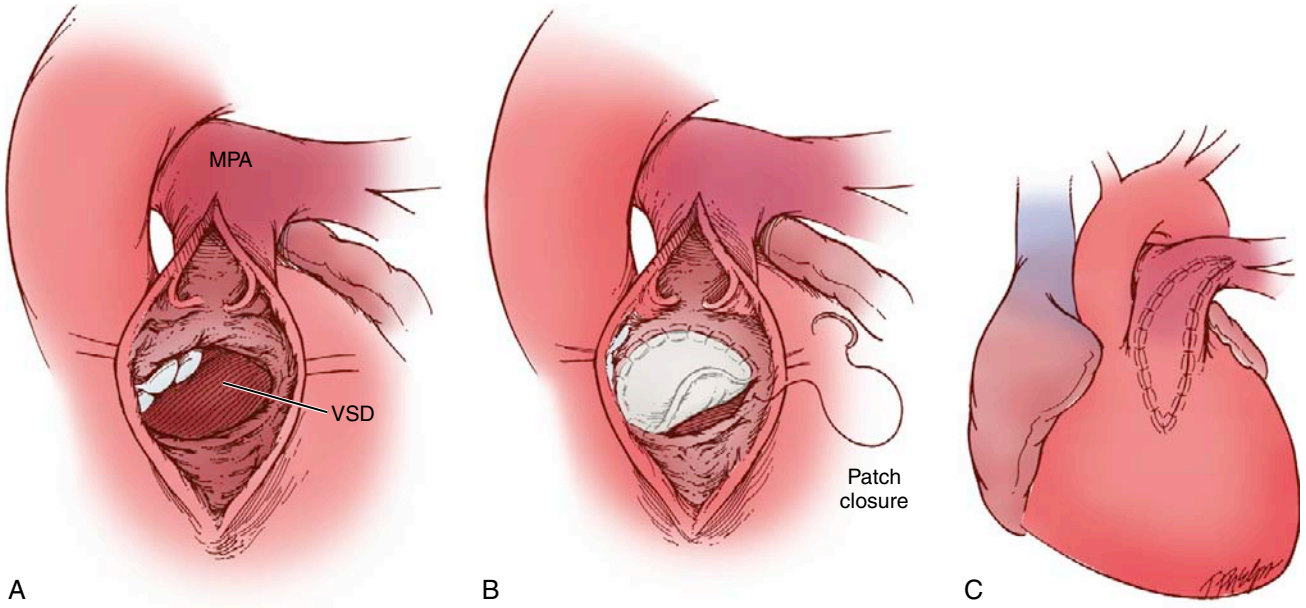


FIGURE 25-62 **A**, The most common ventricular incision used for repair of tetralogy of Fallot is vertical so that it can be extended as shown from the right ventricle across the pulmonary valve annulus and onto the main pulmonary artery *(MPA)*. It is possible to gain adequate exposure to the ventricular septal defect *(VSD)* by extending the incision a short distance beyond the infundibular septum. This "limited ventriculotomy" may help preserve late right ventricular function yet enable adequate enlargement of the hypoplastic area in the right ventricular outflow tract. **B**, The VSD is closed with a prosthetic patch. Right ventricular outflow obstruction is relieved when the outflow tract is enlarged with a patch as shown. **C**, In some cases it may be necessary to extend the incision onto the left pulmonary artery and to taper the patch at its most distal extent.

Closure of Patent Ductus Arteriosus

PDA occurs because of persistence of the fetal ductus arteriosus, which connects the pulmonary artery to the aorta. The condition is common in premature infants. In fetal life, blood bypasses the lungs, traveling directly to the systemic circulation through the PDA. This vessel normally closes shortly after birth as a result of the onset of respiration causing an increase in Pao_2 level and the release of circulating humoral substances. However, if this does not occur, the ductus arteriosus remains open (Figure 25-63), creating a shunt from the aorta through the ductus into the pulmonary circulation. This increases the workload of the heart and causes subsequent enlargement and hypertrophy of the left atrium and ventricle. However, when persistent patency of the ductus is associated with other malformations such as TOF and extreme stenosis of the pulmonary orifice, it is a means of maintaining life. Surgery is not performed if the PDA is serving in a compensatory capacity.

Many children have few symptoms because of the small size of the shunt. A frequent clinical sign associated with this condition is a harsh, continuous murmur. Because the blood passing through the shunt is oxygenated, there is no cyanosis, clubbing, or reduction in peripheral arterial oxygen saturation. However, growth is retarded in children who have a large ductus. Other signs and symptoms may include dyspnea, frequent upper respiratory tract infections, palpitations, limited exercise tolerance, and cardiac failure.

Procedural Considerations. Closure of the PDA is achieved by suture ligation or by division of the ductus. For newborns, the surgeon and anesthesia provider may elect to perform this procedure in the intensive care nursery bed because the operation is a short one. However, after the newborn period, the surgery is done in the OR. The child is placed in a right lateral position. The setup is the same as that described for open-heart surgery, but with special patent ductus clamps and without items for CPB. Generally a left posterolateral approach is used; in some cases, however, a left anterolateral approach is used.

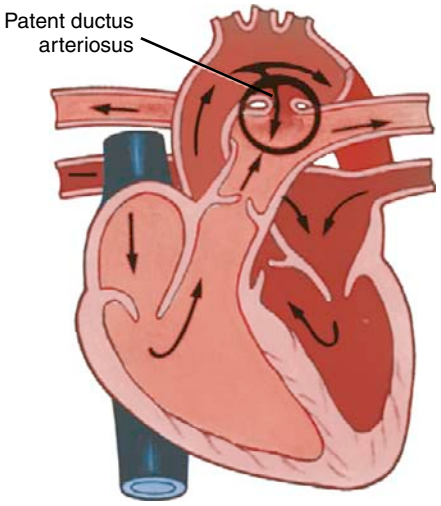


FIGURE 25-63 Patent ductus arteriosus.

Operative Procedure

1. The incision is carried through the muscles over the fourth interspace. The chest wall is entered through the third or fourth intercostal space, with use of items as described for thoracotomy (see Chapter 22). The wound edges are protected and retracted with a Finochietto rib spreader.
2. The pleura is incised with Metzenbaum scissors, and the left lung is protected and retracted with a moist pack and a malleable retractor.
3. The mediastinal pleura is opened between the phrenic and vagus nerves over the region of the ductus. The pleura is retracted by insertion of stay sutures. The recurrent laryngeal nerve is identified and protected. The aortic arch and pulmonary artery are dissected with fine scissors and dry dissectors. Fine arterial branches are divided and ligated with curved Crile or mosquito hemostats and nonabsorbable ligatures and cardiac suture ligatures.
4. The parietal pleura overlying the ductus is dissected with fine vascular forceps and scissors. Stay sutures may be inserted to facilitate retraction.
5. The adventitial layer of the ductus is dissected free. A small portion of the obscure posterior ductus is carefully freed to admit a right-angle clamp.
6. The final step is performed in one of the following ways:
   a. For the suture-ligation method (Figure 25-64, *A*), two ligatures are placed around the ductus—one near the aorta and the other near the pulmonary artery side, both of which are tied in place. Between these two ligatures, two transfixion sutures may be inserted.
   b. For the division of the ductus method, the patent ductus clamps are applied as close to the aorta and pulmonary artery as possible. The ductus is divided halfway through and partially sutured with mattress cardiovascular sutures and continued back over the free edge with an over-and-over whip suture (Figure 25-64, *B*). After both openings are sutured, a sponge is held on the area for compression while the patent ductus clamps are removed.
   c. In premature infants, only a hemoclip may be applied to the ductus because of the friable nature of the ductal tissue. The mediastinal pleura is closed with interrupted sutures. The lung is reexpanded, and a chest catheter may be inserted to establish closed drainage. In newborns, reexpansion of the lung may be accomplished by gradual withdrawal of a catheter during closure; no chest drainage tube is required unless there is oozing. The chest wall is closed in layers, and dressings are applied.

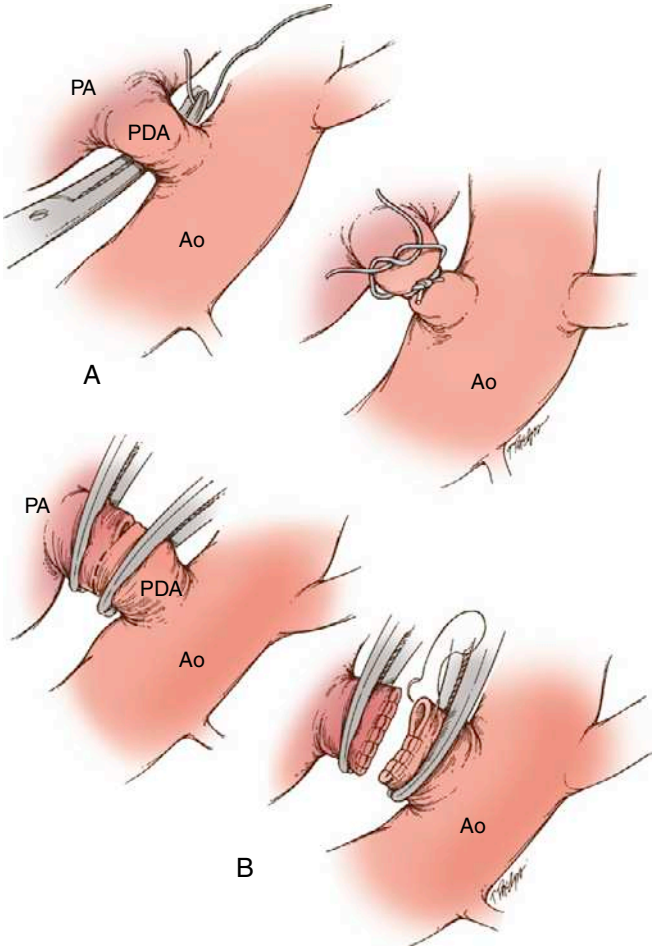


FIGURE 25-64 Surgical correction of patent ductus arteriosus *(PDA)*. **A**, Ligation of ductus arteriosus. **B**, Division of ductus arteriosus. *Ao,* Aorta; *PA,* pulmonary artery.

Repair of Hypoplastic Left Heart Syndrome

Hypoplastic left heart syndrome (HLHS) (Figure 25-65) is one of the most common forms of single ventricle malformation. HLHS describes a range of congenital cardiac malformations that have in common underdevelopment of the left-sided heart structures, which include aortic valve atresia and stenosis with associated hypoplasia or absence of the left ventricle. The ascending aorta and arch are usually only a few millimeters in diameter and are functionally a branch of the ductus arteriosus–thoracic aorta continuum, with blood flowing retrograde through the aortic arch and into the small ascending aorta to the coronary arteries. Mitral valve atresia or stenosis also is present.

Survival in the newborn period depends on a PDA to maintain systemic circulation; therefore these infants are maintained on an infusion of prostaglandin E_1 (PGE_1) to maintain ductal patency before surgical intervention.

Newborns with HLHS typically present with cyanosis, respiratory distress, and variable degrees of circulatory collapse during the first few days of life. If left untreated, a majority of these neonates will die within the first month of life; without surgical intervention, HLHS is fatal.

It was not until the development of the Fontan procedure—a surgical correction for another form of single ventricle malformation (tricuspid atresia)—that long-term survival in patients with HLHS was considered possible. However, because of the neonate's high PVR, the Fontan procedure is not a surgical option in the newborn period. A palliative repair (stage I) was developed in the late 1970s by Norwood to prepare the heart for the Fontan procedure.

Two surgical options for patients with HLHS exist: a series of reconstructive procedures or heart transplantation. The series of reconstructive procedures usually involves three stages. Stage I is performed during the newborn period. The goals of stage I are to (1) maintain systemic perfusion, (2) preserve the function of the only ventricle, and (3) allow normal

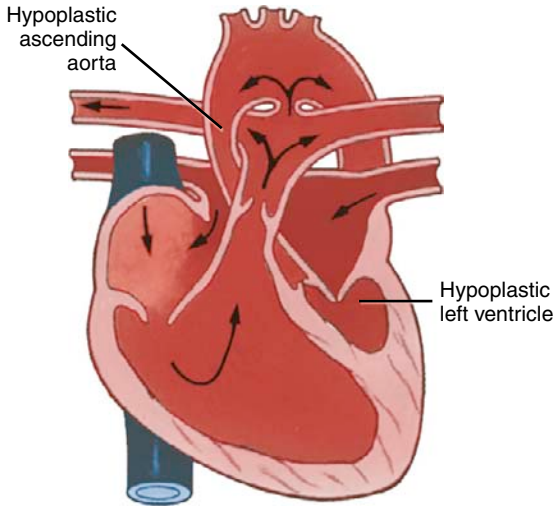


FIGURE 25-65 Hypoplastic left-sided heart syndrome.

maturation of the pulmonary ventricle. The first goal is met by creating an unobstructed communication between the right ventricle and the systemic circulation. This is accomplished by transecting the main pulmonary artery and creating a neoaorta from the main pulmonary artery, native aorta, and pulmonary homograft tissue. The other two goals are met by creating a right modified Blalock-Taussig (BT) shunt and a nonrestrictive interatrial communication. These measures allow for adequate pulmonary blood flow and for the PVR to decrease as the child grows while the volume interposed on the single ventricle is limited.

The modified Fontan procedure was initially performed on a child at approximately 18 months of age. However, since 1989 a staged approach to the Fontan procedure has been undertaken to minimize the effect of rapid changes in ventricular configuration and diastolic function that can be associated with a primary Fontan procedure and its accompanying postoperative complications. In the stage II procedure (hemi-Fontan or the bidirectional Glenn shunt), superior vena cava (SVC) blood flow is directed to the lungs and inferior vena cava (IVC) blood flow continues to flow to the right ventricle. The third and final stage, the modified Fontan procedure, separates the systemic and pulmonary circulations.

Procedural Considerations. Additional items for the open-heart setup include the following:

- Stage I: polytetrafluoroethylene (PTFE) tube graft, 3.5 or 4 mm, and pulmonary homograft tissue
- Stage II: oscillating saw and pulmonary homograft tissue
- Stage III: oscillating saw and PTFE tube graft, 10 mm; a higher-than-usual supply of blood should be available

Operative Procedure

STAGE I (NORWOOD PROCEDURE) (Figure 25-66)

1. A median sternotomy is performed. The aortic cannula is placed into the main pulmonary artery rather than the diminutive aorta, and the venous cannula is placed into the right atrium. CPB is instituted, and the right and left pulmonary arteries are immediately occluded with tourniquets to force the blood through the ductus arteriosus to the systemic circulation.
2. When deep hypothermic circulatory arrest is about to be instituted, the innominate and left carotid arteries are occluded with tourniquets. The venous and aortic cannulae are removed.
3. The septum primum is excised through the venous cannulation site; occasionally a right atriotomy is necessary to facilitate the atrial septectomy.
4. The main pulmonary artery is transected immediately before the bifurcation of the right and left pulmonary arteries.
5. The distal pulmonary artery is closed with a small patch of homograft tissue.
6. The ductus arteriosus is then exposed and closed using a 2-0 nonabsorbable tie. The tie is left long to better expose the thoracic aorta. The ductus is transected.
7. At the point where the ductus was attached to the aorta, the thoracic aorta is opened 1 to 2 cm, and the aortic arch and ascending aorta are opened to a point adjacent to the main pulmonary artery.
8. A gusset of homograft tissue is joined to the aorta starting at the thoracic end, and the pulmonary artery is incorporated at the proximal end of the ascending aorta. A continuous monofilament stitch is used. Occasionally interrupted sutures are used to attach the main pulmonary artery to the aorta.
9. To perform a right BT shunt, the innominate artery is cross-clamped and incised and a 3.5- or 4-mm PTFE tube graft is interposed.
10. CPB is instituted, and the pulmonary end of the shunt is performed by incising the pulmonary artery and interposing the distal end of the tube graft.
11. Immediately after the shunt is completed, the shunt is occluded with a bulldog clamp until termination of bypass.

STAGE II (HEMI-FONTAN PROCEDURE) (Figure 25-67)

1. Because these patients have had previous surgery, an oscillating saw is used for the median sternotomy.
2. The aorta, right atrium, and right BT shunt are exposed.
3. CPB is instituted, and the shunt is immediately occluded with a clip.
4. The branch pulmonary arteries are exposed.
5. Depending on the surgeon's preference, deep hypothermic circulatory arrest may be instituted.
6. An incision is made in the confluence of the pulmonary arteries, extending to the pericardial reflections.
7. An incision is made in the dome of the right atrium, extending to the SVC.
8. The pulmonary artery is then anastomosed to the SVC–right atrial junction.
9. The pulmonary arteries are augmented with a gusset of homograft tissue. In the hemi-Fontan procedure, part of the homograft tissue is incorporated intraatrially as a dam between the common atrium and the vena cava–pulmonary artery anastomosis. In the Glenn shunt, there is no intraatrial incorporation.
10. CPB is reinstituted until the patient is normothermic. CPB is then discontinued, and chest closure is completed.

STAGE III (MODIFIED FONTAN PROCEDURE) (Figure 25-68)

1. A median sternotomy is performed with an oscillating saw.
2. The aorta and right atrium are exposed.
3. CPB is instituted.
4. Deep hypothermic circulatory arrest may be used.

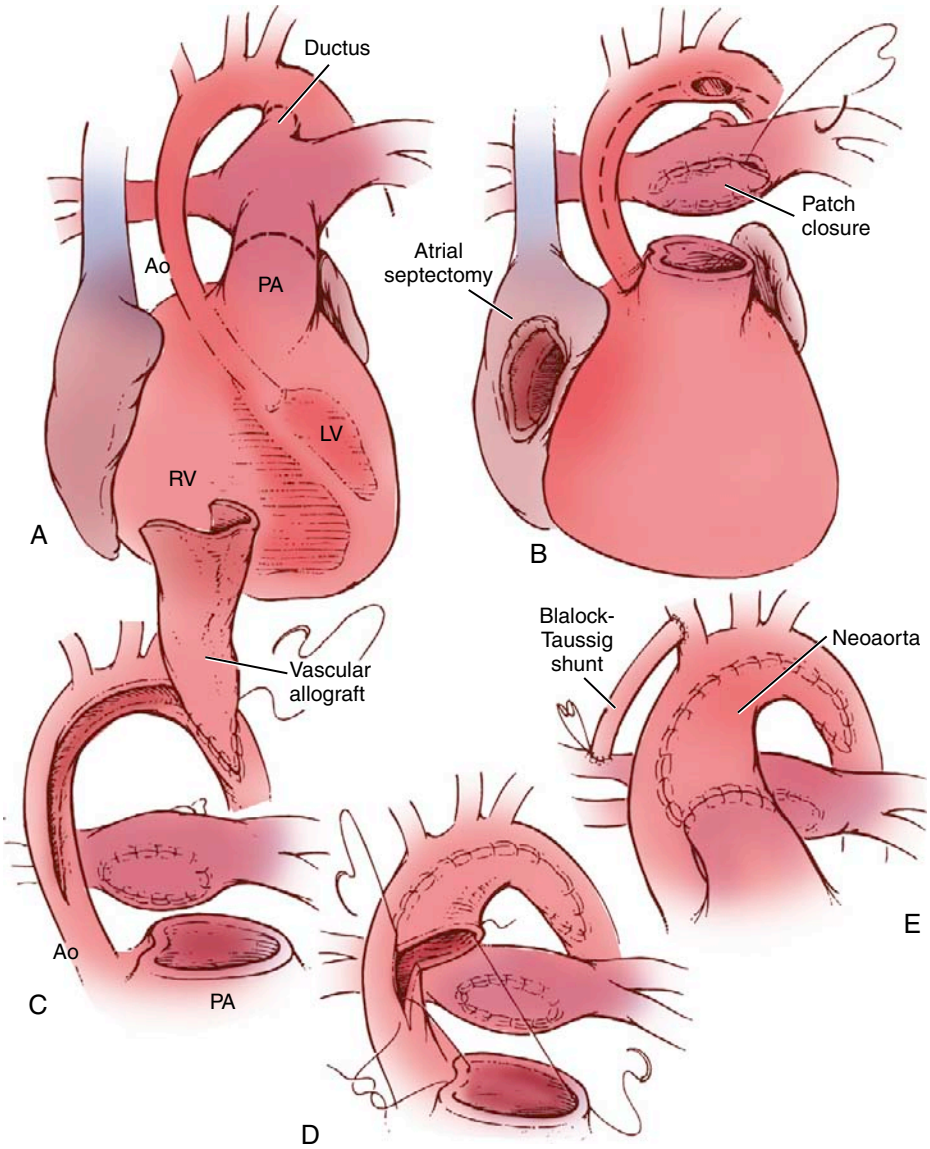


FIGURE 25-66 Stage I Norwood procedure. **A**, Transection points of the main pulmonary artery *(PA)* and ductus arteriosus. **B**, Atrial septectomy to avoid pulmonary venous hypertension. Patch closure of the distal main PA. Division and ligation of the ductus arteriosus. **C** and **D**, Construction of a "neoaorta" with use of the proximal main PA, diminutive ascending aorta, and vascular allograft. **E**, Pulmonary blood flow supplied by a right modified Blalock-Taussig shunt connecting the right subclavian artery to the right PA. *Ao,* Aorta; *LV,* left ventricle; *RV,* right ventricle.

5. A lateral incision is made in the right atrium.
6. A 10-mm PTFE tube graft is cut in half lengthwise and is placed intraatrially by suturing the inferior end of the graft around the orifice of the IVC and up the right lateral free wall of the right atrium to the superior dome of the right atrium. This creates a tunnel in which the inferior blood flow is directed to the pulmonary arteries. The superior vena cava blood flow was directed to the pulmonary arteries during the stage II repair. (The surgeon may perform variations on this procedure, such as excluding a hepatic vein or performing a fenestrated Fontan by making a series of small openings in the PTFE tube graft or a single 4-mm opening with an aortic punch in the graft material.)
7. The atria are closed, and CPB is reinstituted until the patient is normothermic. CPB is then discontinued, and chest closure is completed.

Extracorporeal Membrane Oxygenation

Extracorporeal membrane oxygenation (ECMO) is a therapy used on pediatric patients who have reversible pulmonary or cardiac disease. Many patients are neonates with respiratory disease syndrome (RDS), persistent pulmonary hypertension (PPH), meconium aspiration (MA), or congenital diaphragmatic hernia (CDH) requiring adequate tissue oxygenation and waste removal from the body. In the cardiac patient, it may also be used as a bridge to heart or lung transplantation until donor

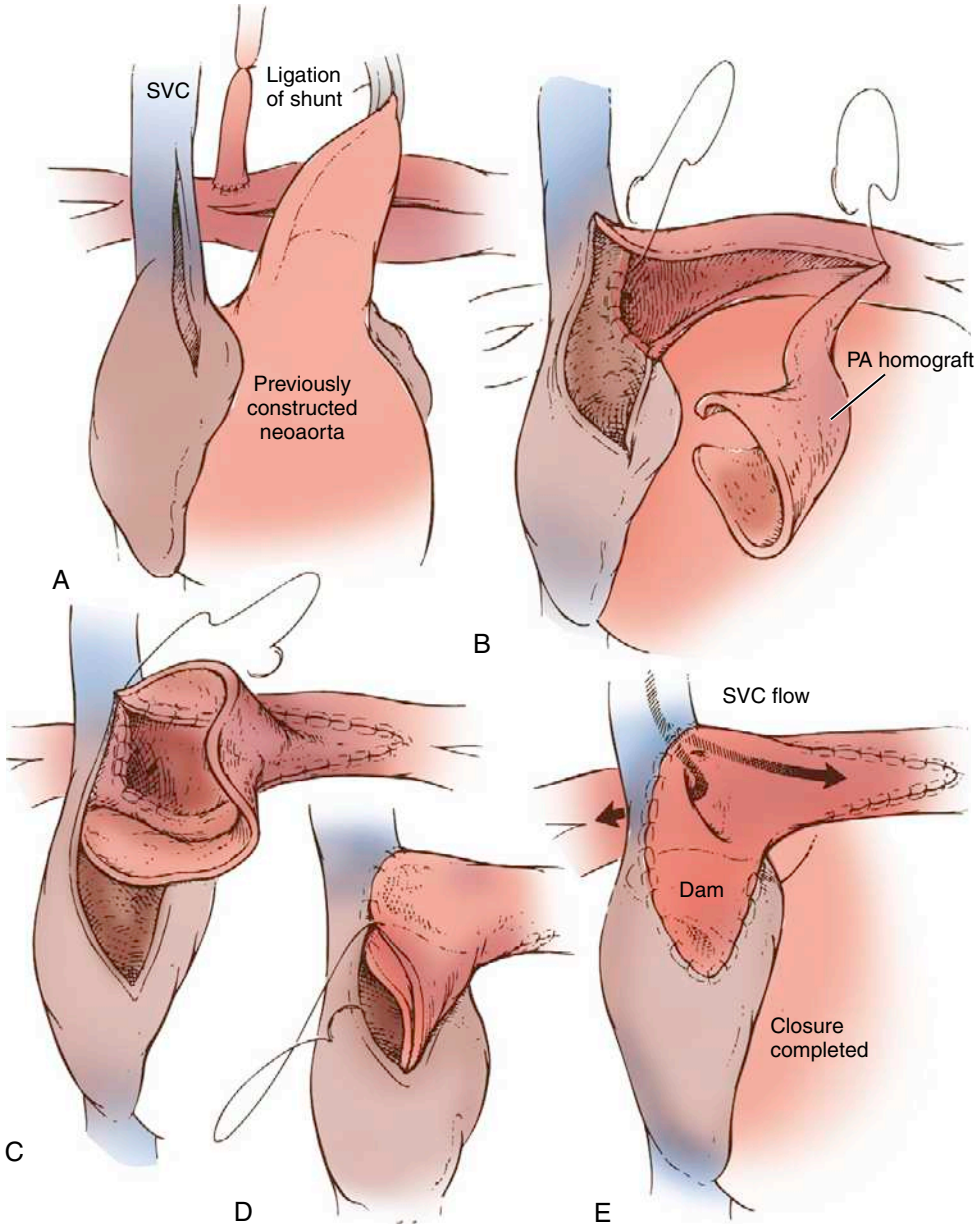


FIGURE 25-67 Hemi-Fontan procedure in a patient with hypoplastic left-sided heart syndrome. **A** and **B**, Ligation of the systemic-to-pulmonary artery shunt and side-to-side anastomosis of the superior vena cava *(SVC)* to the confluence of the pulmonary artery *(PA)* with allograft augmentation. **C** to **E**, Placement of a dam to close the junction of the atrium with the SVC so that saturated pulmonary venous blood mixes in the common atrium with desaturated blood draining from the inferior vena cava. Pulmonary blood flow is supplied exclusively through the SVC.

organs are available. To perform ECMO, a facility must have an established ECMO service.

Most of the time children are placed on ECMO in the ICU. For venoarterial ECMO the surgical approach is usually through the right carotid artery and internal jugular vein. For the cardiac patient after surgical repair, cannulation of the carotid artery and jugular vein provides good venous drainage of the right atrium, and the incision site is remote from the sternotomy wound. However, the surgeon may choose to reopen the sternum on postoperative patients and cannulate the aorta and right atrium. In the OR, for a patient who cannot be successfully weaned from bypass after surgery, the patient's bypass circuit may be switched to an ECMO circuit and the patient may be transferred on ECMO to the ICU.

Procedural Considerations. An area by the patient's bedside should be provided for the ECMO pump, surgical table and instrumentation, electrosurgical unit (ESU), surgeon's headlight, and defibrillator with external and sterile internal paddles. A wall suction outlet should be available. Appropriate surgical attire should be provided for everyone involved with the procedure, and traffic should be limited.

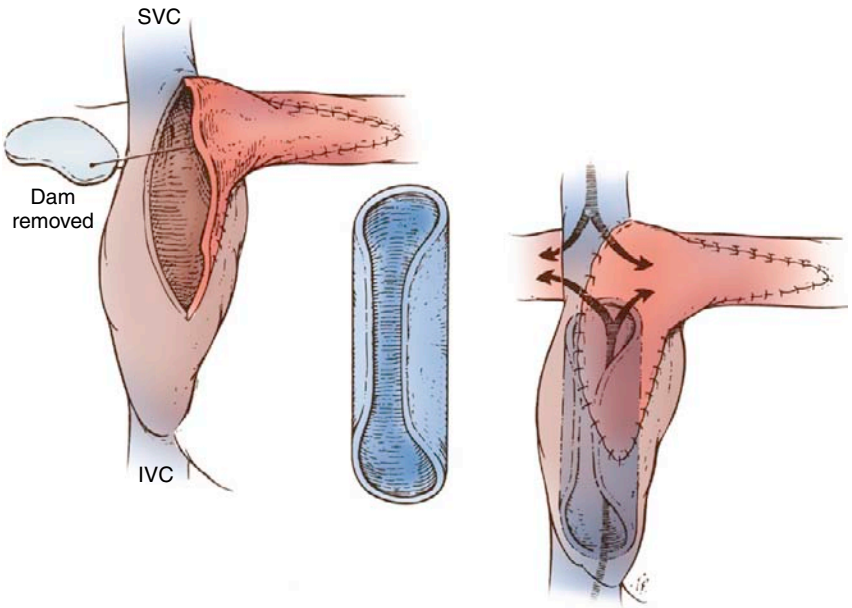


FIGURE 25-68 Conversion of hemi-Fontan to completion of Fontan. Excision of the dam between the right atrium and the superior vena cava–pulmonary artery anastomosis. Inferior vena cava flow is directed to the inlet of the superior vena cava–pulmonary artery anastomosis by a baffle. *IVC*, Inferior vena cava; *SVC*, superior vena cava.

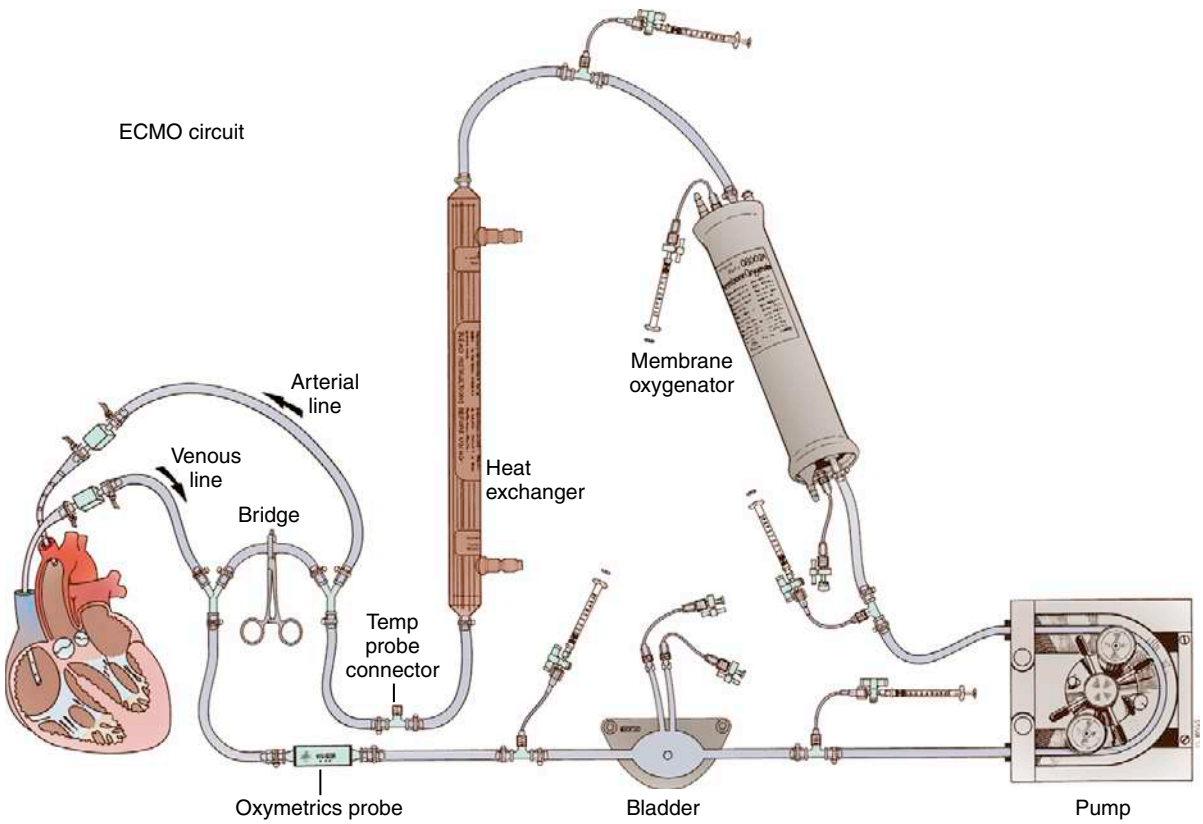


FIGURE 25-69 Extracorporeal membrane oxygenation (ECMO) circuit.

Operative Procedure

FOR NECK CANNULATION. A shoulder roll is placed under the patient, and the neck and chest to the nipple line are prepped and draped. The ears should also be exposed and prepped for use as reference points.

1. An incision is made in the neck, and the right common carotid artery and right internal jugular vein are exposed for venoarterial ECMO.
2. The surgeon may cannulate the vessels through a purse-string suture and then reconstruct these vessels at the time of decannulation.
3. After insertion of the arterial and venous cannulae, the clamped cannulae are connected to the ECMO circuit. All the air is eliminated (Figure 25-69).
4. The cannulae are secured to the skin. The neck incision is closed and dressed. The surgical instruments are kept sterile until proper positioning of the venous and arterial cannulae is confirmed by x-ray examination.

FOR MEDIAN STERNOTOMY CANNULATION. The patient is prepped from neck to umbilicus and draped.

1. The patient has usually had a prior sternotomy incision, and so the sternum is opened with wire cutters.
2. A chest retractor is inserted, and purse-string sutures for cannulation are placed in the aorta and right atrium.
3. The aorta and venous cannulae are inserted and clamped.
4. The clamped cannulae are connected to the ECMO circuit. All the air is eliminated.
5. The sternum is left open to prevent kinking of the cannulae and ECMO pump tubing. The wound is closed with a synthetic patch sutured to the skin. An antibiotic ointment may be applied and an "Open Chest" sign placed on top of the outer dressing to serve as a warning related to potential chest compressions.

REFERENCES

American Academy of Orthopedic Surgeons (AAOS): Children's clubfoot: treatment with casting or operation, 2007, available at http://orthoinfo.aaos.org/topic.cfm?topic=A00296. Accessed May 18, 2009.

American Association for Pediatric Ophthalmology and Strabismus (AAPOS): Frequently asked questions, 2005, available at www.aapos.org/displaycommon.cfm?an=1&subarticlenbr=231. Accessed February 24, 2009

American Cancer Society (ACS): *Cancer facts and figures 2009*, Atlanta, 2009, The Society.

Betz CL, Sowden LA: *Mosby's pediatric nursing reference*, ed 6, St Louis, 2008, Mosby.

Children's Hospital of Philadelphia (CHOP): *Congenital Hyperinsulinism Center,* available at www.chop.edu/consumer/jsp/division/generic.jsp?id=71065. Accessed May 15, 2009.

Cooper A: Early assessment and management of trauma. In Ashcraft KW et al, editors: *Pediatric surgery*, ed 4, Philadelphia, 2005, Saunders.

Cote CJ: Pediatric anesthesia. In Miller RD, editor: *Miller's anesthesia*, ed 6, vol 2, Philadelphia, 2005, Churchill Livingstone.

Davis GT: Hemolytic disorders and congenital abnormalities. In Lowdermilk DL et al, editors: *Maternity and women's health care*, ed 9, St Louis, 2007, Mosby.

Fallat ME: Intussusception. In Ashcraft KW et al, editors: *Pediatric surgery*, ed 4, Philadelphia, 2005, Saunders.

Garcia VF: Umbilical and other abdominal wall hernias. In Ashcraft KW et al, editor: *Pediatric surgery*, ed 4, Philadelphia, 2005, Saunders.

Gronert GA et al: Malignant hyperthermia, In Miller RD, editor: *Miller's anesthesia*, ed 6, vol 2, Philadelphia, 2005, Churchill Livingstone.

Harrington S et al: Pediatric laparoscopy, *AORN J* 88(2):211–236, 2008.

Heher KL, Katowitz JA: Pediatric ptosis. In Katowitz JA, editor: *Pediatric oculoplastic surgery*, New York, 2002, Springer.

Inge TH et al: Bariatric surgical procedures in adolescence. In Ashcraft KW et al, editors: *Pediatric surgery*, ed 4, Philadelphia, 2005, Saunders.

Klein MD: Congenital abdominal wall defects. In Ashcraft KW et al, editors: *Pediatric surgery*, ed 4, Philadelphia, 2005, Saunders.

Laberge JM et al: Teratomas, dermoids and other soft tissue tumors. In Ashcraft KW et al, editors: *Pediatric surgery*, ed 4, Philadelphia, 2005, Saunders.

Melek BH: Atrial septal defect, 2006, available at www.emedicine.com/MED/topic3519.htm. Accessed August 22, 2009.

Medline Plus Medical Encyclopedia: Necrotizing enterocolitis, 2007, available at www.nlm.nih.gov/MEDLINEPLUS/ency/article/001148.htm. Accessed May 21, 2009.

Nuss D et al: Congenital chest wall deformities. In Ashcraft KW et al, editors: *Pediatric surgery*, ed 4, Philadelphia, 2005, Saunders.

Ramaswamy P et al: Ventricular septal defect, general concepts, 2009, available at www.emedicine.com/PED/topic2402.htm. Accessed August 22, 2009.

Rao PS: Tricuspid atresia, 2009, available at www.emedicine.com/PED/topic2550.htm. Accessed August 22, 2009.

Sheth RD et al: Craniosynostosis, 2008, available at: http://emedicine.medscape.com/article/1175957-overview. Accessed August 22, 2009.

Spitz L: Esophageal atresia and tracheoesophageal malformations. In Ashcraft KW et al, editors: *Pediatric surgery*, ed 4, Philadelphia, 2005, Saunders.

Turner CS: Vascular access. In Ashcraft KW et al, editors: *Pediatric surgery*, ed 4, Philadelphia, 2005, Saunders.

Whitaker L: Foreword. In Katowitz JA, editor: *Pediatric oculoplastic surgery*, New York, 2002, Springer.

Wilson D: The child with neuromuscular or muscular dysfunction. In Hockenberry MJ, Wilson D, editors: *Wong's essentials of pediatric nursing*, ed 8, St Louis, 2008, Mosby.

Wilson D et al: The child with musculoskeletal or articular dysfunction. In Hockenberry MJ, Wilson D, editors: *Wong's essentials of pediatric nursing*, ed 8, St Louis, 2008, Mosby.

Wu CL: Pain management. In Miller RD, editor: *Miller's anesthesia*, ed 6, vol 2 Philadelphia, 2005, Churchill Livingstone.

CHAPTER 26

Geriatric Surgery

SHEILA L. ALLEN

Aging is a process that can be described in chronologic, physiologic, and functional terms. Human aging from a physiologic perspective has changed little in the past 300 years. In general, we age neither faster nor slower than we did in Colonial America. Chronologic age, the number of years a person has lived, is an easily identifiable measurement. Average/median life span, or life expectancy, is the age at which 50% of a given population survives. Maximum life span potential (MLSP) is the age of the longest-lived member or members of the population or species. The average life span of humans has increased dramatically, yet our MLSP has not changed substantially. Although the number of people living beyond their 90s has increased more recently, the MLSP, estimated at 125 years for women and somewhat less for men, has not changed significantly in recorded history. Chronologic age or MLSP may not be the most meaningful measurement of age, however. The youth-oriented culture of the United States tends to judge based on age and appearance. Nevertheless, many people who have lived a long time remain physiologically and functionally young, whereas others are chronologically young but physiologically and functionally old (Wold, 2008).

Many aspects of our society will be affected by the growth of the population that is 65 years old or older. Policymakers, families, businesses, and healthcare providers will be challenged to meet the needs of this growing age-group. With the aging of the baby boomers (born between 1943 and 1964), the gerontology boom will occur somewhere between 2010 and 2030, producing the most rapid increase in the older population. Economics will play a factor as individuals born before 1937 will still qualify for full Social Security benefits at age 65 with incremental increases regarding benefit age for all persons born after that time. Those born in 1960 or after will have to wait until age 67 to qualify for full benefits, with reduced benefits calculated for individuals who apply for benefits after age 62 but before the specified retirement age (Wold, 2008). Nearly 36 million people age 65 years and older lived in the United States in 2003, accounting for more than 12% of the total population, and they can be divided into four subgroups (Box 26-1). The population considered oldest-old (age 85 years and older) increased from just more than 100,000 in 1900 to 4.2 million in 2000. In 2011 baby boomers will start turning 65 years old; and this segment of the population will increase at such a rate that the 2030 population is projected to be twice as large as it was in 2000. The 65-year-old and older population will increase from 35 million to 71.5 million, representing nearly 20% of the total U.S. population. Updated figures from 2006 set the number of older Americans 65 and older at 37 million, just over 12% of the total population (Federal Interagency Forum on Aging-Related Statistics, 2008). The growth rate for this age-group is expected to slow after 2030 when the last of the boomers join the older population ranks. After 2030 the baby boomers will move into the oldest-old population (age 85 years and older), which will grow accordingly (Federal Interagency Forum on Aging-Related Statistics, 2008). Figure 26-1 provides population data. The U.S. Census Bureau estimates that the population age 85 years and older could grow from 5.3 million in 2006 to nearly 21 million by 2050 (Wold, 2008). The proportion of the older population (age 65 years and older) varies by state. This proportion is partly affected by the state fertility and mortality levels and partly by the number of older and younger people who migrate to and from the state. In 2006 Florida had the highest proportion of people age 65 years and older: 17%. Pennsylvania and West Virginia also had high proportions: more than 15%. The proportion of the population age 65 years and older varies even more by county. In 2006, 35% of McIntosh County, North Dakota, was age 65 years and older, the highest proportion in the United States. In several Florida counties, the proportion was more than 30%. At the other end of the spectrum was Chattahoochee County, Georgia, with only 2% of its population age 65 years and older (Federal Interagency Forum on Aging-Related Statistics, 2008).

As in most countries of the world, older women outnumber older men in the United States, and the proportion that is female increases with age. In 2006 women accounted for 58% of the older population and for 68% of the population age 85 years and older. The United States is fairly young by comparison with other countries, with just more than 12% of its population age 65 years and older. In most European countries, the older population comprised more than 15% of the population, and it included nearly 20% of the population in both Italy and Japan in 2006 (Ebersole et al, 2008). Mirroring the total U.S. population, the elder population is more racially diverse than ever before. By 2050 programs and services for older people will require greater flexibility to meet the needs of a more diverse population. In 2006 non-Hispanic whites accounted for nearly 81% of the U.S. older population; African Americans, just over 9%; Asians, nearly 3%; and Hispanics (of any race), nearly 6%. Projections are that by 2050 the composition of the older population will change to 61% non-Hispanic white, 18% Hispanic, 12% African American, and 8% Asian. The older Hispanic population is projected to grow the fastest, from just more than 2 million in 2005 to 15 million in 2050, and to be larger than the older African American population by 2028. In 2006 nearly 1 million older Asians lived in the United States; by 2050 this population is projected to be almost 7 million (Federal Interagency Forum on Aging-Related Statistics,

2008). Figure 26-2 illustrates resident population by racial and ethnic composition.

Those older than 100 years are the fastest-growing age-group among the U.S. population older than 65 years. The U.S. Census Bureau, generally conservative in its estimates of the aged population thus far, now estimates there will be more than 200,000 American centenarians in 2020 and 500,000 to 4 million by the year 2050. Translating these demographics into healthcare trends produces even more startling implications for perioperative patient care. As a result of the "graying" of America, healthcare will never be the same. Most older persons have at least one chronic condition, and many have multiple conditions. Chronic diseases that are rarely cured, such as heart disease, stroke, cancer, and diabetes, are among the most common and costly health conditions. These long-term health conditions negatively affect quality of life, contributing to declines in functioning and the inability to remain in the community. Although chronic conditions can be prevented or modified with behavioral interventions, five of the six leading causes of death among older Americans are chronic diseases (Federal Interagency Forum on Aging-Related Statistics, 2008). Figure 26-3 lists the percentages of chronic diseases by gender. Between 1992 and 1999, the hospitalization rate in the older population increased from 306 hospital stays per 1000 Medicare enrollees to 365 per 1000. In 2005 the rate decreased to 350 per 1000 enrollees; however, the average length of stay decreased from 8 days in 1992 to 5.7 days in 2005. The number of Medicare enrollees staying in skilled nursing facilities increased from 28 per 1000 in 1992 to 79 per 1000 in 2005. The utilization rates for many services change based on changes in medical technology and physician practice patterns (Federal Interagency Forum on Aging-Related Statistics, 2008). The dramatic growth in elderly surgical patients punctuates the necessity for perioperative nurses to recognize the special needs of these patients. Understanding how normal aging changes and chronic disease affect the successful outcome of any surgical procedure is critical and is therefore the emphasis of this chapter.

BOX 26-1

Categorizing the Aging Population

- 65 to 74 years of age: the young-old
- 75 to 84 years of age: the middle-old
- 85 to 99 years of age: the old-old
- 100 years of age or more: the elite-old

From Ignatavicius DD: Health care of older adults. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, St Louis, 2010, Saunders.

Perioperative Nursing Considerations

Preliminary Evaluation

Before an elderly patient actually arrives in surgery, the physician considers many factors to determine whether the benefits outweigh potential risks. In the past, elders were not considered good candidates for surgery merely because of age

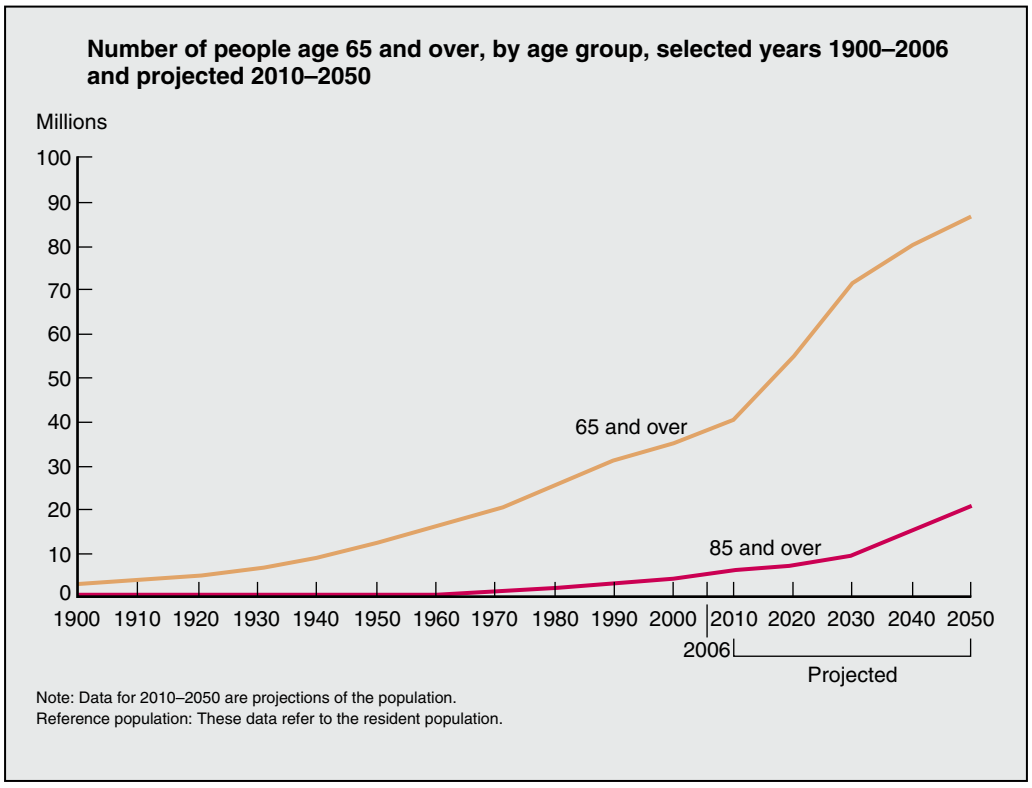


FIGURE 26-1 Actual and projected population data for people age 65 years and older.

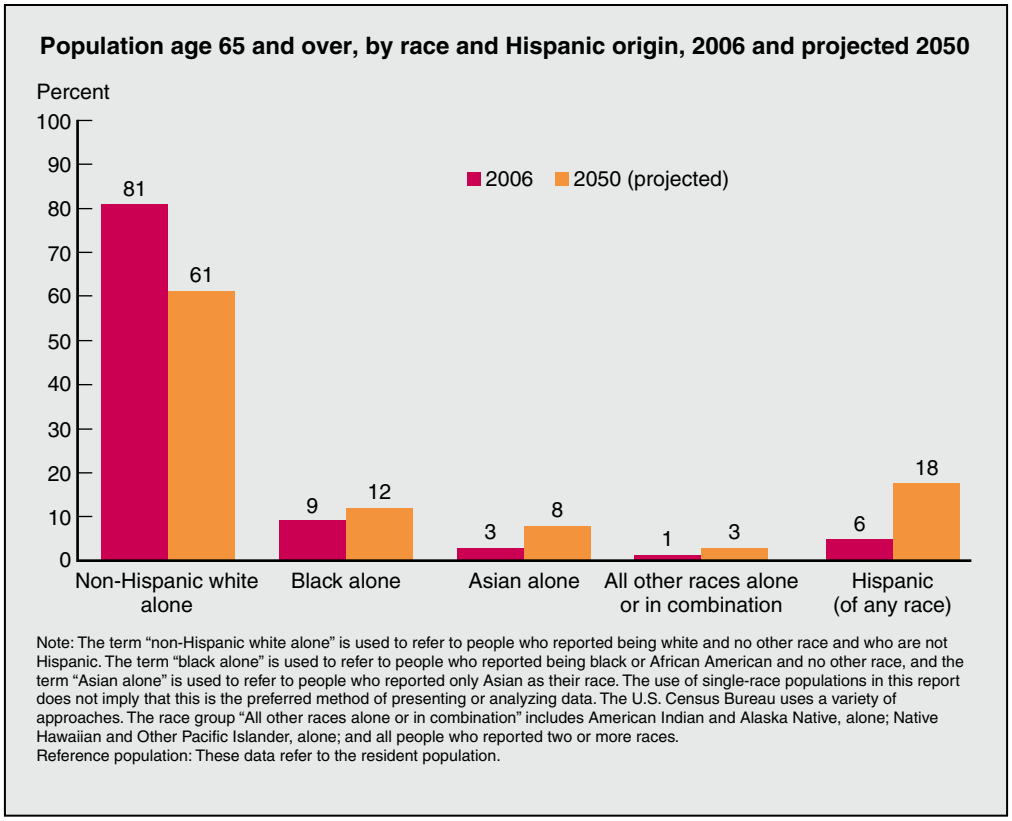


FIGURE 26-2 Ethnic population data for people age 65 years and older.

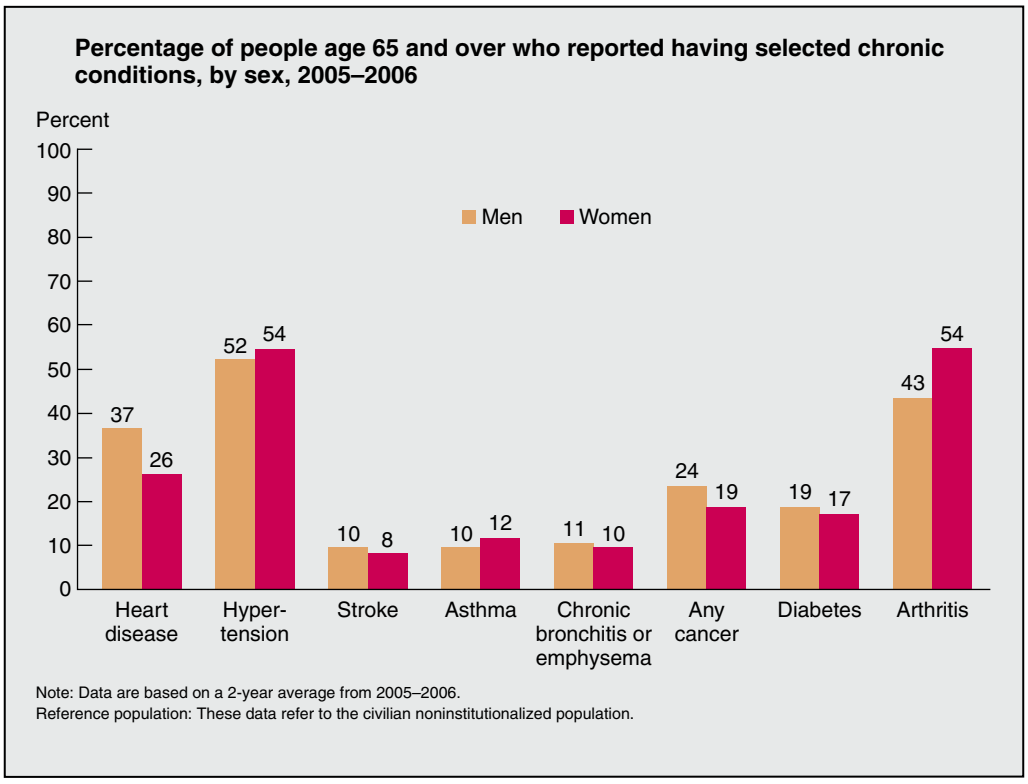


FIGURE 26-3 Chronic disease by gender in people age 65 years and older.

(History box). Uncertainty about the value of surgery in elders and about the operative risks prevailed. Because surgical morbidity and mortality increase with age and complexity of disease conditions, a thorough understanding of the physiology of aging is necessary when considering surgery on older patients (Evidence for Practice). Although improvements in technology, monitoring techniques, and anesthesia have made surgery safer for older patients, age remains a significant risk factor. Nevertheless, adequate assessments of the functional age and the physiologic reserve of the elderly surgical patient are of paramount importance (Wold, 2008).

According to Kim and Zenilman (2007), the occurrence of perioperative mortality in geriatric surgical patients is influenced by three factors—presence of co-existing disease, emergency surgery, and site of surgery:

1. *Presence of co-existing disease as quantified by the American Society of Anesthesiologists (ASA) Physical Status Classification.* Patients with an ASA status of IV or V are consistently

HISTORY

Evolution of Nursing Care for the Elderly

Societal attitudes toward the elderly population throughout the world have had a significant impact on elder status and access to resources. Historically, respect and reverence for elders were not always the societal norm. In ancient times, the Romans had little respect for elders. Egyptians dreaded the thought of getting old, and leaders such as Aristotle prevented elderly individuals from having any involvement in matters of government. Throughout the Dark and Middle Ages, and even into the Industrial Age, those who were youthful and productive had higher status. Elderly people were seen as nonproductive and a drain on resources.

Cultures that had no written language highly regarded their elders and looked to them as the teachers of succeeding generations. The ancient Chinese saw old age as a great accomplishment, deserving of honor. In general, the status of older persons has been influenced by the rate of societal change; slow rates of change were associated with higher status for elders, whereas rapid change found elders "out of touch," only knowing how things were, not how they are. Today we are in the midst of a rapidly changing society. Unlike anything that has happened before, elders' influence and status are rising along with their numbers.

Nursing care of the elderly population has transitioned through similar changes. Caring for older persons was a very unpopular segment of nursing practice. Nurses who aspired to care for elders were regarded as being less capable. It was not until 1966 that the first Division of Geriatric Nursing was established in the American Nurses Association (ANA). Ten years later, in 1976, the Division of Geriatric Nursing was changed to the Gerontological Nursing Division of ANA to more aptly reflect a broader scope of care. This change helped focus nursing attention toward a more accurate view of the elderly population, who were living life in all dimensions—not just as ill older adults. The Gerontological Society of America (GSA) devotes its efforts through interdisciplinary collaboration in research and practice.

In terms of surgical care of the aged, the definition of elderly has changed. The age that was considered too old for surgery has also changed—from patients only 50 years old in the early half of the twentieth century to patients well into their 80s, 90s, and even 100s in the early twenty-first century, now being successfully treated by surgical means. Perioperative nurses can expect to see the numbers of older and very old patients continue to rise in surgical settings. With the segmentation of age-specific competencies, perioperative nurses have more resources from which to base their care. Assisting elders to achieve the maximum benefit from their surgery with more meaning and quality of life is an integral component of perioperative patient advocacy and patient safety.

Modified from Ebersole P et al: *Toward healthy aging: human needs and nursing response,* ed 7, St Louis, 2008, Mosby.

EVIDENCE FOR PRACTICE

Considerations for Geriatric Surgery

The following principles of geriatric surgery can be used as a guide for practitioners to improve care for elderly surgical patients:

- Clinical presentation of disease may differ from the general population and may lead to delay in diagnosis.
- Lack of organ system reserve affects the elder's ability to handle severe stress, such as extensive or emergency surgery, and may be apparent only after surgery.
- Perioperative risk increases when preoperative preparation is decreased or suboptimal. Examples of preoperative preparation include cessation of smoking; administration of perioperative antibiotics; treatment of hypertension, anemia, and bronchitis; and prophylaxis of thromboembolic complications.
- Elective surgery produces far better outcomes than surgery performed under emergent conditions. Because of the elder's lack of reserve and the inability to conduct adequate preoperative preparation, the risk of emergency surgery is associated with at least a threefold increase in mortality and morbidity as compared to planned or elective procedures.
- Meticulous attention to detail can help avoid minor complications that may escalate into major adverse events in elderly patients. Restoring and maintaining homeostasis, lowering the risk of septic complications, preventing anastomotic leaks, and monitoring hemodynamics greatly reduce the surgical risk.
- Physiologic age is a better indicator of risk in surgery on elderly people than is chronologic age. Most surgeons agree that age alone is not a contraindication to surgery. In fact, studies confirm that even the very old can have successful positive surgical outcomes when their physical health status is considered to be uncomplicated by chronic disease.

Modified from *American Society of Anesthesiologists syllabus on geriatric anesthesiology,* available at www.asahq.org/clinical/geriatrics/prean_eval.htm. Accessed April 6, 2009.

found to have greater mortality than those with a physical status of I or II.

2. *Emergency surgery.* Surgical risk in elders increases dramatically when the surgery is of an emergent nature.
3. *Site of surgery.* Major vascular, intrathoracic, and intraabdominal procedures are reported to have a higher surgical risk than other surgical procedures in elders.

Surgical decision-making regarding elders can be difficult. As the baby boomers become seniors, they will be very different from healthcare consumers of the past. They will tolerate less and expect more. They will expect to be partners in decision-making regarding their care and will be more demanding in terms of quality and service (Williams, 2005). A frequent mistake is to compare the risk in elderly patients with that of younger patients. Elderly patients have an increased tendency for slower metabolism, multiple chronic diseases, and a decreased reserve capacity of their organs to respond to stress, as compared to younger patients (Berger et al, 2008). What should be considered is the risk of not operating and the quality of life expected. Although the recommendation for surgery is within the purview of the physician, perioperative nurses should be aware of its implications. Surgical intervention and management should be tailored to the patient's symptoms, overall functional and health status, and the predicted advantage of palliative intervention. Important factors that need to be evaluated are: (1) disease course versus life expectancy, (2) state of independence, (3) personal motivation, and (4) surgical risk versus nonoperative management.

1. *Disease course versus life expectancy:* Surgical intervention may not be appropriate if the prognosis of the disease is poor. However, if the patient has several years of life expectancy left and is likely to outlive the condition with minimal morbidity, surgical treatment may be the treatment of choice.
2. *State of independence:* The patient's right to self-determination and making healthcare decisions should always be considered. The need for independence is of utmost importance to elderly persons, and most of them are far more interested in maintaining health and independence than longevity. Complications of surgery are not well tolerated by elders and can quickly develop into life-threatening situations. If surgical intervention will further incapacitate an already debilitated person, alternative treatment should be considered. However, if surgery will help alleviate debilitating conditions and improve or maintain independence, it should be considered an appropriate modality of care.
3. *Personal motivation:* Evaluation of the elderly patient's level of motivation must be considered when surgery is planned. Many elderly patients are reluctant to undergo surgery because of concerns that the surgery will not improve their quality of life or will make them more dependent or destine them to a life in a care facility. In addition, they do not want to withstand the pain, discomfort, and rigors of surgery and the recuperative period necessary to treat a condition that does not really bother them very much or that they have "learned to live with." This lack of motivation will have a negative influence on the results of the surgery. Conversely, some elders expect and in some cases demand the best of care. They believe that the money they spend on taxes and healthcare entitles them to the very best that healthcare has to offer, regardless of its practicality. Nonetheless, patients who show a strong sense of determination in doing all that is necessary to get well and stay well are better candidates for surgery than those who believe illness is a prelude to death. Obviously, the outcome of surgery is enhanced if the patient is motivated to have a positive result.
4. *Surgical risk versus medical management:* Deciding between the risks of medical or nonoperative management and surgical intervention can be difficult for elderly patients. Surgical and anesthetic risks increase in proportion to the emergent nature of the patient's condition. When an acute emergency condition taxes an already overburdened physiologic state, survival is less likely. Patients may die even if the surgery was considered successful because of complications resulting from the complexity of the patient's co-morbid condition. Nonetheless, healthcare providers need to be sensitive to this possibility when communicating with family members. To increase the chances of survival from a surgical procedure, the elderly person must be in optimum condition and adequate preoperative assessment and preparation must precede an elective procedure.

The following considerations should be included when deciding to proceed with surgery in elders (Berger et al, 2008):

- Is there a clear indication for surgery, including a likelihood of disease progression?
- What practical limitations will be imposed on the patient with the progression of the disease?
- How much improvement can be expected after the surgical procedure?
- What is the expectation for quality of life with or without the surgery?
- How aware is the patient and the patient's family about the problem and proposed solutions?
- What risks are there for negative outcomes related to the procedure and the presence of co-morbid conditions?
- Has an adequate preoperative assessment and preparation preceded an elective procedure?

There are many important considerations related to the extent of surgical treatment. Therefore the decision for surgery relies heavily on the patient's physical status at the time of surgery and on the extent of disease progression. When treating patients who are nearing the end of life, attention should shift from solely maximizing survival to maximizing the quality of life and dignity while minimizing suffering. Early identification of problems with aggressive, preventive surgical treatment is considered more appropriate than waiting for problems to develop.

Perioperative nurses have a unique opportunity to assess and screen for signs of emotional and physical abuse in elderly patients during their preoperative assessment and while assisting with surgical positioning. Box 26-2 lists signs that may indicate abuse. If such signs are present, the perioperative nurse should report the suspected abuse to the appropriate authority. Reporting laws and regulations vary by state and facility.

In elderly patients, the consent process may require additional time to ensure that the patient understands and adequately answers the questions posed. If the older adult patient is comatose, has some disease or level of brain injury that inhibits decision-making, or is nondecisional, information must be relayed to the appropriate decision-maker (designated family member or person with power of attorney for healthcare). In advocating for the older adult, the perioperative nurse should

BOX 26-2

Signs That May Indicate Elder Abuse

- The older person demonstrates *excessive* agreement or compliance with the caregiver.
- The older person shows signs of poor hygiene, such as body odor, uncleanliness, or soiled clothing or underpants.
- The older person has malnutrition or dehydration.
- The older person has burns or pressure sores.
- The older person has bruises in various stages of healing that may indicate repeated injury.
- The older person lacks adequate clothing or footwear.
- The older person has not received adequate medical attention.
- The older person verbalizes lack of food, medication, or care.
- The older person verbalizes being left alone or isolated in some way.
- The older person verbalizes fear of the caregiver.
- The older person verbalizes his or her lack of control in personal activities or finances.

From Wold GH: *Basic geriatric nursing,* ed 4, St Louis, 2008, Mosby.

ensure any questions, concerns, or issues of the patient or the patient's decision-maker are addressed before the surgery. The principles of bioethics are the underlying basis for the nurse's ethical actions. The six principles are as follows:

1. Autonomy—respecting others and allowing individuals to make uncoerced, voluntary decisions
2. Beneficence—acting in the best interests of the patient
3. Fidelity—keeping promises by maintaining privacy and confidentiality of patient issues
4. Justice—treating individuals according to what is owed to them or fair
5. Nonmaleficence—directing healthcare providers to do no harm
6. Veracity—telling the truth

Regardless of the age of the patient, the development of ethical competency is an important component of the practice of perioperative nursing (Schroeder, 2004).

Assessment

In elderly persons a preoperative medical assessment is conducted to determine present physiologic functioning. Because of changes in biologic function of individuals over time, clinical pathways, rigid guidelines, algorithmic approaches, and other strategies of diagnostic investigation and resource allocation are likely to be less efficient for elders if based solely on age criteria. Healthcare providers, clinical investigators, and health policymakers must recognize that increasing variability becomes more important with chronologic age (Williams, 2005). Chronologic age as a valid predictor of a patient's response to surgery is not a reliable measurement. It gives little indication of the physiologic or biologic age and condition of a person. For example, a 75-year-old person can be in better physical and mental condition for surgery than a 65-year-old person. Biologic age as a measurement criterion is much more reliable. Establishing biologic age, however, becomes the greatest challenge. One tool, the Comprehensive Geriatric Assessment (CGA), is a multidimensional evaluation that scrutinizes medications, functional ability, co-morbid conditions, cognitive ability, mental function, nutritional status, and socioenvironmental factors. The CGA may be used both to identify at-risk individuals and to guide interventions. When evaluated as a screening tool in the geriatric community, it has been shown to detect new and unsuspected problems in 76% of elderly persons living at home. In geriatric medical studies the CGA has been found to be potentially beneficial in reducing the incidence of hospitalization, falls, delirium, and readmission. It is predictive of both morbidity and mortality in older patients (Kim and Zenilman, 2007).

Evaluation of functional status typically includes assessment of the patient's ability to perform activities of daily living (ADLs) (personal care tasks) and instrumental activities of daily living (IADLs) (everyday tasks). The scoring system that is employed for assessing co-morbidity in surgical patients is the American Society of Anesthesiologists Physical Status Classification. Additional measures of co-morbidity include the Cumulative Illness Rating Scale for geriatrics and the Charlson Comorbidity Index (Kim and Zenilman, 2007).

Impaired nutritional status is highly prevalent among the elderly; as many as 12% of men and 8% of women in the healthy geriatric population are considered undernourished. Higher rates of surgical complications and increased postoperative mortality have been observed in patients with poor nutritional status, as determined by a low body mass index, weight loss, a low preoperative serum albumin level, or a low Mini Nutritional Assessment score. Preoperative cognitive dysfunction has been associated with increased postoperative complications and worse survival in elderly surgical patients. Cognitive ability can be assessed with the Mini-Mental State examination (Kim and Zenilman, 2007).

Depression and the lack of social support are also linked to adverse outcomes in older surgical patients. A tool that is commonly employed in screening for depression in the elderly is the Geriatric Depression Scale. Several tools are available for quantifying social support resources in elderly patients. One such tool is the Medical Outcome Study Social Support Survey, which yields a score on a scale of 0 to 100 and includes "emotional" and "tangible" subscales. Another commonly used measure of social support is the Seeman and Berkman Social Ties Score, which measures social ties in four different areas.

An interdisciplinary approach is necessary to consider the complex health needs of the elderly patient in an effort to provide quality care. Application of these findings identifies operative risk, minimizes postoperative complications, and establishes the presence and status of any concomitant disease process that could negatively affect the outcome of the surgery. The preoperative nursing assessment is conducted to plan patient care throughout the perioperative period. In particular, assessment data are used to establish presurgical baseline data so that health status changes, primarily during the intraoperative and postoperative periods, are more readily recognized. The nurse's data collection includes the standard assessment information with considerations of co-existing conditions and a review of the patient's medication list (Box 26-3). Polypharmacy is an issue for many elderly patients and is a concern because of the physiologic changes associated with aging that lead to susceptibility to alterations in pharmacokinetics and susceptibility to adverse drug reactions.

BOX 26-3

Preanesthesia Evaluation Data

Preanesthesia evaluation data include but are not limited to the following:

- Complete medical history with systems' review and anesthetic history, including self or family difficulty with anesthesia
- Complete surgical history
- Proposed surgical procedure
- Allergies—drug, food, environmental, latex
- Routine medications—prescription, over-the-counter (OTC), herbal, diet, recreational
- Current physical information—height, weight, baseline vital signs
- Social history—cultural and religious beliefs, alcohol and tobacco use
- Mental status—emotional clues; learning barriers; sensory, sight, or speech impairments
- Prosthetics—dentures, glasses or contacts, hearing aids, assistive devices (walker, wheelchair), implanted devices, prosthetics, body piercings
- Socioeconomic issues—transportation, home support
- Advance directives—living will, do-not-resuscitate (DNR) directive

Modified from Woogler JM: Preoperative testing and medication management, *Clin Geriatr Med* 24:573-583, 2008.

Chronic conditions may interfere with the elderly person's ability to distinguish between recent and long-standing ailments. Therefore the preoperative interview, especially in elderly persons, should be conducted in a quiet, relaxed environment with as few distractions as possible. The elderly person should be allowed to respond to each question independently without prompting from a spouse or other family members unless absolutely necessary. This helps to maintain the patient's dignity, independence, and control, which are extremely important to the older adult.

Normal Age-Related Changes. Aging is a biologic process characterized by the inevitable, progressive, predictable evolution and maturation until death. Aging is not the accumulation of disease, although the two are related in subtle, complex ways. A fundamental principle is that biologic age and chronologic age are not the same. Different individuals age at different rates. Physical aging occurs in different organ systems at different rates, influenced by lifestyle choices and socioeconomic status (Williams, 2005). In general, the aging process imposes a decline in organ functions, atypical responses to pain and temperature, alterations in pharmacokinetics (Surgical Pharmacology), and atypical signs and symptoms of disease, all of which may vary from one elderly person to the next. Having a clear understanding of normal age changes helps establish appropriate nursing diagnoses and develop a plan of care (Box 26-4). The following review of systems focuses on age-specific changes of particular importance to the perioperative plan of care.

PHYSIOLOGIC CHANGES

Integumentary System. The nails become thick and tough, and the circulation in the feet may decrease (Table 26-1). A nick or cut can lead to a serious infection. Color and texture of hair change, and the loss of pigmentation results in graying of hair. Decrease in oil content makes the hair dull and lifeless, and the amount of hair decreases. The skin loses elasticity and subcutaneous fat and becomes more prone to shear force and pressure injury. Because of the thinness of the skin and small-vessel fragility, bruising and hemorrhaging are quite common. Dry skin develops because of decreased oil and sweat production from sebaceous and sweat glands, respectively. As a result, skin breakdown and pressure ulcers, as well as wound infections, develop more easily. The vascular system of the skin has nutritional and protective roles. It is necessary for body heat regulation, provides defenses against microbial and physical damage, provides nutrient supply to the avascular epidermis, and promotes wound healing. Having an intact vascular system to maintain these skin role characteristics is extremely important for a patient undergoing surgical intervention. However, papillary capillaries, responsible for epidermal nourishment and heat dissipation, degenerate with aging. What is left is only the horizontal arteriovenous plexus lying beneath the skin surface. This progressive impairment of vascular circulation and tissue nutrition and the loss of subcutaneous tissue predispose to a feeling of cold, especially in cool environments such as the OR. Therefore the ability to maintain thermoregulation is compromised in elders and must be controlled through external measures.

Respiratory System. Pulmonary complications in the elderly account for nearly 50% of postoperative complications in the total population of surgical patients (Wold, 2008). Lungs lose elasticity, which contributes to a decrease in functional residual capacity, residual volume, and dead space. Lungs increase in size and are lighter in weight with aging. A rigid chest wall is the result of calcification of costal cartilages, osteoporosis, and dorsal kyphosis. Muscles responsible for inhalation and exhalation may be weakened, resulting in a diminished ability to increase and decrease the size of the thoracic cavity. All these changes contribute to a minimal tidal exchange, which makes the elderly patient more susceptible to pulmonary complications, such as adult respiratory distress syndrome (ARDS), pneumonia, and aspiration. Lung changes are not usually obvious at rest. However, when the person becomes active, breathing may be more difficult. The ability to cough and clear the upper airway is lessened, and such reduction may increase the chance of respiratory tract infections and diseases, some of which can be severe enough to threaten the elderly person's life.

Cardiovascular System. A decrease in coronary artery blood flow is more likely in elderly persons. Because of a shift in blood flow, there is a greater decrease in circulation to the kidneys and liver than to the brain and heart. Blood pressure rises as a result of increased arterial resistance. When the elderly person is at rest, the heart rate remains approximately the same as that of a younger person. However, the older heart requires a longer recovery time after each beat, which means that it reacts poorly to stress and anxiety-produced tachycardia. In general, the capacity of the cardiovascular system to tolerate and buffer insults is limited. Activity, exercise, excitement, and illness increase the body's need for oxygen and nutrients. The older heart may be unable to meet these needs. Arteries lose their elasticity and become narrow, causing a weakened heart to work harder. As a result, less blood flows through the arteries, causing poor circulation in many parts

SURGICAL PHARMACOLOGY

Medication and the Elderly

Perioperative nurses caring for older adults must consider factors that affect the choice of medications and the effects of those medications on this population. Older adults may not tolerate the standard dosages used for younger adults and are at higher risk for side effects and toxicity. Dosages of drugs may initially be smaller than those used for the general adult population and then titrated based on the patient's response and therapeutic effect. Older adults have less reserve, and chronic disease may contribute to drug reactions. Physiologic changes may affect the absorption, distribution, metabolism, and excretion of medications. Older adults also have a higher prevalence of nonprescription drug use (e.g., analgesics, antacids, laxatives, supplements). A thorough medication history is essential to provide safe care. The nurse should partner with the surgeon and anesthesia provider to ensure that drug therapy is individualized based on the patient's baseline condition, actual physiologic impairments, and severity of preexisting illness.

Common adverse drug reactions in older adults include the following:

- Edema
- Dizziness
- Nausea and vomiting
- Urinary retention
- Anorexia
- Diarrhea
- Dry mouth
- Constipation
- Fatigue
- Confusion
- Weakness

Age-related changes that may impact medication administration in the perioperative period are as follows:

CHANGES IN ABSORPTION

- Increased gastric pH
- Decreased gastric blood flow
- Decreased gastrointestinal motility

CHANGES IN DRUG DISTRIBUTION

- Decreased amounts of total body water
- Increased ratio of adipose tissue to lean body mass, causing storage of lipid-soluble drugs and decreased plasma drug levels
- Decreased albumin levels
- Decreased cardiac output

CHANGES IN METABOLISM AND EXCRETION

- Decreased liver size
- Decreased hepatic blood flow
- Decreased liver enzyme activity
- Decreased renal blood flow
- Reduced glomerular filtration rate, leading to slower excretion times for medications and allowing serum drug levels to rise

Modified from Hodgson BB, Kizior RJ: *Saunders nursing drug handbook 2009,* St Louis, 2009, Saunders; Ignatavicius DD: Health care of older adults. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, St Louis, 2010, Saunders.

of the body. Elders have an increased risk for aortic arch disruption, myocardial contusion, and aneurysm development. A complete, comprehensive cardiac workup should be performed before the elderly patient is scheduled for any surgical procedure (Workman, 2010).

Digestive System. As a person ages digestive glands decrease the amount of secretions; mucus becomes thicker, causing dysphagia; and saliva becomes more alkaline. Loss of teeth or poorly fitted dentures make chewing difficult, resulting in digestion problems. Foods that are difficult to eat are avoided, and such avoidance can affect overall nutrition. Decrease in peristalsis and a reduction of gastric motility—the results of muscle tone loss—cause a delay in stomach emptying. Potential traumatic injuries to the bowel and mesenteric infarction are more likely to occur (Wold, 2008). The absorption of drugs is affected because of a reduction of blood flow to abdominal viscera, a reduction in the amount of hydrochloric acid secreted, and delayed gastric emptying. Decreases in the levels of total body water and plasma volume result in a smaller volume of distribution for water-soluble drugs. Because the percentage of body fat increases and the lean body mass decreases, the storage of lipophilic drugs, such as diazepam and lidocaine, is enhanced. These factors are of particular importance for assessing the patient's response to preoperative, anesthetic, and postoperative medications.

Urinary System. Nephrons decrease in function with age, so by 75 years of age a person has probably lost one third to one half of original nephron function. Elasticity and tone are lost in the ureters, bladder, and urethra, which lead to incomplete emptying of the bladder. By age 50 years at least 50% of all men have some degree of benign prostatic hypertrophy (BPH) and the prevalence increases with each decade of life (Ebersole et al, 2008). Difficulty in voiding and retention of urine are common with this condition. Total bladder capacity also declines, so elderly persons experience a more frequent and urgent need to urinate. Because blood flow to the kidneys is decreased, patients are at greater risk for fluid overload, fluid and electrolyte imbalance, and alterations in the elimination of medications. During the perioperative phase of the patient's

BOX 26-4

Age-Related Physiologic Changes

HEMATOPOIETIC AND LYMPHATIC SYSTEM
- Increased plasma viscosity
- Decreased red blood cell production
- Increased immature T cells

RESPIRATORY SYSTEM
- Decreased tissue elasticity, resulting in pooling of secretions in lower lung bases
- Increased calcification of cartilage, leading to increased rigidity of the rib cage, decreased lung capacity, and reduced cough efficiency
- Less ciliary activity by bronchial lining
- Reduction in number of capillaries, resulting in decreased gas exchange and drying of mucous membranes

CARDIOVASCULAR SYSTEM
- Changes in cardiac muscle tone and blood vessel elasticity, leading to decreased tissue oxygenation and decreased venous return
- Dysrhythmias; rapid or slow heartbeat
- High blood pressure related to atherosclerosis
- Chest pain or shortness of breath on exertion
- Decreased cardiac output, causing decreased circulation to extremities

DIGESTIVE SYSTEM
- Dental issues (e.g., tooth loss, periodontal disease), leading to chewing issues
- Decreased saliva production
- Relaxation of esophageal muscle tone, increasing the prevalence of esophageal reflux
- Decreased gastric secretions
- Bowel dysfunction from decreased peristalsis

URINARY SYSTEM
- Loss of nephron units
- Decline in renal tissue growth
- Reduced kidney size
- Reduced bladder capacity
- Increased prostate size in men
- Weakened bladder muscles with consequent postvoid residual

MUSCULOSKELETAL SYSTEM
- Progressive loss of muscle strength from decreased muscle mass
- Decreased fluid in intervertebral disks
- Postural changes, such as curvature of the spine from decreased bone calcium
- Joint and back pain/stiffness
- Bone breakdown overcomes bone building, with resultant osteoporosis
- Decreased tissue elasticity, resulting in decreased mobility and flexibility

NERVOUS SYSTEM
- Loss of neurons, leading to decreased reflexes
- Slower reaction time from loss of nerve fibers
- Changes in sleep patterns; less rapid eye movement (REM) and deep sleep
- Decreased amounts of neuroreceptors, resulting in decreased perception of stimuli

SENSORY SYSTEM
- Decreased tear production
- Increased lens discoloration, which decreases color perception
- Decreased muscle tone in eye, leading to decreased pupil diameter, decreased night vision, increased refractive errors, increased sensitivity to glare
- Loss of hair cells in inner ear, leading to balance problems
- Decreased joint mobility in bones of inner ear
- Decreased number of papillae on tongue

ENDOCRINE SYSTEM
- Decreased pituitary secretions (growth hormone), leading to decreases in muscle mass
- Reduction in the production of thyroid-stimulating hormone
- Decreased production of parathyroid hormone
- Increased prevalence of diabetes mellitus

REPRODUCTIVE SYSTEM

Female
- Decreased estrogen levels
- Decreased tissue elasticity
- Increased vaginal alkalinity

Male
- Decreased testosterone levels
- Circulatory changes

Modified from Wold GH: *Basic geriatric nursing,* ed 4, St Louis, 2008, Mosby.

hospital stay, the greatest number and variety of drugs are given; the cumulative effect increases the chances for adverse and consequential results.

Musculoskeletal System. Changes to the elderly person's skeleton, such as the loss of bone mass, contribute to skeletal instability and make fractures of the hip, rib, distal radius, and vertebrae very common. Curvature of the spine and arthritis of the joints are also common. Pain as a fifth vital sign is routinely evaluated for all patients. In elders, long-standing conditions such as arthritis, neuralgia, and ischemic disorders produce chronic pain. Back pain is related to dehydration and decreased flexibility of the vertebral disks. These changes result in a gradual loss of height, loss of strength, and decreased mobility. Poor posture tends to be proportional to the degree of back pain experienced and may greatly compromise internal organ function. Joint range of motion is impaired to varying degrees and may affect surgical positioning. Extra care in positioning patients in the OR should be taken with the elderly patient, ensuring appropriate padding and joint protection (Wold, 2008).

Nervous System. Although not functionally significant, a steady loss in the number of neurons begins at about 25 years of age. An inappropriate or slow response to stimuli is primarily a result of a decrease in some organ systems' ability to send reliable messages to the brain and spinal cord. Nerve cells are particularly sensitive to lack of oxygen. Because elderly persons may have, in varying degrees, cerebral arteriosclerosis and atherosclerosis, decreased blood flow and nervous system

TABLE 26-1

Age-Related Skin Changes

Physiologic Change	Results
Decreased vascularity of dermis	Increased pallor in white skin
Decreased amount of melanin	Decreased hair color (graying)
Decreased sebaceous and sweat gland function	Increased dry skin; decreased sweating
Decreased subcutaneous fat	Increased wrinkling
Decreased thickness of epidermis	Increased susceptibility to trauma
Increased localized pigmentation	Increased prevalence of brown spots (senile lentigo)
Increased capillary fragility	Increased purple patches (senile purpura)
Decreased density of hair growth	Decreased amount and thickness of hair on head and body
Decreased rate of nail growth	Increased brittleness of nails
Decreased peripheral circulation	Increased longitudinal ridges on nails, increased thickening and yellowing of nails
Increased androgen/estrogen ratio	Increased facial hair in women

From Wold GH: *Basic geriatric nursing,* ed 4, St Louis, 2008, Mosby.

deficits, such as insomnia, irritability, visual motor deficits, and memory loss, may occur. These patients are more likely to experience subdural hematomas or closed head injuries from falls. Other neurologic changes significant to perioperative care include a loss of position sense in the toes, decreased tactile sense, and atypical response to pain. In addition, aging is associated with disruption of thermoregulation (Wold, 2008); inadvertent hypothermia (temperature below 36° C [96.8° F]) is a common problem in elders (see Chapter 9 for a full discussion of preventing unplanned hypothermia in adult surgical patients). In the OR, maintaining balance between heat gain (e.g., metabolic production, muscular contraction, hot ambient temperature) and heat loss (e.g., radiation, convection, evaporation, ventilation, cold fluid infusion, blood loss, antithermoregulatory drugs, impaired heat production) can be difficult in older surgical patients.

SENSORY CHANGES. Sensory changes in vision, hearing, taste, smell, and touch may influence the patient's response to care. If preadmission communication is done, the perioperative nurse may ask about vision and hearing and remind patients to bring their glasses and hearing aids to the facility (Clayton, 2008). Farsightedness, or presbyopia, in the aging person is a result of the lens becoming more rigid and less pliable with age. Consequently, visual acuity and accommodation are decreased. Color perception changes as a result of a yellowing of the lens, which makes distinguishing blue, green, and purple more difficult for the elderly person. Of particular importance in the OR is an awareness of the older person's difficulty in adapting to changes in light. Moving patients from a dimly lit holding area to the bright lights of the OR can cause momentary "blindness."

Presbycusis, or loss of hearing sensitivity, is irreversible, bilateral, and primarily sensorineural, although metabolic and mechanical causes are also possible. It is the most frequent cause of hearing loss in the geriatric patient. Hearing loss, which appears to be greater in men than in women, is mostly within the higher frequencies (above 1000 Hz). In addition, cerumen thickens and the eardrum becomes less pliable, and such changes also contribute to diminished hearing. Often geriatric patients are labeled "confused" or "senile" because they respond inappropriately to questions they did not hear or they describe what they see inaccurately because of poor vision.

Changes in taste and smell begin to occur at approximately 60 years of age and become more pronounced with advanced age. Older adults have two to three times more difficulty in detecting flavors than do young adults. Oral hygiene, dental disease, and decreased salivary function may also alter tasting ability. There is a close association between the sense of smell and human behavior. Smell can affect emotions when a person recalls a particular odor. Other functions include protection of the individual by warning of danger in the air, such as smoke or gas fumes; assistance in digestion; and helping a person to remember or recollect. In elders, the sense of smell can be reduced, as well as the ability to identify odors (Wold, 2008).

Changes in sensitivity to touch often accompany the aging process, but the degree of change varies among individuals. In some cases, losses can be related to neuropathy caused by disease, injury, or circulatory problems. Decreased sense of touch can affect the elderly person's ability to localize stimuli and can also reduce the speed of reaction to tactile stimulation. For example, an older person may have difficulty differentiating among coins, fastening buttons, or grasping small items.

PSYCHOLOGIC CHANGES. Physiologic and psychologic stress may result in an acute state of confusion or delirium in the geriatric patient that is analogous to convulsions as a stress reaction in the pediatric patient. In elders, mental change can be a warning of some underlying problem. It is of pivotal importance to determine the patient's interpretation of pain in the assessment phase. Confusion or delirium should therefore not be dismissed as an expected behavior of the geriatric patient. Delirium occurs in more than 80% of intensive care patients and patients at the end of life and in as many as 50% of hospitalized elders. It is associated with increased length of stay, increased morbidity, poorer functional outcomes, increased risk of nursing home placement, and increased patient care costs. Several studies suggest that delirium is lessened when pain is appropriately managed, as determined in the study by Robinson and colleagues (2008) of hip fracture patients. The most important assessment factor is determining whether the confusion is

BOX 26-5

Strategies for Communicating with Impaired Elderly Adults

When communicating with elderly adults who have cognitive impairments, perioperative nurses and surgical technologists should consider the following strategies:

- Try not to startle the person when starting a communication.
- Approach from the front, knock, or announce your presence by calling the person's name.
- Approach patients who have a left-sided hemiparesis from the right side.
- Identify yourself.
- Communicate when the person is most alert.
- Eliminate or reduce noise and distractions.
- Make sure you have the person's attention before speaking.
- Try to use a variety of words or descriptions until meanings are clear.
- Ask clear, specific questions.
- Ask only one question at a time.
- Pay attention to the emotional context of conversation.
- Use pictures and gestures in addition to words.
- Have the person sit up for conversation whenever possible.
- Keep messages simple and repeat as needed.
- Be patient and do not interrupt. Slow down the pace of communication.
- Treat the person as normally as possible.

From Wold GH: *Basic geriatric nursing,* ed 4, St Louis, 2008, Mosby.

BOX 26-6

Mnemonic for Assessing Pain in Demented and Nonverbal Elders

B	What **Behaviors** did you see?
O	How **Often** did the behaviors occur?
D	What was the **Duration** of behaviors?
I	How **Intense** were the behaviors?
E	How **Effective** was the treatment, if given?
S	What made the behaviors **Start or Stop**?

Modified from Ferris M: Pain in the cognitively impaired elderly: guidance for clinicians, *Adv Pract Nurs eJournal,* posted May 15, 2008, available at www.medscape.com/viewarticle/573642. Accessed January 14, 2009.

RESEARCH HIGHLIGHT

Older Surgical Patients at Greater Risk for Developing Cognitive Problems

Patients older than age 60 who have elective surgeries such as hysterectomies, joint replacements, and other nonemergent, inpatient procedures are at an increased risk for long-term cognitive problems. A Duke University Medical Center study found that elderly patients who developed postoperative cognitive problems were more likely to die in the first year following surgery. Memory and the ability to process information were measured in 1000 adult patients. Problems with cognitive dysfunction were more common in those patients with lower educational level and a history of stroke that left no noticeable neurologic impairment.

One hypothesis that explains why some patients suffer this dysfunction is that surgery and the accompanying anesthesia might cause inflammation in the brain that can affect the patient's ability to learn, retain, or remember information. The types of interventions to prevent or mitigate the detrimental effects of surgery and anesthesia on the aging brain will be the subject of further research.

Modified from Clinical Rounds: Older surgical patients at greater risk for developing cognitive problems, *AANA News Bulletin* 62(3):9, March, 2008.

chronic or acute. Chronic conditions, such as depression and Alzheimer's disease, can make communication with the patient difficult. Depending on the stage of disease, patients may or may not be able to understand explanations. Family members are the best resource to determine the patient's ability to comprehend and respond to questions and instructions. Behavioral changes, such as aggressiveness, agitation, and paranoia, are not uncommon. Soft restraints may be necessary during local procedures in the OR to ensure patient safety. Taking the time to talk slowly, being deliberate in movements, getting to know the patient, and developing a trusting relationship before surgery can help to lessen the patient's anxiety and control the combative outbursts that occur in some Alzheimer's patients (Box 26-5). A mnemonic for pain assessment in demented and nonverbal elders is described in Box 26-6. The American Society of Pain Management Nursing (ASPMN) has created guidelines for assessing pain:

- Ask the patient about pain.
- Search for potential causes of pain.
- Observe behaviors.
- Seek surrogate reports of pain.
- Do an empiric analgesic trial (Ferris, 2008).

Acute confused states or delirium in elders can be precipitated by a number of conditions and may be the sole manifestation of a life-threatening complication. Delirium in elders may be evidenced by alteration in level of consciousness, inattention, disorganized thinking, or an acute onset of mental status change.

Some of the most common predisposing factors for confusion or delirium in hospitalized elders are increasing age (Research Highlight), baseline brain damage, drug or alcohol addictions, fatigue, social and psychologic stressors, and sleep deprivation. Apparent confusion could be caused from drugs; infection; withdrawal from alcohol; metabolic, cerebrovascular, or cardiac disorders; trauma; or cancer. Conditions such as fecal impaction, changes in routine, urinary bladder distention, dehydration, electrolyte imbalance, and stress can also affect cognition in elders (Touhy, 2008). Even the disruption of relocation into the hospital, which brings the patient into an unfamiliar environment, can cause acute confusion, particularly during the postoperative period. Validation of the patient's previous mental state with a relative or significant other can help to determine if the onset occurred since hospitalization.

Routine Laboratory and Diagnostic Tests. The physiologic changes of aging do not significantly alter the diagnostic values of complete blood count (CBC), differential cell count, platelets, urinalysis, and blood chemistry results; therefore abnormalities should be evaluated. A slight increase may be noted in the levels of potassium, fasting blood glucose, postprandial blood glucose, oral glucose tolerance, total cholesterol, and

thyroid-stimulating hormone. A decrease in the amounts of vitamin B_{12}, folic acid, magnesium, and albumin and decreased creatinine clearance may also be noted. The chest x-ray film may reveal increased anteroposterior diameter, osteopenia, and degenerative joint disease. The heart size should appear normal, even in elders. Cardiomegaly can contribute to postoperative complications and should be evaluated. The electrocardiogram (ECG) may show P-wave notching, ST-segment depression or left ventricular hypertrophy, and T-wave flattening or inversion that are associated with an increased risk of myocardial ischemia (Berger et al, 2008). An increase in bundle branch block, hemiblock, and first-degree block may also be noted, largely as a result of degenerative disease of the conduction system. Opinion about the number of preoperative laboratory tests to be ordered varies. Use of a focused history and physical examination yields important information regarding which preoperative tests are indicated. Preoperative testing should be based solely on the history, physical examination, and planned surgical procedure.

Because many elderly patients take several medications, assessing their drug history is important. The patient's physician will determine which medication should be withheld during the preoperative period and which should be administered with a sip of water the morning of surgery. Any patient who has been receiving steroids within the previous 12 months should receive parenteral steroids starting the evening before surgery and continuing through the initial postoperative course.

Control of diabetes is often difficult during the perioperative period. For patients taking oral hypoglycemic agents, the medication is generally withheld and serum glucose and urinary glucose levels are closely monitored. Diabetic patients treated with long-acting parenteral insulin typically discontinue it on the day of surgery and regular insulin is given during the preoperative period. Diabetic patients who are fasting the morning of surgery should take their insulin as directed by the anesthesia provider and have an intravenous (IV) line inserted for infusion of 5% dextrose and water on admission to the OR.

Additional Assessment Data. Additional data regarding the patient can be gained from observation of appearance, behavior, dress, and language. For instance, does the patient's apparent age (how old the patient looks) match the chronologic age? Facial expressions and contradictory behaviors can help the nurse assess the patient's mental status. Perioperative nurses in the preoperative area can gather additional data by noting the patient's clothing. For example, does the clothing size indicate signs of weight loss? Is clothing stained or burned? What is the condition of the patient's shoes? The patient's use of language and communication skills should also be assessed when formulating a teaching plan.

Another important but often overlooked area of assessment is dental/oral health evaluation. Disorders of the oral cavity can affect the nutritional condition of the patient. Many elderly persons simply do not attempt to eat because of ill-fitting dentures or poor oral health. In addition, the condition of the patient's temporomandibular joint and the presence of an oral disorder, including loose teeth and dentures, can make the difference between a smooth and safe anesthesia induction and a disastrous anesthesia experience.

The risk for impaired nutritional intake is exacerbated by other factors, such as reduced salivary gland activity, receding gums, and thinner tooth enamel, with concomitant brittleness in the teeth. Esophageal mobility is reduced, and a more relaxed cardiac sphincter slows emptying in the esophagus. Moreover, weakened intestinal musculature and slower peristalsis in the lower gastrointestinal (GI) tract may lead to constipation. The confluence of these factors often results in poor nutrition. For the elderly surgical patient, this can have deleterious effects, especially for wound healing.

Life changes can also affect nutritional status. Of particular importance are the losses endured with aging, such as the loss of one's spouse, family, or friends through death or relocation; loss of a prior standard of living through retirement; and loss of physical or mental well-being. These changes can affect older people to the point that they either cannot afford to buy nutritious foods or lose the ability or interest to prepare food. The ultimate effect, among other things, is a nutritionally debilitated patient. Any nutritional deficits should be corrected before surgery because the success of the operative procedure, the rate of wound healing, and the length of hospital stay are directly related to the nutritional state.

Determination of Operative Risk. After assessment of the patient is completed, conditions that can add to the patient's operative risk may be identified (Box 26-7). Medical disorders (including cardiac, abdominal, and thoracic) as well as multiple operations performed on an emergency basis significantly increase operative risk. Whenever possible, medical conditions are treated before surgery. Sometimes correction is not possible, and the risk of forestalling surgery outweighs any other medical problem. The determination of operative risk for the patient is generally based on the ASA Physical Status Classification (Sieber and Pauldine, 2005). Although the anesthesia provider performs the actual classification of the patient, familiarity with the parameters from which a decision is made is important:

- Class I: normal, healthy patient; no gross organic disease
- Class II: patient with mild to moderate systemic disease with functional impairment
- Class III: patient with severe systemic disease that limits activity but is not incapacitating
- Class IV: patient with incapacitating systemic disease that is a constant threat to life
- Class V: moribund patient not expected to survive 24 hours with or without the operation
- Class E: emergency procedure (applied to any of the previous classifications)

The most common surgical procedures in the elderly population that pose a greater risk of death are as follows:

- Acute intestinal vascular insufficiency
- Fracture of neck of femur
- Malignant neoplasm of colon
- Perforated diverticulum of colon
- Peripheral arterial occlusive disease
- Ruptured abdominal aortic or thoracic aneurysm

Other factors that are considered in determining operative risk are the patient's cognitive and functional states. Surgeons and anesthesia providers can assess the patient's cognitive state through the use of tools such as the Folstein Mini-Mental State Evaluation (MMSE). The MMSE evaluates four areas: orientation, registration, attention/calculation, and language. Points are assigned to each area; a perfect score is 30. A score below 24 indicates cognitive impairment, which may increase operative

BOX 26-7

Risk Factors for Surgery in Elders

SURGICAL RISKS
- Emergency surgery
- Site of surgery
  - Vascular
  - Aortic
  - Intrathoracic
  - Intraperitoneal
- Duration of procedure (more than 3.5 hours)

ANESTHETIC RISKS
- American Society of Anesthesiologists (ASA) classifications III to V
- Age older than 75 years
- Preexisting medical disease (hypertension; diabetes mellitus; cardiac, renal, liver, or respiratory disease)

DISEASE-RELATED RISKS
- Cardiovascular
  - Angina
  - Previous myocardial infarction
  - Congestive heart failure
- Pulmonary
  - Bronchitis
  - Pneumonia
- Cigarette smoking
- Digestive
  - Poor nutritional status or malnutrition
  - Protein deficiency
  - Cirrhosis
  - Active peptic ulcer
- Endocrine
  - Adrenal insufficiency
  - Hypothyroidism

COGNITIVE IMPAIRMENT
- Dementia
- Acute confusional state (delirium)
- Alzheimer's disease

OTHER FACTORS
- Dehydration
- Anemia
- Recent stroke
- Malignancy
- Low albumin level
- Impaired mobility
- Patient living in institutional care

Modified from Kim SS, Zenilman ME: The elderly surgical patient. In Souba W et al, editors: *ACS surgery principles and practices,* ed 6, Ontario, Canada, 2007, BC Decker.

risk and increase the likelihood for postoperative complications. Functional status can be assessed through scoring the patient's ability to perform physical tasks. Each task is assigned a metabolic equivalent (MET). Tasks range from the ability to feed and dress oneself (1 MET) to the ability to participate in strenuous activity, such as football or skiing (10 METs). The inability to function above 4 METs is associated with increased perioperative cardiac events and long-term risk (Berger et al, 2008).

Nursing Diagnosis

In evaluating, synthesizing, and prioritizing the data collected during the preoperative assessment, the perioperative nurse can formulate nursing diagnoses that will form the basis of the plan of care.

Nursing diagnoses related to the care of geriatric surgical patients might include the following:
- Risk for Deficient Fluid Volume
- Ineffective Thermoregulation
- Risk for Impaired Skin Integrity
- Disturbed Sensory Perception (visual or auditory)
- Risk for Perioperative Positioning Injury
- Ineffective Family Therapeutic Regimen Management
- Risk for Infection

Outcome Identification

Outcomes identified for the selected nursing diagnoses could be stated as follows:
- The patient will maintain age-appropriate fluid volume levels intraoperatively and postoperatively.
- The patient will maintain normothermia ±1° F throughout the perioperative period.
- The patient's skin integrity will remain intact intraoperatively.
- The patient's perception and interpretation of environmental and sensory stimuli will be accurate throughout the perioperative period.
- The patient will be free from perioperative positioning injury.
- The patient receives appropriate medication or medications, safely administered during the perioperative period.
- The patient is free from signs and symptoms of infection.

Planning

As a result of anatomic and physiologic effects of aging, geriatric patients have, in varying degrees, a general decline in organ function and an altered ability to recover from stressful events. In addition to normal age changes, many older adults experience one or more chronic conditions that influence the risk of surgery. Successful surgical outcomes in the geriatric patient depend on elective versus emergency surgical procedures, optimum physical condition of the patient, thorough preoperative assessment, close intraoperative and postoperative monitoring, and preventive measures to decrease the likelihood of complications. Collaboration with the entire surgical team can create an environment that is safe, efficient, and caring and provides for a positive patient outcome.

A Sample Plan of Care for a geriatric surgical patient is shown on pp. 1170-1171.

Implementation

Perioperative geriatric patient care is very similar to the care provided to younger adults. However, modifications that involve consideration of age-specific differences between the

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Risk for Deficient Fluid Volume related to nothing-by-mouth (NPO) status and intraoperative blood and body fluid losses secondary to age-associated decrease in total body water and plasma volume

OUTCOME
The patient will maintain age-appropriate fluid volume levels intraoperatively and postoperatively.

INTERVENTIONS
- Review medical history for presence and number of chronic diseases.
- Review, document, and communicate significant abnormal laboratory findings.
- Monitor and record intraoperative intake and output.
- Monitor and calculate estimated blood loss on sponges and in suction canisters.
- Distinguish between blood and irrigation fluid amounts in suction canister or canisters.
- Ensure visibility of the urine drainage bag.
- Ensure availability of blood and fluid replacement products as needed.
- Monitor and report intake and output to anesthesia provider, surgeon, and postanesthesia care unit (PACU) nurse.

NURSING DIAGNOSIS
Ineffective Thermoregulation related to poikilothermy secondary to age-associated physiologic decompensation

OUTCOME
The patient will maintain normothermia (±1° F) throughout the perioperative period.

INTERVENTIONS
- Identify risk factors for unplanned hypothermia.
- Use warm blankets during transport to the OR, and replenish as needed throughout the perioperative period (include the patient's feet within blanket covering).
- Adjust and maintain ambient room temperature at comfortable levels.
- Place warmed sheet on OR bed before patient transfer.
- Use active warming intraoperatively by applying forced air–warming system.
- Monitor patient's temperature.
- Provide additional head covering (cloth, plastic, or reflective) during surgical procedures.
- Minimize exposure of patient.
- Use warmed irrigation and preparation solutions (as recommended by manufacturer).
- Administer warmed blood and blood products and intravenous (IV) fluids at room temperature.
- Remove wet linens before transport to the PACU.

NURSING DIAGNOSIS
Risk for Impaired Skin Integrity related to preoperative and intraoperative procedures secondary to alterations in skin turgor, sensation, peripheral tissue perfusion, and skeletal prominence

OUTCOME
The patient's skin integrity will remain intact intraoperatively.

INTERVENTIONS
- Review risk factors for intraoperative pressure ulcer development.
- Assess potential pressure areas before anesthesia induction and positioning, noting bruises, sores, skin tears, rashes, lesions, and pressure ulcers.
- Avoid friction and shearing forces by using a four-person lift, a liftsheet, or lifting device when transferring patient to or from OR bed and turning patient to desired surgical position.
- Prevent wrinkling of linen under the patient or positioning devices.
- Place electrosurgical dispersive pad in the most appropriate area while avoiding bony prominences.
- Avoid pooling of solutions under the patient.
- Apply tape sparingly to prevent skin injury during removal. If tape must be used, consider paper tape or a nonadherent dressing on fragile skin. Gauze wrap, stockinette, or tape alternatives may also be considered.
- Position the patient.
- Evaluate for signs and symptoms of physical injury to skin and tissue.

NURSING DIAGNOSIS
Disturbed Sensory Perception (visual or auditory) related to removal of eyeglasses or hearing aid in the OR secondary to age-associated changes in sensory organs

OUTCOME
The patient's perception and interpretation of environmental and sensory stimuli will be accurate throughout the perioperative period.

INTERVENTIONS
- If the patient uses an assistive device (e.g., hearing aid), leave in place as long as possible. Provide necessary information before removing assistive device.
- Remove OR mask to introduce self and explain procedures before surgery.
- Ask the patient to state his or her name, and continue to call the patient by stated name.
- Attract the patient's attention before speaking.
- Face the patient directly and on the same level (when possible) while speaking.
- Speak slowly and distinctly in a low-pitched, clear voice, frequently rephrasing and verifying communication.
- Control noise in the surgical setting.
- Use gestures to supplement words.
- Write instructions as needed to clarify information; use matte-finish paper.
- Allow ample time for patient to ask questions.
- Prepare patient for changes in light intensity, and allow time to adapt to lighting changes.
- Assist patient with transfers and mobility.
- Inform patient before positioning or procedures done before anesthesia induction.

NURSING DIAGNOSIS
Risk for Perioperative Positioning Injury related to positioning procedures secondary to musculoskeletal changes and associated chronic pain

OUTCOME
The patient will be free from perioperative positioning injury.

INTERVENTIONS
- Assess pain and skeletal/range-of-motion limitations before anesthesia induction and positioning.
- Assess potential pressure areas before anesthesia induction and positioning.
- Place safety strap above the knees; prevent undue pressure on the popliteal space and heels.
- Ensure that armboards are maintained at less than a 90-degree angle.

SAMPLE PLAN OF CARE—cont'd

INTERVENTIONS—cont'd
- Provide adequate padding to protect potential pressure areas.
- Maintain body alignment within restrictions imposed by chronic pain and musculoskeletal age-related changes.
- Use gentleness during positioning and turning.
- Keep head and neck in a comfortable position that limits hyperextension.

NURSING DIAGNOSIS
Ineffective Family Therapeutic Regimen Management

OUTCOME
The patient receives appropriate medications, safely administered during the perioperative period.

INTERVENTIONS
- Administer prescribed antibiotic therapy and immunizing agents as ordered.
- Administer prescribed medications and solutions.
- Administer prescribed prophylactic treatments.
- Label all medications on the sterile field.
- Validate medication orders with perioperative team.

NURSING DIAGNOSIS
Risk for Infection

OUTCOME
The patient is free from signs and symptoms of infection.

INTERVENTIONS
- Implement aseptic technique.
- Monitor for signs and symptoms of infection.
- Initiate traffic control.
- Administer care to invasive device sites.
- Assess susceptibility for infection.
- Protect from cross-contamination.

two groups are made. The perioperative nurse who recognizes the special needs of the elderly patient during what may be the most critical period of hospitalization helps to enhance the course of surgical intervention and postoperative recovery (Patient Safety). All members of the surgical team must work together in all phases of the perioperative continuum to provide an environment that focuses on the needs of the patient.

Preoperative Preparation. The preoperative period is an opportune time to evaluate the patient's psychosocial status and educational needs. As mentioned, the motivation of the patient can affect operative risk and successful surgical outcomes. Awareness of psychologic and emotional status is as important as awareness of physiologic status. Often the patient's concerns are focused on the spouse or other family members rather than on the impending surgery. An unexpected hospitalization can be very disruptive to an elderly patient who perhaps was the sole caretaker of an ill spouse, parent, or even a pet. In addition, the concern for quality of life and the fear of institutionalization after surgery can be extremely upsetting. This population has the highest morbidity and mortality in the adult population. Using the assistance of a discharge planner or case manager to arrange for resources may help allay the patient's concerns.

Sensory deficits, occurring either as a result of age-related changes or merely because eyeglasses and hearing aids are removed, can make communication with geriatric patients more difficult. Unresponsive or uncooperative behavior may be inappropriately diagnosed as dementia, expected as part of aging, and ignored. As discussed, acute confusion or delirium in elders is the most important indicator of possible underlying conditions that could seriously and adversely affect surgical intervention and outcomes. Knowing whether the patient's cognitive impairment is recent or chronic will provide direction for planning postoperative care.

The perioperative nurse should take advantage of the time spent in the preadmission interview, presurgical care unit, preoperative holding area, or the surgical corridor to introduce herself or himself and explain events to follow. Because a surgical mask is generally not required in these areas, this is the most opportune time for talking with the older adult. Once the patient is taken into the OR, a reassuring touch and remaining close to the patient, particularly during anesthesia induction, can help to decrease anxiety.

Anesthesia Induction. The perioperative nurse shares with the anesthesia provider any pertinent assessment data that may affect anesthesia. A medical history of asthma, previous patient or family anesthesia problems, abnormal laboratory data, and physical limitations affecting induction or airway management are important findings. The following anesthetic issues contribute to the morbidity and mortality of the older population:
- Active or unstable concurrent diseases
- Decreased mobility
- Intubation difficulties
- Gravity of the surgical procedure
- Myocardial depression from anesthetic agents
- Potentially altered respiratory and cardiac reserves

Elderly patients frequently have changes in airway anatomy that make appropriate ventilation difficult. Changes in facial contour from sunken cheeks or lack of dentition can result in an inadequately fitting anesthesia mask. Keeping dentures in place often offsets this problem; however, if intubation is planned, dentures are usually removed. The joints of the head and neck may exhibit limited range of motion, making intubation and airway management more difficult in elders. Identification of these potential problems before anesthetic administration facilitates a smooth induction period.

The choice of anesthesia in the elderly patient depends on physiologic status, length of the operative procedure, and preference of the anesthesia provider. IV sedation with local anesthesia may be selected for herniorrhaphy or other procedures that do not entail complicated manipulation of organs. Regional anesthesia (e.g., spinal, femoral, brachial, axillary, or peribulbar blocks) may be chosen over general anesthesia for specific surgical procedures (e.g., cataract extraction, transurethral resection of prostate [TURP]) because blood loss, deep vein thrombosis, and pulmonary embolism are less likely to occur (Sieber and Pauldine, 2005). The use of spinal anesthesia may be effective for orthopedic surgical procedures, such as

PATIENT SAFETY

Prevention of Deep Vein Thrombosis in the Elderly

Providing safe care for older adults in the perioperative setting requires the nurse and surgical technologist to have a thorough knowledge of the changes associated with aging and the risk factors for surgical complications. One change associated with aging is the increased risk for the development of deep vein thrombosis (DVT). The chances for developing DVT increase with age and double each decade of life over the age of 40 years. For example, a person who is 80 years old is twice as likely to develop DVT as someone who is 70 years old and 16 times more likely as someone who is 40 years old. The incidence of DVT is more than 150-fold higher among hospitalized patients than those in the community.

DVT is triggered by the Virchow triad: venostasis, hypercoagulability, and vessel wall inflammation, which leads to intravascular coagulation and the formation of a structureless mass of red blood cells, fibrin, and other cellular components. Several risk factors may increase the likelihood of DVT in an older person and include the following:

- Immobility; physical limitations that influence ambulation and movement
- Congestive heart failure
- Hypertension
- Use of diuretics, which contribute to dehydration and hypercoagulability
- Obesity
- Smoking
- Varicose veins
- Atherosclerosis

Prevention of DVT in the older person begins in the preoperative phase of care. Whenever possible, the nurse should contact the patient well in advance of the planned procedure to begin education on DVT precautions. Before surgery, patients should avoid long airline travel or immobility. Walking and increasing the activity level before surgery can improve the patient's venous return as well as overall health state. Unless contraindicated by the patient's condition or physician's order, the nurse should advise patients to drink adequate fluids up until the time of their nothing-by-mouth (NPO) status to help maintain hydration. Whenever possible, the patient should be instructed about leg exercises (e.g., ankle rolls, leg lifts) to be performed before and after the surgery.

When the patient arrives in the preoperative area, the nurse should consult with the surgeon to ensure that antiembolic stockings or sequential compression sleeves are ordered for the patient. Antiembolic stockings improve venous return by squeezing and closing venous valves, preventing pooling and stagnation of blood in the lower extremities. Sequential compression devices, which alternately inflate and deflate, serve to push the blood in the extremities back toward the heart. The nurse should demonstrate the leg exercises to be performed in the postoperative period and assess the patient's understanding and mastery through return demonstration and also discuss the benefits of early ambulation.

Before anesthesia induction, the nurse ensures the patient's antiembolic stockings are placed correctly with no wrinkles or rolling that might impede venous return and verifies that the sequential compression device is functioning normally. If the patient's feet are accessible during long procedures, the nurse should perform periodic passive range-of-motion exercises to maximize venous blood return (if possible without compromising the sterile field).

The nurse encourages the patient to move his or her legs and perform the recommended exercises as soon as possible in the postanesthesia care unit (PACU). The PACU staff should reinforce the preoperative teaching about DVT prevention and ensure the patient's caregiver also understands the instructions.

Pharmaceutical prophylaxis for DVT may be a consideration in some patients. Medications used for DVT prophylaxis are described in Chapter 23.

Modified from Wadlund DL: Prevention, recognition, and management of nursing complications in the intraoperative and postoperative surgical patient, *Nurs Clin North Am* 41:151-171, 2006; Jaffer AK, Brotman DR: Prevention of venous thromboembolism after surgery, *Clin Geriatr Med* 24:623-625, 2008; *Understanding deep vein thrombosis*, available at www.clotcare.com/clotcare/dvt.aspx. Accessed April 6, 2009.

hip fractures or knee replacements. Flexibility of the elderly patient or the presence of arthritic problems must be considered before attempting administration of a spinal anesthetic. In patients undergoing vascular or abdominal procedures, an epidural catheter may be considered for postoperative pain management.

Accurate predictions of how the elderly patient will respond to drugs or anesthetics are difficult to make because of a decrease in systems' function. Older patients have both an altered pharmacodynamic (relation between plasma concentration and drug effect) and an altered pharmacokinetic (distribution and elimination of drugs) response to drugs. These physiologic changes can affect medication administration because of a longer or shorter duration of action and less predictable effects. The increasing age of the patient decreases the dose requirement of anesthetic. This includes agents that induce anesthesia (e.g., thiopental sodium, etomidate, propofol) and narcotics. The induction dose of a barbiturate required for a 70-year-old patient will be less than that for patients 20 to 30 years old. Minimal blood levels of a drug may produce undesired side effects before therapeutic levels are reached. Likewise, reduced liver and kidney function, altered body composition, decreased albumin level, and decreased cardiac output all modify the aged person's ability to eliminate drugs from the body. Age-related changes in homeostatic mechanisms affect the older adult's ability to deal with physiologic stresses of surgery, such as fluid depletion, volume overload, or hypoxemia. Mild hypothermia of only 1° to 3° F below normal can increase postoperative myocardial ischemia and ventricular tachycardia. The incidence of hypothermia is greatest with combined epidural-general anesthesia (Sieber and Pauldine, 2005). The perioperative nurse should be prepared to respond quickly in assisting the anesthesia provider to stabilize the patient when adverse reactions occur.

Positioning. Protection of skin integrity is of utmost importance. Loss of subcutaneous fat, poor skin turgor, and tissue fragility can worsen a postoperative skin problem. Elderly patients should be lifted into position, rather than slid or dragged, to prevent shearing injuries. Aging changes in the

RISK REDUCTION STRATEGIES

Body Temperature and the Elderly

Temperature fluctuations are common in elders as a result of impaired thermoregulation. Response to cold, including vasoconstriction and shivering, is diminished in elders, and the core temperature must be lower to trigger a response than that required in younger adults. Intraoperative hypothermia may be associated with altered coagulation and increased surgical site bleeding (Rutherford et al, 2008). Other complications associated with hypothermia include vasoconstriction, poor tissue perfusion, and reduced oxygen tension, predisposing the patient to wound infection (Kulaylat and Dayton, 2008). For elderly patients with coronary artery disease, hypothermia may cause increased oxygen consumption, which could lead to myocardial ischemia (Sherwood et al, 2008).

Perioperative nurses collaborate with the anesthesia provider and the surgeon to ensure measures are in place to minimize the effects of hypothermia. Prevention of hypothermia is critical as the elderly patient generally lacks reserves to withstand prolonged shifts in temperature. Increasing the ambient OR temperature will help stabilize the effects of heat loss. Devices such as warmed blankets or forced air–warming blankets are highly recommended, particularly when a lengthy surgical procedure is expected. Special care should be taken by the perioperative nurse to prevent injury, such as burns, to the elderly patient with the use of such devices. When the body is exposed to cold temperatures, blood is shunted away from peripheral body parts to the head. Because the head lacks fat storage capacity and vasoconstriction capabilities, heat loss from the head can be as much as 25% to 60% of total body heat loss. The nurse should provide elderly patients some form of head covering to prevent additional effects of inadvertent hypothermia.

Prepping solutions should be carefully chosen to prevent skin irritation and should be warmed (if recommended by the manufacturer) to help decrease hypothermic effects. The nurse ensures the patient is not lying in a prep solution or on wet linens to reduce skin injury and inadvertent lowering of body temperature. The surgical technologist must be aware of the consequences of using cold irrigation solutions and ensure that any irrigation provided to the surgeon is appropriately warmed.

Modified from Kulaylat MN, Dayton MT: Surgical complications. In Townsend CM et al, editors: *Sabiston textbook of surgery,* ed 18, Philadelphia, 2008, Saunders; Rutherford EJ et al: Hematologic principles in surgery. In Townsend CM et al, editors: *Sabiston textbook of surgery,* ed 18, Philadelphia, 2008, Saunders; Sherwood ER et al: Anesthesiology principles, pain management, and conscious sedation. In Townsend CM et al, editors: *Sabiston textbook of surgery,* ed 18, Philadelphia, 2008, Saunders.

musculoskeletal system accentuate bony prominences and decrease the range of motion. These skeletal changes coupled with limitations imposed by chronic pain make positioning one of the most important considerations of care. The provision of appropriate positioning devices is pivotal to the protection from injury for this population of surgical patients. Arms are placed on padded armboards with the palms up and fingers extended. Armboards are maintained at less than a 90-degree angle to prevent brachial plexus stretch. If there are surgical reasons to tuck the arms at the side, the elbows are padded to protect the ulnar nerve, the palms face inward, and the wrist is maintained in a neutral position (Denholm, 2009). A drape secures the arms. It should be tucked snuggly under the patient, not under the mattress. This prevents the arm from shifting downward intraoperatively and resting against the OR bed rail.

Often, because of musculoskeletal deformity and chronic pain, elderly patients cannot fully extend the spine, neck, or upper and lower extremities. Using padding devices to compensate for these limitations not only makes the patient more comfortable during the procedure but also prevents residual pain or injury postoperatively. Depending on the situation, positioning the patient before anesthesia induction may be best so that the patient can direct positioning efforts in regard to comfort.

Skin Preparation and Thermoregulation. Aging skin is more susceptible to rashes, infection, and inflammation. A common complaint of the elderly is dry skin that may be part of the natural aging process or can be related to diseases such as anemia, malignancy, kidney disease, or diabetes. Medications, such as corticosteroids, may cause skin to become more fragile. Changes in the dermal receptor cells can alter the ability of the elderly to perceive sensations of pressure and touch, as well as changes in temperature.

Decreased muscle tissue and activity, reduced subcutaneous fat, and diminished peripheral circulation are some of the changes in aging that can have a negative impact on thermoregulation (Wold, 2008). The perioperative environment can expose the elderly patient to cool temperatures and hazardous chemicals, thus requiring the perioperative registered nurse to assume extra caution in this environment (Risk Reduction Strategies).

Aseptic Techniques and Safety Measures. Age-related changes in functioning of the immune system and some age-associated diseases have a detrimental effect on the aging body's ability to appropriately respond to infection. The risk of developing a healthcare-associated infection in an acute-care facility ranges between 3% and 15% (Goldrick, 2005). Diminished cough reflex and reduced ciliary action weaken specialized defense mechanisms. Pneumonia is the second most common healthcare-associated infection, preceded only by urinary tract infections (UTIs) (Goldrick, 2005). Incomplete emptying of the bladder can cause a UTI, which causes significant morbidity in older adults.

Immobility and drug therapy alter flora in the intestines. Infection and delayed wound healing are poorly tolerated and sometimes fatal in debilitated elderly patients. In addition to adherence to aseptic technique, there are other measures employed in the OR to protect aging patients from the risk of infection. Because length of surgical procedure is related to incidence of infection, the nurse should ensure that needed supplies and equipment are readily available. The surgical technologist should be familiar with the procedure being performed to maximize efficiency to prevent unnecessary delays, decrease exposure of the surgical site, and reduce the length of time the elderly patient is anesthetized.

Fluctuations in fluid volume are common in aging patients. Volume deficits occur as a natural course of aging, whereas

TABLE 26-2

Important Clues in the Initial Assessment of Dehydration in Older Adult Patients

Clinical Indicator	Water Deficiency	Water + Electrolyte Deficiency
MEDICAL HISTORY	Recent >3% weight loss Impaired water intake Increased perspiration (fever, tachypnea, heat)	Recent >3% weight loss Vomiting, diarrhea, diuretic, drug use, diabetes, bleeding
PHYSICAL EXAMINATION		
Tongue dryness	Present	Present
Longitudinal tongue furrows	Present	Present
Dry mucous membranes, mouth	Present	Present
Upper body muscle weakness	Present	Present
Confusion	Present	Present
Speech difficulty	Present	Present
Sunken eyes	Present	Present
Blood pressure	Unchanged or decreased	Highly decreased
Pulse rate	Unchanged or decreased	Highly decreased
LABORATORY TESTS		
Serum creatinine	Increased	Increased
Serum urea	Increased	Highly decreased
Tonicity	Highly decreased	Unchanged or decreased
Urinary output	Decreased	Decreased, unchanged, or highly decreased
Urinary sodium concentration	Decreased	Decreased, unchanged, or highly decreased

Modified from Faes MC et al: Dehydration in geriatrics, *Geriatr Aging* 10(9):590-596, 2007, available at http://cme.medscape.com/viewarticle/567678-1. Accessed January 8, 2008.

volume excess can occur from intraoperative fluid replacement. The age-related failure of homeostasis to adjust for stressful disturbances has been demonstrated by changes in fluid balance. Large variability in the way different organs are affected by dehydration results in atypical symptoms in older adults (Faes et al, 2007). Table 26-2 provides important clues for assessing dehydration. Careful measurement of intake and output is essential. Communication among team members regarding blood loss during the procedure can prevent complications. The nurse and surgical technologist must collaborate to ensure accuracy in irrigation distributed to the sterile field and used during the procedure. The team closely monitors discarded sponges, suction canister contents, and urinary output as part of volume assessment. During the hand-off report, the nurse reports intraoperative IV fluid volumes, estimated blood loss, and other parameters to the postanesthesia care unit (PACU) staff for their continued assessment and evaluation.

Evaluation

Because of the relatively fine line between stability and development of postoperative complications, the elderly patient's response to surgery must be closely evaluated. Before transporting the patient to the PACU, the perioperative nurse should assess the care provided intraoperatively by evaluating expected versus actual outcomes. Specific outcome criteria established for each nursing diagnosis provide the basis for evaluation of care. Many of the nurse's actions at the end of the intraoperative phase provide data for evaluation of care.

The nurse collaborates with the anesthesia provider to complete and record the patient's intake and output measurements. Because of the consequences of postoperative dehydration or fluid volume overload in the elderly patient, fluids are increased or decreased accordingly. Blood loss is carefully evaluated, recorded, and reported.

The wound is closely observed for bleeding before dressing application and postoperatively because the elderly person's ability to recover from hemorrhage and shock is extremely poor. Anticipated frequency of dressing change, as in a draining wound, should govern the method used to secure the dressing. A minimal amount of tape should be used because its removal can cause additional skin trauma. Depending on the wound site and character, rolled gauze, stockinette, or similar bandaging over the primary dressing may be the best choice so that tape is not applied directly to the skin. Another alternative is the use of Montgomery straps. For smaller wounds, the least possible amount of hypoallergenic tape should be used. Because infection is poorly tolerated, the choice of dressing should maximize wound protection while being the least irritating to the skin.

The nurse examines the patient for signs of injury, particularly over bony prominences and under the electrosurgical dispersive pad. To prevent skin injury postoperatively the patient should be carefully lifted from the OR bed to the stretcher. Pain is assessed and compared with preoperative levels. Evaluation of musculoskeletal pain will determine intraoperative positioning effectiveness.

Evaluation of body temperature is particularly important in elders because postoperative hypothermia is quite common and can precipitate agitation and confusion or delirium. To prevent any adverse response, the nurse covers the patient with warmed blankets and uses a forced air–warming unit until the patient is transported to the PACU.

Depending on the patient's level of consciousness, the nurse should explain the impending transfer to the PACU as a form

BOX 26-8

Preoperative Risk Factors for Postoperative Delirium in Elders

- Age 80 years or older
- Decreased education level
- Decreased functional status
- Alcohol or sedative-hypnotic withdrawal
- Depression
- Drug interaction or polypharmacy; duration of anesthesia
- Endocrine and metabolic problems
- History of dementia-like symptoms
- Low mobility
- Presence of multiple diseases
- Sensory impairments
- Surgical procedures considered major in nature
- Emergent or urgent surgical procedures
- Dehydration
- Low serum albumin level
- Abnormal preoperative serum sodium, glucose, or potassium level
- American Society of Anesthesiologists (ASA) class III or IV
- Uncontrolled pain
- Urinary elimination problems

Modified from Rudolph JL, Marcantonio ER: Delirium. In Duthie EH et al, editors: *Practice of geriatrics,* ed 4, Philadelphia, 2007, Saunders; Bargi AS, Rico A, Ruiz JG: Evaluation and management of elderly patients at risk for postoperative delirium, *Clin Geriatr Med* 24:667-686, 2008.

of reality orientation for the patient. As appropriate, the nurse should introduce the patient to the PACU nurse and explain what to expect in the unit. Explanations should always precede any procedure. Often the elderly person is reluctant to cooperate simply because no one has taken the time to explain what is going to happen.

Verbal communication between the perioperative and PACU nurses should include any pertinent preoperative and intraoperative information that could affect postoperative care outcomes. This information includes pain levels; physical and sensory limitations; intake and output measurements; allergies; type and location of catheters, drains, packing, and implantable devices; anesthetics and medications received; and any unusual occurrences that could affect the patient's recovery. Perioperative nurses should be aware of the risk for the phenomenon known as postoperative delirium, a condition that can occur in elderly patients. Box 26-8 lists the most frequently identified preoperative risk factors for postoperative delirium.

Documentation of outcome evaluation can be phrased as follows:

- Skin integrity was maintained free from redness, bruises, and abrasions; patient reported no pain or impairment of the skin; and there were no apparent signs or symptoms of infection.
- Fluid balance was maintained; urinary output was within normal limits; the patient's forehead skin was checked and had good turgor; and vital signs were stable.
- Temperature was ±1° F of normal range; skin was warm to touch; and patient verbalized comfort.
- The patient accurately perceived and interpreted environmental stimuli, expressed and demonstrated understanding of procedures, and responded appropriately to auditory and verbal stimuli.
- Perioperative positioning injury was effectively prevented; and the patient had no complaints of increased pain and no compromise in musculoskeletal ability and range of motion from preoperative levels.
- Medications used during the intraoperative procedure caused no apparent adverse reaction.

The type and extent of surgery may affect postoperative pain. Elderly persons may not complain of pain, but this does not indicate that pain does not exist. Those patients with cognitive impairment may experience pain but may be unable to verbalize it. Box 26-9 gives key elements of pain assessment and management in older adults.

Contemporary pain control delivery systems and techniques offer a variety of treatment routes and modalities. Various routes may be employed to deliver medication for pain control: oral, intramuscular, IV, regional (i.e., spinal or epidural), or patient-controlled analgesia (PCA). Cognitive modalities that may be employed are distraction, relaxation (i.e., biofeedback), or hypnosis. Physical modalities that may be used are cold, exercise, heat, immobilization/rest, massage, positioning, or transcutaneous electrical nerve stimulation (TENS).

Clinical management of pain should be multimodal and individualized for the patient, procedure, and circumstance. Evaluation of the balance between pain control and side effects should be documented, timely, routine, and specific.

Patient and Family Education and Discharge Planning

Education should be conducted at a time when the patient is at rest rather than during preoperative or postoperative procedures. Too many stimuli from outside sources can interfere with the patient's ability to concentrate and motivation to learn. The nurse ensures the patient's physical comfort and privacy. Education will be ineffective in the patient who is uncomfortable or in pain. Age-related changes can affect the elderly patient's ability to learn new material; therefore modification of traditional teaching approaches should be used to enhance effectiveness. Patient education should consider health literacy and be individualized based on how the patient will best understand the information (Research Highlight).

A comprehensive discharge plan should identify and address communication barriers, incorporate the patient's current mental and physical condition, address environmental issues that can be improved to support recovery, and diminish the social support challenges. Sensory changes in vision and hearing, cognitive impairment, and literacy level can be communication barriers that interfere with the patient's ability to understand and retain information. Giving the patient postoperative instructions in written form helps with retention, and modifications using large, easy-to-read typeface on matte-finish paper of warm tones (yellow, tan) make the instructions easier to read. It may be helpful to have a magnifying glass available and supplemental light on the object or surface involved in the teaching/learning activity. Family members or significant others who are present should be included in the educational session so that they can provide reinforcement at home.

The discharge plan should consider the patient's ability to perform ADLs, ambulate, and manage his or her preexisting medical condition after surgery. The older person's basic

BOX 26-9

Pain and Older Adults

PREVALENCE OF PAIN

Recognize that older adults are at great risk for undertreated pain.

BELIEFS ABOUT PAIN

In addition to receiving less analgesia than younger adults, older adults tend to report pain less often. These findings may be related to beliefs and concerns about pain and the reporting of pain. Many older people hold the following beliefs and concerns about pain:

- Pain is something that must be endured; it is part of life.
- Expressing pain is unacceptable or is a sign of weakness.
- Complaining of pain will result in being labeled as a "bad" patient.
- Nurses are too busy to listen to complaints of pain.
- Pain signifies a serious illness or impending death.

Nurses should be aware of the beliefs of older patients regarding pain management. Nurses and other caregivers often undermedicate these patients and are sometimes reluctant to administer the prescribed analgesics.

ASSESSMENT

- Ask about present pain only.
- Use a standard scale, such as the numeric faces or Iowa thermometer rating scale.
- Explain the scale each time it is used.
- Use verbal descriptions other than pain, such as "ache," "sore," and "hurt."
- Use visual representations of pain measures rather than mental images of pain rating scales. Be sure that the patient is wearing glasses and hearing aids if needed and available.
- Alter a written pain scale to include large lettering, adequate space between the lines, nonglossy paper, and appropriate color for increased visualization.
- Provide adequate lighting and privacy to avoid distracting background noise.

CONSIDERATION FOR COGNITIVELY IMPAIRED PATIENTS

- Assess for nonverbal indications of pain (facial expressions, grimacing, vocalizations, body movements, behavioral changes).
- Remember to "assume pain is present" in cognitively impaired patients in the perioperative setting.
- Consider an analgesic trial.

MANAGEMENT OF PAIN

- Be aware of adverse effects of acetaminophen (hepatotoxicity and nephrotoxicity) and nonsteroidal antiinflammatory drugs (NSAIDs) (gastrointestinal [GI] bleeding and nephrotoxicity).
- Start low and go slow with opioid dosing.
- Avoid the use of meperidine, codeine, and propoxyphene.
- Use methadone and tramadol with caution.
- Older adults and those with renal disease should not take meperidine because of the prolonged half-life of its drug metabolite, normeperidine.
- Use nondrug pain-relief measures.

Modified from McGuire L: Pain: the fifth vital sign. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, St Louis, 2010, Saunders.

RESEARCH HIGHLIGHT

The Impact of Health Literacy on Consumer Understanding

Health literacy is a factor for perioperative nurses to consider when providing patient education. Health literacy includes both the ability to understand instructions on prescription drug bottles, appointment slips, medical education brochures, physician's directions, and consent forms and the ability to negotiate complex healthcare systems. Health literacy is not simply the ability to read. It requires a complex group of reading, listening, analytic, and decision-making skills, and the ability to apply these skills to health situations. Nearly half of all adults possess limited health literacy that may challenge their ability to understand and use health information. Older adults are particularly vulnerable. Two thirds of U.S. adults age 60 and older have inadequate or marginal literacy skills, and 81% of patients age 60 and older at a public hospital could not read or understand basic materials such as prescription labels.

The objective of this study was to explore the impact of health literacy on consumers' use and understanding of quality information about postacute rehabilitation facilities. Study participants were patients and caregivers of patients age 50 years or older who had a diagnosis of stroke, hip fracture, or joint replacement. A sample size of 29 participants consisting of 17 patients and 12 caregivers was used in the study. Researchers identified key terms essential to item comprehension, including functional status, cognitive status, discharge to home or community, length of stay, patient satisfaction, delirium, moderate to severe pain, and pressure ulcers. To determine comprehension and health literacy, researchers then asked patients and caregivers to define these terms in their own words. Study results indicated that patients had the most difficulty in defining the terms cognitive functional status and discharge to home or community. Approximately one in five respondents could not correctly define the key terms that were presented to them. Data analysis revealed that barriers to understanding and processing of concepts included complexity of the information presented, use of medical terminology, and partial comprehension.

Based on the study results, researchers recommend the following actions regarding health literacy that are applicable to perioperative nurses interacting with elderly consumers:

- Texts and graphs, if used for patient education, should be simplified by reducing details and wordiness.
- Healthcare providers should limit their use of medical terminology and jargon.
- Brief definitions of key terms should be provided when complex health concerns are discussed.
- Words that consumers use to define key concepts should be used.

Modified from Magasi S: Rehabilitation consumers' use and understanding of quality information: a health literacy perspective, *Arch Phys Med Rehabil* 90:206-212, 2009; National Network of Libraries and Medicine: *Health literacy,* available at http://nnlm.gov/outreach/consumer/hlthlit.html. Accessed April 14, 2009.

medical condition does not change because of surgery. Content should focus only on relevant information about surgical procedures or postoperative recoveries; relating it to previous life experiences helps the patient grasp the concepts more readily. The nurse should provide the most important information first. If motor skills (i.e., crutch walking, dressing change) are involved, all steps should be taught one at a time and mastery should be demonstrated before moving to the next step. Increased time is often necessary when teaching motor skills.

Discharge planning begins during the preoperative assessment. Sufficient time is needed to make appropriate decisions about postdischarge care to prevent complications, reduce the risk of rehospitalization, and minimize stress to the patient and the caregivers. Consideration should be given to the environment to which the patient will be transferred following the surgery. Although the plan should consider that older adults prefer to keep their autonomy, the postoperative care may require special facilities, such as a rehabilitation center or long-term care facility, at least for a time.

The type of surgery and expected postoperative recovery period determine the extent of resources and social systems needed, such as durable medical equipment, home health and homemaker services, extended care, social and community services, and physical rehabilitation. The success of postdischarge outcomes in elders is influenced by the patient's self-assessment of health as good or excellent, the complexity of the patient's medical condition, the patient's history of being able to maintain responsibility for his or her own health, and the patient's family or social networks. Many elders undergo procedures on an ambulatory basis (Ambulatory Surgery Considerations). Discharge needs of the patient should be evaluated as early as possible so that appropriate education, referrals, and home preparation can be completed before the patient leaves the hospital or ambulatory facility.

AMBULATORY SURGERY CONSIDERATIONS

Procedures of the Eye

Cataract surgery is among the most common ophthalmic surgical procedures performed in older adults. Some degree of cataract formation is expected in all people older than 70 years of age. The majority of these procedures are performed in an ambulatory setting, with patients returning home the day of surgery. Cataracts are associated with factors including trauma, inflammation, genetic predisposition, metabolic disease, and cigarette smoking, but aging is by far the most common factor. Most eye surgery patients make the decision to have the procedure done after months of deliberation and slow, progressive loss of vision. The overall risk of death is low and does not significantly change whether local or general anesthetic is used. Intraocular lenses can be safely implanted in the majority of patients. Microsurgical wound closure ensures a secure incision that allows immediate ambulation. The surgical stress is considered so low and visual rehabilitation so rapid that severe visual impairment is considered a reasonable indication to perform surgery even if the elderly patient is debilitated (see Chapter 17 for an in-depth description of cataract surgery).

Surgical Interventions

The elderly account for the majority of cancer patients; patients 65 and older account for 70% of cancer deaths and 56% of all newly diagnosed cancers. Surgical intervention is generally accepted to be a part of the standard of care. Breast cancer is six times higher in older patients and the biologic behavior of breast tumors differs in the elderly. Physicians must consider these differences along with the understanding that undertreatment is associated with increased morbidity and higher recurrence rates. More than 50% of lung cancer patients are older than 65. Colorectal cancer is the second most common cancer in the United States. The mainstay of treatment modalities for these kinds of cancer is surgical intervention (Kim and Zenilman, 2007).

Surgical procedures that are common among the geriatric population are governed more by pathologic condition than by anatomy and are directly related to the common diseases affecting older adults. Healing is an important consideration in the decision to perform surgery on this population. The level of tissue oxygen is the main factor in determining wound healing and is influenced by factors such as cardiovascular status and anemia. Other factors are included in Box 26-10. In the text that follows, some surgical procedures that are commonly seen in elderly patients are briefly discussed. Reference is made to other sections of the text for a more in-depth description of the technical aspects of the procedures.

COMMON SURGICAL PROCEDURES IN GERIATRIC PATIENTS

It is becoming common for patients well past 85 years of age to have surgery with relatively good outcomes. Decisions are no longer based solely on surgical risk but rather on optimal disease management and the preservation of quality of life. This shift in thinking has taken us beyond just getting the patient through the surgery and has produced a genuine concern about what the surgery will do for patients in the remaining years of life.

Thyroid Surgery

In the elderly population, thyroid gland dysfunction is common and associated with significant morbidity because the symptoms are often subtle, absent, or confused with co-existing

BOX 26-10

Factors That Influence Wound Healing

- Anemia
- Congestive heart failure
- Diabetes
- Hepatic failure
- Hypothyroidism
- Hypovolemia
- Malignancy
- Nutrition (protein, glucose, minerals, vitamins A and C)
- Peripheral vascular disease
- Renal failure
- Rheumatoid arthritis

Modified from Bradley SF: Infections. In Duthie EH et al, editors: *Practice of geriatrics,* ed 4, Philadelphia, 2007, Saunders.

diseases. Hypothyroidism occurs in 10% to 15% of patients older than 60 years and is more frequent in females than males (Rehman et al, 2005).

Typical symptoms of thyroid disorders may be absent or erroneously attributed to co-morbid conditions or normal aging. The polypharmacy used in the treatment of elderly patients can interfere with normal thyroid function. Drugs such as lithium or amiodarone may cause primary hyperthyroidism. For example, an elderly man taking medication for hypertension, congestive heart failure, and atrial fibrillation with complaints of fatigue, weakness, constipation, and weight gain may be considered to have these symptoms because of medication or medical conditions, whereas the symptoms could also be caused by hypothyroidism.

A rare complication of hypothyroidism, myxedema coma, affects patients older than 75 years. Confusion, disorientation, lethargy, thinning eyebrows and hair, hoarse voice, bradycardia, cardiomegaly, pericardial effusion, hypothermia, hyponatremia, and pseudomyotonic reflexes characterize this condition.

The great masquerader in the elderly population is hyperthyroidism and can easily be missed in patients older than 60 years. It can be severe and even life-threatening. Elderly patients may not have a goiter, exophthalmos, or other ophthalmopathy. Hyperthyroidism may also cause osteoporosis. Almost any condition that can make a person ill can cause euthyroid sick syndrome; so elders are more susceptible because of their co-morbid conditions. Medication to suppress hormone secretion by the gland, surgery to remove the hyperfunctioning tissue, and radioactive iodine (RAI) to destroy the gland are the three treatment options. Although surgery is a less attractive option, it must be employed when RAI is ineffective in the presence of a single nodule or multinodular toxic goiter or when the patient has dysphagia, tracheal compression, or suspected malignancy. Following surgery, the perioperative nurse must be aware of the possibility of a hyperthyroid storm that can be precipitated by the stress of the procedure, systemic infections, and anesthesia induction. (See Chapter 15 for an in-depth description of operations of the thyroid.)

Abdominal Surgery

Accurate diagnosis of abdominal disease is important in elders to plan timely and appropriate surgical interventions. However, clinical signs of abdominal disease, such as tenderness, pain, muscle rigidity, and fever, are frequently less obvious in elderly patients. The common use of nonsteroidal antiinflammatory drugs (NSAIDs) may mask symptoms or even predispose elderly patients to acute abdominal disease.

The most common causes of acute abdominal complaints in older patients are biliary tract disease, intestinal obstruction, GI hemorrhage, hernia, diverticulitis, and appendicitis. Common abdominal procedures in people older than 65 years include cholecystectomy, lysis of adhesions, appendectomy, and partial excision of the small bowel (Wold, 2008).

Most often, surgery is performed for complications of calculus disease and less often for malignant obstruction of the bile ducts. The prevalence of gallstones increases with age. Because laparotomy is a stressor in older ill patients, laparoscopic cholecystectomy is considered the preferred surgical approach in elderly patients with both symptomatic and asymptomatic gallstone disease. (See Chapter 11 for an in-depth description of operations of the biliary tract.)

The age-group older than 65 years has seen an increase of ulcer disease. Many believe that the higher incidence of *Helicobacter pylori* infection, prevalent use of NSAIDs, and prevalence of cigarette smoking in elders account for the age-related differences. Up to 80% of peptic ulcer–related deaths occur in patients older than 65 years (Berger et al, 2008).

GI bleeding is a frequent indication for hospitalization affecting a substantial number of elderly people. A coordinated approach to diagnose and manage these patients can optimize favorable outcomes. Per Yachimski and Friedman (2008) key points to remember include the following:

- Immediate attention should be focused on hemodynamic stabilization followed by diagnostic assessment to identify the source of bleeding.
- Outcomes are influenced by the use of anticoagulant therapy, the presence of medical co-morbidities, and the nature of the lesion.
- Peptic ulcer disease is usually the most frequent source of upper GI bleeding. Rebleeding and morbidity can be reduced with gastric acid suppression and endoscopic hemostatic therapy.
- Diverticular disease is the most frequent source of lower GI bleeding. Urgent colonoscopy to identify the bleeding site and perform hemostasis is indicated. Persistent, recurrent diverticular bleeding may necessitate emergency colectomy that is associated with higher morbidity and mortality.
- Tolerance of procedural sedation must be critically considered in providing safe, effective endoscopy for elderly patients.

In selecting the procedure to correct the source of GI bleeding, the surgeon considers the patient's overall condition, history of chronic versus acute symptoms, and bleeding location. Elderly patients tolerate a surgical procedure better than they tolerate prolonged or recurrent bleeding. (See Chapter 10 for an in-depth description of ulcer surgery.)

Hernia

The estimated incidence of abdominal wall hernia in persons older than 65 years is 13 per 1000, with a fourfold to eightfold increase in the incidence in men. Fifty percent of all hernias are indirect inguinal, 20% are direct inguinal, 10% are ventral, 6% are femoral, 3% are umbilical, and 1% are esophageal-hiatal (Berger et al, 2008). The elective repair of inguinal and femoral hernias is strongly advised because of the risk of incarceration with subsequent emergency surgery. Many hernia repairs in elderly patients are emergency procedures because of incarcerations and small bowel obstruction. When elective, the operation may be performed as an ambulatory procedure; IV sedation and local anesthesia provide a very satisfactory alternative to general or spinal anesthesia.

Laparoscopic techniques for hernia repair have gained popularity because of associated shorter hospital stay, minimal pain postoperatively, and early recovery. However, the necessity for general anesthesia makes this approach one that may not be advisable in elders. Decisions for local versus spinal or general anesthesia are made based on the patient's overall physiologic status and surgical risk.

In elderly men the co-existence of inguinal hernia and prostatism is fairly common. Depending on the size of the prostate, the hernia repair should be postponed until after the prostate surgery.

Not unusual in elders are large, neglected scrotal hernias. The repair of these hernias is not routine in that the abdominal wall defect may be so large that primary repair cannot take place without tension. Synthetic abdominal wall replacements are helpful in the management of such large hernias. The repair of huge scrotal hernias can have a tremendous benefit on the personality of the geriatric patient, who is much relieved after removal of what can be considered an accessory appendage that is offensive, difficult to clean, and often an impedance to daily activities. (See Chapter 12 for an in-depth description of herniorrhaphy.)

Genitourinary Surgery

The predominant reason for urologic surgery in elderly men is benign prostatic hypertrophy (BPH). BPH may be silent or have minimal symptoms in the presence of severe bladder decompensation. As part of history taking, the nurse should determine if symptoms such as dysuria, straining at micturition, and hematuria exist. Prostate surgery, especially transurethral resection of the prostate (TURP), is relatively safe and generally well tolerated. The majority of BPH operations are performed to relieve symptoms, such as nocturia, slow stream, intermittency, and double voiding. TURP is indicated if the surgeon believes that total resection can be accomplished in 1 hour and that no bladder disease or impairment to urethral access is present.

A surgical alternative to TURP is transurethral incision of the prostate (TUIP). The complications associated with TUIP are significantly fewer than those occurring after TURP, especially bleeding, retrograde ejaculation, and impotence. It is a more desirable alternative to TURP for patients with prostates weighing less than 30 g. Other alternatives are laser prostatectomy, transurethral vaporization of the prostate, microwave hyperthermia, and transurethral needle ablation. These techniques are gaining acceptance because they can be done as outpatient procedures using local anesthetic. Genitourinary (GU) procedures may also be performed to correct incontinence. Incontinence in elderly men can result from nerve-damaging events such as radical prostatectomy and spinal cord injury. Surgical treatments can include artificial sphincter creation, formation of a bulbourethral sling, and a urinary diversion procedure (Men's Guide to Urinary Incontinence, 2008).

Older women experience urinary incontinence more frequently than younger women. Sneezing, coughing, and laughing may cause urine to leak from the bladder. The decision to have surgery should always be based on appropriate diagnosis, evaluation of all treatment modalities, and realistic expectations from surgical intervention. Surgical choices can include urethral sling, retropubic suspension, and tension-free vaginal tape surgery. Factors that can impair a positive outcome include, but may not be limited to, obesity, radiation therapy, aging, chronic cough, poor nutrition, low estrogen level, postmenopausal, and strenuous physical activity (Women's Guide to Urinary Incontinence in Females, 2008). (See Chapter 14 for an in-depth description of GU procedures.)

Ophthalmic Surgery

Because of elders' long life span, undergoing eye surgery (most commonly for cataracts) is more likely than other surgical procedures. Most ophthalmic procedures are minimally invasive and have a high success rate. Because elderly patients may have concurrent systemic disease, even a low-stress procedure should not be treated lightly. Age-related changes, such as hearing loss and musculoskeletal disease, may pose a challenge during ophthalmic surgery because the patient must lie still for long periods and be able to follow verbal instructions. Patients with chronic lung disease lying in the supine position may experience coughing, which can increase intraocular pressure and jeopardize the outcome of the surgery.

Orthopedic Surgery

Osteoporosis is the most obvious skeletal change that occurs with advancing age. It leads to susceptibility to fracture, which doubles every 5 years after 50 years of age. An approximate loss of 25% to 40% of the mineral content of the bone must be present before detectable change is evident on x-ray films (Murray, 2010). To some degree, osteoporosis is related to a lessening of physical activity, but other risk factors are female gender, Northern European ancestry, multiparity, lean body build, and excessive alcohol intake (Murray, 2010). Osteoporosis is also related to decreased hormonal secretion; thus postmenopausal women are more prone to develop the condition and therefore more likely to sustain a hip fracture.

Age-related changes in bone increase the prevalence of displaced femoral and intertrochanteric fractures of the upper femur. The prevalence of hip fracture increases with advancing age, is more common in women, and is higher in institutionalized patients. Because the usual cause of death in patients with upper femur fracture is pulmonary embolus, surgery is designed to relieve the severe pain, allow movement in and out of bed, and return the patient to his or her former environment as quickly as possible with minimal debilitation. Between 25% and 50% of individuals who sustain hip fractures are more dependent after the fracture, with deterioration occurring more often in women older than age 75, those with a poor clinical result, and those who were already dependent before the fracture. More than 60% of all joint replacements are in individuals older than 65, and females are almost twice as likely as males to have joint replacement surgery. Outcomes depend on the number of procedures the surgeon and facility have performed; the timing of the surgery; and the patient's medical status, perioperative management, and rehabilitation (Ebersole et al, 2008). A displaced femoral neck fracture must be surgically repaired or healing will not occur. In elderly patients, 70 years and older, prosthetic replacement is usually done because it allows for early ambulation and will last throughout the remaining years of the patient's life. Intertrochanteric and subtrochanteric fractures are best treated with internal fixation. These methods also allow for early mobility.

Degenerative joint disease (osteoarthritis) and inflammatory polyarticular disease (rheumatoid arthritis) are the primary indications for total joint replacement in the hip and knee. In these patients, pain that disrupts normal daily activities and interrupts sleep is the major reason for surgery regardless of the patient's age. Octogenarians and nonagenarians achieve successful pain relief and report satisfaction after the procedure. Methyl methacrylate bone cement is often used in orthopedic procedures in spite of its cardiotoxic effect. Cardiac arrest from cement insertion is a possible risk for frail patients. Supplemental inspired oxygen at the time of insertion, irrigation of the bone to remove excessive marrow elements, and

retrograde insertion of the cement are methods to prevent the risk of adverse effects (Burlingame and Blanchard, 2009). Usually knee replacement procedures are elective, and patients have better functional status and a higher bone mass than those with hip fracture. (See Chapter 19 for an in-depth description of hip and knee surgery.)

Vascular and Cardiovascular Surgery

The most frequent vascular conditions treated surgically in the older population are abdominal aortic aneurysms, carotid artery disease, and peripheral vascular disease. In patients 65 years and older the mortality from elective aneurysm repair is less than 5% in spite of existing co-morbidities. Emergency repair for ruptured aneurysm carries an operative mortality of more than 50% (Berger et al, 2008). Peripheral vascular surgery for limb salvage can be safely performed in patients older than 80 years and may be indicated for ischemic rest pain and nonhealing ulcers.

Cardiovascular disease is a significant cause of death in older patients. More than 55% of coronary artery bypass graft procedures are performed on patients older than 65 years. Several risk factors associated with increased mortality include emergency procedure, severe left ventricular dysfunction, mitral insufficiency requiring combined procedure, elevated preoperative creatinine level, chronic obstructive pulmonary disease (COPD), anemia, and prior vascular surgery. Factors associated with morbidity in the elderly population include obesity, diabetes mellitus, aortic stenosis, and cerebrovascular disease (Berger et al, 2008). (See Chapters 23 and 24 for a more in-depth description of vascular and cardiac surgery, respectively.)

ADDITIONAL CONSIDERATIONS

Regardless of the age of the patient every surgical procedure possesses a certain amount of risk. With increasing life expectancy, the number of surgical procedures performed on older adults will increase. Nonetheless, just as co-morbidity and emergent surgery increase surgical risk so do the physiologic deficits of aging. Procedures that are performed in the thorax or the peritoneal cavity are considered high risk. Procedures of moderate risk include vascular and hip procedures, and low-risk procedures include prostatectomy and mastectomy. However, any procedure, even those considered low risk, can have poor outcomes, depending on the patient's overall condition. Caution is advised even with the ever-increasing numbers of minimally invasive surgeries (e.g., laparoscopy). It seems logical that elders would benefit from smaller incisions that produce less postoperative pain, atelectasis, and ileus. However, the extent of hemodynamic and pulmonary consequences of CO_2 pneumoperitoneum is still unclear. In patients with severe cardiac or pulmonary disease, recommendations include invasive monitoring to maintain adequate volume loading and use of alternate gas sources or gasless techniques.

When surgical intervention is being considered in elders, it is important to remember the following:

- Age alone should not be a barrier to surgery in elders.
- Elderly persons with conditions treatable by surgery have as much right as younger patients to benefit from modern surgery, anesthesia, and medical and intensive care techniques.
- Medical and surgical techniques that can enhance the older person's life should be equally available to patients regardless of age.
- Elderly patients have special needs because of their atypical presentation of disease, multiple medical disorders or co-morbidity, impaired homeostasis, and altered drug response.
- Most elderly patients are mentally competent and should therefore always be involved in making decisions about their plan of care.

An ethical consideration with elderly surgical patients centers on the dilemma of do-not-resuscitate (DNR) orders. The organization's policy must give the patient a voice in the intraoperative area. Even though the patient may have made end-of-life decisions, the fact that the patient has signed the surgical informed consent implies that he or she seeks to improve quality of life, which is incompatible with withholding cardiopulmonary resuscitation (CPR). It is difficult to differentiate between a cardiac arrest precipitated by anesthesia and one that is spontaneous. The anesthetic agent itself promotes cardiovascular instability. Consideration should be given to the medical indications for the procedure with the goal of treatment to alleviate pain and morbidity and provide for the patient's comfort. The guiding principle in the decision to maintain or suspend DNR orders should be respect for the patient's autonomy. Elderly patients have the right to participate in the process for making end-of-life decisions.

As more procedures are performed, there are ways to assist perioperative nurses to prepare for the care of the elderly population:

- Educate staff members by reviewing the special needs of this age-group.
- Develop a separate process for preoperative assessment, and use multiple screens for evaluation of older patients.
- Improve communication and collaboration among healthcare providers.

Understanding the age-specific needs of the older surgical patient will be critical to successful outcomes for these patients. The 2004 Institute of Medicine (IOM) report *Keeping Patients Safe: Transforming the Work Environment of Nurses* highlighted the critical connection between patient safety and safe work environment (Spence-Laschinger and Leiter, 2006). The report determined that a safe and supportive nurses' work environment reduces threats to patient safety in healthcare organizations. Numerous studies summarized in the report have linked inadequate staffing to negative clinical outcomes, such as cardiac arrests, death, increased length of stay, pneumonia, postoperative infections, and pressure ulcers. The recommendations from the report were knowledge based and centered on the four basic components of all organizations:

1. Organizational management
2. Workforce deployment practices
3. Work design
4. Organizational culture (Beyea, 2004)

An organizational culture of safety must include a blame-free response to medical mistakes. Potential for errors must be recognized as opportunities to review process and policy to prevent future mistakes. Perioperative nurses have the responsibility to contribute to the creation of a culture of safety in the workplace to improve safety in the workplace for patients and nurses.

To ensure that older Americans receive high-quality, appropriate care, the Institute of Medicine recommends the following steps:

1. Enhance the competence of all healthcare personnel involved in the delivery of geriatric care instead of depending on specialists.
2. Provide stronger incentives to recruit and maintain geriatric practitioners.
3. Apply more flexible models of care to enable self-care for patients and informal caregivers (Institute of Medicine, 2008).

Future technical advances in surgery and anesthesia will continue to provide for beneficial surgery performed on older and older patients. The perioperative nurse who approaches the care of elders with this in mind not only will enhance the surgical outcome but also will significantly affect the patient's overall quality of life.

REFERENCES

Berger DH, Dardik A, Rosenthal R: Surgery in the elderly. In Townsend CM et al: *Sabiston textbook of surgery*, ed 18, Philadelphia, 2008, Saunders.

Beyea SC: A critical partnership—safety for nurses and patients, *AORN J* 79(6):1299–1302, 2004.

Burlingame B, Blanchard J: Bone cement implantation syndrome, *AORN J* 89(2):399–400, 2009.

Clayton JL: Special needs of older adults undergoing surgery, *AORN J* 87(3):557–570, 2008.

Denholm B: Tucking patient's arms and general positioning, *AORN J* 89(4):755–757, 2009.

Ebersole P et al: *Toward healthy aging: human needs and nursing response*, ed 7, St Louis, 2008, Mosby.

Faes MC et al: Dehydration in geriatrics. *Geriatr Aging* 10(9):590–596, 2007, posted to Medscape December 26, 2007, available at http://cme.medscape.com/viewarticle/567678-1. Accessed January 8, 2008.

Federal Interagency Forum on Aging-Related Statistics: *Older Americans 2004: key indicators of well-being.* Federal Interagency Forum on Aging-Related Statistics. Washington, DC, March 2008, U.S. Government Printing Office.

Ferris M: Pain in the cognitively impaired elderly: guidance for clinicians. *Adv Pract Nurse* eJournal posted May 15, 2008, available at www.medscape.com/viewarticle/573643. Accessed January 14, 2009.

Goldrick BA: Infection in the older adult, *Am J Nurs* 105(6):31–34, 2005.

Institute of Medicine: *Retooling for an aging America: building the health care workforce*. Washington, DC, 2008, The National Academies Press, available at www.iom.edu/CMS/3809/40113/53452.aspx. Accessed August 21, 2008.

Kim SS, Zenilman ME: The elderly surgical patient. In Souba W et al: *ACS surgery principles and practices*, ed 6, Ontario, Canada, 2007, BC Decker.

Men's Guide to Urinary Incontinence. Updated July 21, 2008, available at www.webmd.com/urinary-incontinence-oab/mens-guide/urinary-incontinence-in-men-surgery. Accessed April 13, 2009.

Murray CA: Interventions for clients with musculoskeletal problems. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care*, ed 6, St Louis, 2010, Saunders.

Rehman SU et al: Thyroid disorders in elderly patients, *South Med J* 98(5):543–549, 2005.

Robinson S et al: Aging and delirium: too much or too little pain medication, *Pain Manag Nurs* 9(2):66–72, 2008.

Schroeder K: Principles and applications. In Merriman JA et al: *Ethics in perioperative practice*, Denver, 2004, AORN, Inc.

Sieber FE, Pauldine R: Anesthesia and the elderly. In Miller RD, editor: *Miller's anesthesia*, ed 6, vol 2, Philadelphia, 2005, Churchill Livingstone.

Spence-Laschinger HK, Leiter MP: The impact of nursing work environments on patient safety outcomes: the mediating role of burnout engagement, *J Nurs Admin* 36(5):259–267, 2006.

Touhy TA: Cognition and caring for persons with cognitive impairment. In Ebersole P et al: *Toward healthy aging: human needs and nursing response*, ed 7, St Louis, 2008, Mosby.

Williams ME: *Physical diagnosis in elderly people*. Release date: March 23, 2005, available at www.medscape.com/viewprogram/3955. Accessed April 12, 2009.

Wold GH: *Basic geriatric nursing*, ed 4, St Louis, 2008, Mosby.

Women's Guide to Urinary Incontinence in Females. Updated September 17, 2008, available at www.webmd.com/urinary-incontinence-oab/womens-guide/urinary-incontinence-in-women-surgery. Accessed April 13, 2009.

Workman ML: Assessment of the eye and vision. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care*, ed 6, St Louis, 2010, Saunders.

Yachimski PS, Friedman LS: Gastrointestinal bleeding in the elderly, *Nat Clin Pract Gastroenterol Hepatol* 5(2):80–93, 2008.

CHAPTER 27

Trauma Surgery

DIANE CATHERINE SAULLO

Trauma is ranked as one of the foremost public health issues in the United States today. Unintentional injury related to trauma is the fifth leading cause of death today and the leading cause of death for persons aged 1 to 44 years (Barclay, 2009). Trauma is the leading nonobstetric cause of maternal mortality and is associated with fetal mortality directly related to the severity of maternal injury (Cusick and Tibbles, 2007). Whether the injury is a result of a motor vehicle collision, violence, crime, or work-related injury, trauma occurs unplanned and without warning. The unpredictable nature of trauma poses a major challenge to the perioperative nurse and the patient care team.

The potential for injury has existed since the beginning of humanity. Most of the major advances in care of critically injured patients have been accomplished through experience in the military. Clearly, the shorter the response time, the greater the survival rate for casualties. This was demonstrated by the success of the mobile army surgical hospitals (MASH) during the Korean conflict and again during the Vietnam conflict; MASH brought the necessary supplies, equipment, and personnel closer to the battlefields and, consequently, improved patient outcomes.

Eventually this concept was applied to the civilian population and is now commonly referred to as the "golden hour" of trauma care. More specifically, the golden hour refers to the time immediately after the injury when rapid and definitive interventions can be most effective in the reduction of morbidity and mortality. The golden hour starts at the scene, where prehospital personnel determine the severity of injury, initiate medical treatment, and identify the most appropriate facility to which to transport the patient. Traumatic deaths may occur in three phases, or time frames. The first occurs immediately after the injury. This accounts for approximately 50% of the deaths from trauma and is usually a result of lacerations to the heart or aorta or brainstem injury. These patients rarely survive transport to the hospital and die at the scene. The second phase occurs within the first 1 to 2 hours after the injury, representing approximately 30% of total fatalities. These patients have injuries to the spleen, liver, lung, or other organs that result in significant blood loss. This is the group in which definitive trauma care (i.e., appropriate and aggressive resuscitation with adequate volume replacement) may have the most significant effect (the golden hour). The third phase occurs days to weeks after the injury, often during the intensive care phase, and is usually caused by complications or a failure of multiple organ systems.

The wars in Iraq and Afghanistan have resulted in some changes in the way traumatic injuries are managed; the military has not set up convalescence centers as in Vietnam and Desert Storm. Rather, the doctrine of "essential care in theater" is followed. Physicians and nurses have been trained to provide immediate care, keeping in mind the treatment resources that will be available at the next level of care. Soldiers with upper body injuries are surviving because of body armor. However, there is no protection for upper extremities; therefore there are many amputations being performed, including above-elbow and shoulder disarticulations. The new philosophy is to stress continuity of care with the goal of returning the soldier to the highest possible level of function.

Time is of the essence in providing definitive care to the critically injured person. A significant number of patient deaths can be prevented if rapid transport is provided from the scene to a facility equipped to provide resuscitation and treatment in an efficient and timely manner. This concept is reflected in the national development of the Emergency Medical Services (EMS) system. Facilities and resources are allocated and coordinated to provide specific interventions for a group of patients. For example, facilities that meet certain criteria to accommodate the specialized needs of the critically injured patient are designated as *trauma centers*. Communities establish transfer and triage protocols that allow for a trauma patient to reach the appropriate facility with the least out-of-hospital time possible. This may be accomplished by a helicopter with a specially trained flight crew or by the use of ground transport with an Advanced Life Support (ALS) ambulance team (Figure 27-1).

Trauma centers (TC) are classified based on the scope of services and resources that are available. A level I TC is capable of providing total care for every type of injury. Accepting this designation commits the TC to providing qualified personnel and equipment necessary for rapid diagnosis and treatment on a 24-hour basis. A level II TC provides comprehensive care for all injuries but lacks some of the specialized clinicians and resources required for the level I designation. A level II facility may provide surgical intervention if the critical nature of the injury dictates immediate intervention before transfer to a level I facility. A level III facility provides prompt evaluation, resuscitation, emergency surgery, and stabilization, as needed, before transfer to a higher-level facility. The American College of Surgeons (ACS) recommends that in level II and III centers, an OR team is readily available at all times. Depending on the population served and the volume of urgent cases, this requirement may be met with on-call staff. A level IV trauma center has the ability to provide advanced trauma life support before patient transfer. These facilities may be located in rural areas with limited access and may be a clinic or a hospital.

Although the risk for death is 25% lower for a severe injury treated in a level I TC (Barclay, 2009), not all patients

require the services of a level I TC and so may be transported to the closest emergency department for care. New guidelines and recommendations for triage, first developed as a position statement by the ACS in 1986, have been published (Barclay, 2009). Known as the "Decision Scheme," this algorithm guides EMS personnel through the following four decision points: physiologic parameters, anatomic parameters, mechanism of injury (MOI), and other special considerations. Personnel review physiologic parameters. Patients with a Glasgow Coma Scale score less than 14, systolic blood pressure less than 90 mm Hg, or respiratory rate less than 10 breaths per minute or greater than 29 breaths per minute should be transported to the highest level facility available. The anatomic parameters include specific types of injuries, such as penetrating injuries of the neck or torso, flail chest, or proximal long bone fracture; these patients are also transported to the highest level facility available. The MOI and other special considerations, such as age or prior medical history, are also reviewed to determine to what level facility the patient is transported (History box).

Trauma patients require immediate access to the OR 24 hours per day, 365 days per year. A sudden influx of a large

FIGURE 27-1 New Hanover Health Network EMS Air Link rescue at the beach.

HISTORY

Triage Development

The origin of the term "triage" is sketchy but the earliest use was seen in the late 1700s and is attributed to Baron Dominique Jean Larrey. He said, "Those who are dangerously wounded should receive the first attention, without regard to rank or distinction."

Triage was further developed during the Civil War. The injured were separated into immediate treatment versus delayed treatment versus no treatment. Amputation was the most common life-saving procedure performed; gunshot wounds to the abdomen were often ignored because of high mortality and lack of resources. A more formal triage system was developed in World War I and was advanced in World War II. Air-medical transport was first used in the Korean War.

Field triage criteria for civilian injuries refer to the decisions of prehospital personnel about where to transport the injured. Before the 1970s the injured were simply transported to the nearest facility with little prehospital intervention. In 1976 the American College of Surgeons (ACS) established the designation of "trauma centers" and set standards of personnel, facility, and processes to provide optimal care of the injured. Prehospital triage in the 1970s and early 1980s was based on anatomic, physiologic, and mechanistic domains. The establishment of specialized trauma centers led to one of the first triage protocols for trauma patients in 1987, developed by the ACS and know as the *Optimal Resources' Guide*.

With the establishment of both specialized trauma centers and triage guidelines, the problems of overtriage and undertriage became evident, which included diagnostic and treatment delays or errors, increased morbidity and mortality, and missed injuries. In 1990 the ACS revised the field triage decision scheme to include, among other things, use of the Revised and Pediatric Trauma Scores. The 1990 revisions included mechanism of injury criteria related to vehicular deformity and motorcycle criteria and established a four-step versus the previous three-step process. The dictum of the ACS guidelines became, "when in doubt take to a trauma center." The guidelines were revised in 1993 and included changes in the Glasgow Coma Scale and the addition of automobile-bicycle collision criteria; the 1999 revisions changed the triage process within the trauma system so patients who met specific physiologic or anatomic criteria were taken to the highest level of care available.

Opportunities for further development of triage criteria include:

- Standardization of the criteria used to define overtriage and undertriage
- Improved balance between transport distance and severity of injury
- Incorporation of automated vehicular telemetry information to determine severity of injury

Modified from Mackersie RC: History of trauma field triage development and the American College of Surgeons criteria, *Prehosp Emerg Care* 10(3):287-294, 2006.

number of trauma patients to a trauma center may necessitate triage or classification of those less seriously injured as less urgent, allowing immediate access for the critically injured patients. The elective surgery schedule may need to be interrupted to expedite care for the trauma patient or patients. Scheduling policies and procedures are established collaboratively by the departments of surgery, trauma, anesthesia, and perioperative nursing services. Consequently, the perioperative nurse and surgical technologist need to be familiar with supplies and equipment located in the OR designated for trauma or in the ORs that are used most frequently for these patients.

Perioperative Nursing Considerations

Preliminary Evaluation: Mechanism of Injury

Because of the unpredictable timing of trauma, it is often the on-call perioperative nursing team who cares for injured patients requiring surgical intervention. In contrast to an elective surgical procedure, little information may be known about trauma patients and preparation time is often abbreviated. A working knowledge of the MOI is essential to assist the perioperative nurse in rapid patient assessment.

MOI, or kinematics, involves the action of forces on the human body and their effects. Knowing the forces applied provides valuable information in evaluation of the patient and injuries that may be present. The first EMS team to respond to the scene of an injury must carefully evaluate the patient in relation to the MOI. For example, the position of the victim in a car, whether the person was the driver or a passenger seated in the back seat or front seat, estimated velocity of the vehicle, location of impact, and use of a seat belt or air bag are all pieces of information used to determine the index of suspicion about the probable causes of injuries to the patient. After immediate threats to life are addressed, the MOI can provide valuable clues as to probable cause of injuries. This systematic approach can reduce morbidity and mortality (Table 27-1).

The MOI is a product of the type of injuring force and the resulting tissue response. The velocity of the collision, the shape of the object, and the tissue's flexibility influence the magnitude of the injury sustained. For example, long bone tissue has little or no flexibility. A strong collision involving a long bone most often results in a fracture of some type. In contrast, soft tissue injury from a colliding force may result in a contusion, since this tissue has greater flexibility.

Blunt trauma is injury resulting from a combination of forces, such as acceleration, deceleration, shearing, and compression, that do not result in a break of the skin. Morbidity and mortality may be greater than with penetrating trauma because identification of injuries is more difficult when injuries are less obvious. Causes of blunt trauma include motor vehicle collisions (MVCs), contact sports injuries, aggravated assault, and falls. Even low-energy trauma, such as that associated with low-level falls, can produce significant injuries.

TABLE 27-1

Biomechanics in Trauma

Mechanisms of Injury	Phases of Injury
	Examples
Vehicle of transfer of energy from environment to human host	Falls Motor vehicle crashes Bullets Stabbing instruments Blasts/bombs
	External Forces
DECELERATION FORCES	
Decrease in speed of a moving object or person	Victim strikes steering column Victim impacts ground
ACCELERATION FORCES	
Increase in speed of a moving object or person	Pedestrian thrown when struck by moving vehicle
BLAST FORCES	
Heat, light, pressure Low- and high-velocity missiles	Bomb explosion Bullets Stabbing instruments
	Internal Forces
Human body's response to kinetic energy load	Stress Cells separate, stretch, compress, or shear Strain Tissue damage or deformation from stress
	Types of Injuries
Describing for clinical and diagnostic purpose	Blunt vs penetrating Closed vs. open Primary vs secondary Direct vs. indirect

Modified from Emergency Nurses Association (ENA): *Trauma nursing core course,* ed 6, Des Plaines, Ill, 2007, Author.

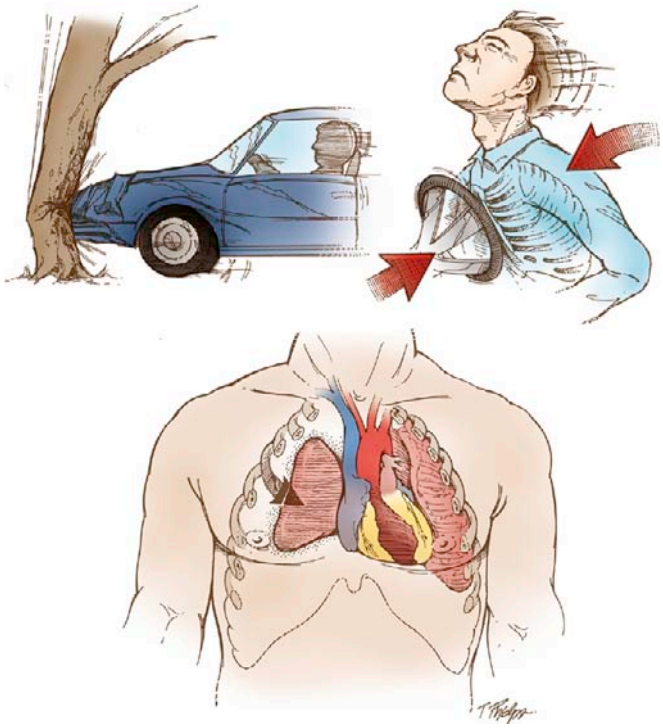


FIGURE 27-2 The three collisions of a head-on motor vehicle crash: the car hits an object; the occupant's body impacts on some surface within the motor vehicle; and the result is a collision between internal tissues and the rigid body surface structures.

Acceleration and deceleration injuries occur most frequently in blunt trauma. A ruptured thoracic aorta is an example of an injury that occurs as a result of these types of forces. In an MVC the large vessels are stopped or decelerated rapidly, resulting in vessel damage caused by stretching that exceeds the vessel's elastic ability. This affects the aorta at the ligamentum arteriosum, the anatomic point where it is affixed tightly to the chest wall, just below the origin of the subclavian artery. This shearing below the attachment site causes a rupture as the aorta continues to move in a forward motion after the chest wall motion has stopped.

MVCs account for a high degree of blunt trauma. During an MVC, actually three collisions occur (Figure 27-2). The first collision is that of a car into another object. The second collision is the impact of the occupant's body on the vehicle's interior. The third collision occurs when an internal body structure hits a rigid bony surface. A coup-contrecoup injury of the brain, for example, is the result of an acceleration force to one area of the brain and a deceleration force to an opposite area. Front and side air bag deployment along with the use of seat belts can decrease the severity of traumatic injury (Research Highlight).

Falls also cause a significant number of traumatic deaths in the United States. Injuries are most commonly associated with children experiencing falls more than twice their height. In adults, falls more than 10 to 15 feet are usually accompanied by significant injury. Deceleration forces in falls produce forces of stretching, shearing, and compression. Consequently, aortic injuries are also suspect in this group of patients. Skeletal injuries occur as well, because of the compressive forces present.

RESEARCH HIGHLIGHT

Impact of Airbags

Seat belts were introduced in motor vehicles more than 40 years ago and have been refined during that time. After mandatory use legislation, seat belt use increased and there was an associated decrease in crash fatalities by up to 50%. Today, it is clear that seat belts reduce injuries and save lives.

Airbag use has increased in the last 15 years, and while published data are limited, indications are that airbags are associated with less severe injury (based on a study of second-generation depowered airbags). One study showed an almost 50% decrease in injuries to the brain, face, and cervical spine. Another study demonstrated that airbags alone were associated with a decrease in fatalities; a combination of airbags and seat belts had a greater protective effect. Other studies concluded that airbags are associated with an increase in extremity injury and are more effective at higher speeds.

Using the trauma registry, the authors conducted a study looking at motor vehicle collision victims admitted over an 11-year period, for a total of 14,390 patients. The patients were divided into four groups: unrestrained (n = 7881), airbag only (n = 692), seat belt only (n = 4909), or airbag and seat belt (n = 908). Although separate use of airbags and seat belt was associated with reduced injury, a larger association was seen when both airbags and seat belts were used. The conclusion states that seat belts, with or without airbags, are associated with decreased in-hospital mortality and a change in injury pattern, as well as reduced injury severity and hospital resource use.

From Williams RF et al: Impact of airbags on a level 1 trauma center: injury patterns, infectious morbidity, and hospital costs, *J Am Coll Surg* 206(5):962-969, 2008.

Penetrating trauma is a result of the passage of a foreign object through tissue. The degree or extent of tissue injury is a function of the energy that is dissipated to the tissue and the surrounding areas. The anatomic structures most often injured include the liver, intestines, and vascular system. The extent of the injury relates to the nature of the foreign object (e.g., bullet caliber, knife size), distance from the weapon, structures penetrated, and amount of energy dissipated to the structures.

The velocity of a bullet is responsible for the degree of injury or cavitation to the tissue. A low-velocity bullet is one that travels at a lower speed (1000 feet per second or less) and disrupts only the bullet tract and its immediate surrounding area. A high-velocity weapon, such as used by the military, fires a bullet traveling at a greater speed (3000 feet or more per second) and causes significantly more damage and tissue destruction, since the bullet tract involves more extensive surrounding tissue (Figure 27-3). The distance from the weapon also influences the degree of injury because the velocity is greatest when the bullet leaves the weapon and decreases as it travels. In addition, the type of bullet (e.g., shotgun shells with multiple pellets and hollow-point bullets, which mushroom on impact) influences the degree of injury. Commonly the entrance wound is smaller than the exit wound because of the dissipation of energy, but an exit wound may not always be present. If the bullet completely fragments or is lodged in an internal structure, there will not be an exit wound. Depending on the position of the bullet and any injury that could be caused by attempting to remove it, bullets are not always removed.

Stab and impalement wounds are considered to be low-velocity wounds. The associated injuries usually correspond to the path of the penetrating object. Factors such as the object's width and length assist in identification of the possible occurrence of injuries. A single injury site may penetrate several different organs or cavities. Penetrating injuries located at or below the nipple line may cause both chest and abdominal injuries. This is attributable to the diaphragmatic excursion that occurs with inspiration and expiration. Impaled objects should not be removed at the scene or in the emergency department (ED). The impaled object provides a tamponade effect to injured blood vessels and is removed only when the ability to control potential bleeding from those vessels is present. Wound debridement may also be necessary. Therefore these objects are removed in the OR, where the needed supplies and instrumentation are located.

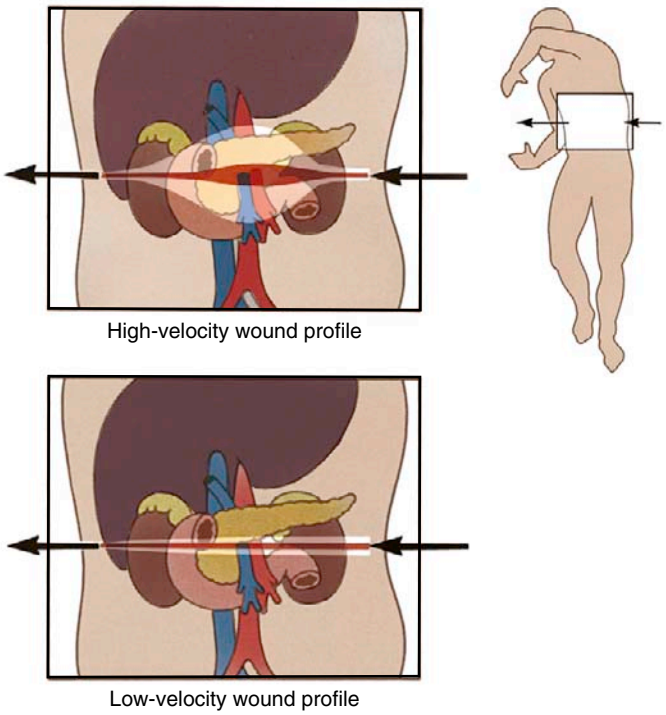


FIGURE 27-3 Potential injury path of high- and low-velocity bullets.

Injuries that result from explosions are related to the effects of the blast. With the threat of domestic terrorism on the rise, the treatment of blast victims may become more frequent in trauma settings. Blast trauma inflicts injuries in a number of ways. Primary blast injury is the result of a direct pressure wave on the body. Secondary injury is associated with the impact of debris and fragments energized by the blast, which act like high-velocity missiles. Tertiary injuries result from the blast wind, since air is accelerated and may cause traumatic amputations or limb or skull fractures (Born, 2005). The type of injury sustained and its intensity are directly related to factors such as the size of the blast and the proximity of the victim or victims. Patients from a blast explosion may present with penetrating injury, contusions, lacerations, amputations, abrasions, avulsions, evisceration, and various degrees of burns (Table 27-2).

Thermal and electrical tissue damage and inhalation injuries may occur from an explosion or as a sole mechanism of injury. These patients are usually resuscitated and require operative intervention for debridement on a nonemergent basis, unless the injury is limb- or life-threatening.

Injuries can be scored objectively according to their severity. This scoring system assists medical personnel in more effective triage and provides a universal method of communication among facilities, departments, and nursing personnel. According to Barclay (2009), the ACS guidelines, as published by the National Expert Panel on Field Triage, now recommend the use of the Decision Scheme (Table 27-3).

Assessment

The resuscitative process begins with arrival of emergency personnel on the scene and ends when the patient has been stabilized, received definitive care, and undergone a complete

TABLE 27-2

Mechanisms of Blast Injuries

Category	Areas Affected	Types of Injuries
Primary: Caused by blast itself	Gas-filled organs most susceptible:	
	◆ Eye	Rupture of globe
	◆ Middle ear/tympanic membrane	Rupture and permanent deafness possible
	◆ Lungs	Pneumothorax, alveolar rupture, air embolus
	◆ GI tract	Abdominal hemorrhage, contusions, rupture
	◆ Central nervous system	Diffuse cerebral hemorrhage, cerebral air embolism, concussion syndrome (injury without physical signs)
Secondary: Caused by debris and projectiles	Any body part	Varies depending on size of projectiles: penetrating or blunt injury
Tertiary: Caused by victim being thrown against stationary objects	Any body part	Similar to those seen in motor vehicle crashes: fractures, traumatic amputations, closed/open brain injury
Quaternary: Exacerbation or complications of existing conditions	Any body part	Burns, crush injuries, inhalation of dust or toxic gases causing exacerbation of asthma or COPD, angina

Modified from Emergency Nurses Association (ENA): *Trauma nursing core course,* ed 6, Des Plaines, Ill, 2007, Author.

and thorough physical examination to determine all injuries sustained. When the patient arrives in the ED, the trauma team initiates a primary assessment. This is a logical, orderly process of patient assessment for potential life threats. These assessment activities are based on established protocols for advanced trauma life support (ATLS). The mnemonic "ABCDE" is used, representing assessment of the following:

- ***A***irway (with cervical spine precautions)
- ***B***reathing
- ***C***irculation
- ***D***isability (brief neurologic examination)
- ***E***xposure (to reveal all life-threatening injuries) and ***e***nvironmental control (thermoregulation)

Airway interventions may include manual maneuvers (chin-lift, jaw-thrust), insertion of oral or nasopharyngeal airways, or intubation. The trauma team may also perform emergent procedures, such as tracheotomy or needle cricothyrotomy, to secure the patient's airway. Pulse oximetry and capnography monitoring are used. If cervical spine precautions were not implemented before arrival at the hospital, the team initiates them before performing any other procedures on the patient. A trauma team member can stabilize the head and neck, if necessary, until a cervical collar is placed. Once placed, the team does not remove it until a cervical radiograph clears the neck of injury.

During this time, the surgeon or ED physician and trauma team identify and correct life threats that are present before progressing to the next part of the examination. A patient requiring immediate surgery is transported to the OR, undergoes surgical intervention, and then is transferred to the postanesthesia care unit (PACU) or intensive care unit (ICU), depending on his or her condition. On the other hand, a patient may have a penetrating wound with evisceration of abdominal contents. However, correcting the obvious defect, which is currently not life-threatening, is postponed until the trauma team is assured that the patient has a patent airway and an effective breathing pattern and cervical spine precautions have been implemented. An evisceration needs to be corrected, but an inadequate airway is an immediate life threat and assumes priority.

Depending on the patient's injury, the surgeon may order an arterial blood gas (ABG) measurement. This test provides an accurate assessment of the ventilatory status of the patient and also evaluates resuscitative airway and breathing interventions (Table 27-4). Metabolic acidosis or a large base deficit (pH <7.35 or >7.45), with all other causes ruled out, may indicate internal bleeding.

After the trauma team completes the primary assessment and corrects any immediate life threats, they perform a secondary assessment. The purpose of the secondary assessment is to identify all injuries present. Sometimes the secondary assessment may be completed by the perioperative nurse, the PACU nurse, or the critical care nurse. This assessment is a more in-depth, head-to-toe evaluation of the patient. Inspection, palpation, percussion, and auscultation are used in the complete head-to-toe assessment to reveal any deformities, open injuries, tenderness, or swelling. The assessment begins at the head and face and then moves to the neck (including the spine), the chest, the abdomen, and the pelvis. The four extremities are next; distal pulses, motor function, and sensation are assessed. The final check is the back; the patient is carefully log-rolled to the side for a full visual and tactile assessment (Evidence for Practice).

The patient's vital signs, including a rectal or tympanic temperature, unless contraindicated, are obtained. Often during resuscitation, the nurse will insert a Foley catheter to monitor urine output and fluid resuscitation efforts. The nurse should inspect the urinary meatus for the presence of blood before inserting the catheter. If blood is noted, the nurse notifies the

TABLE 27-3

Decision Scheme Recommendations*

Steps	Transition	Recommendations
Step 1		Transport to TC for any of the following: GCS <14, systolic BP <90 mm Hg, respiratory rate <10 or >29 breaths/min
	1 to 2	These patients have potentially serious injuries and should be transported to highest level TC available
Step 2		Transport to TC for any of the following: penetrating injuries of head, neck, torso, and extremities proximal to elbow and knee; flail chest; 2 or more proximal long bone fractures; crushed, degloved, or mangled extremity; amputation proximal to wrist and ankle; pelvic fracture; open or depressed skull fracture; paralysis
	2 to 3	If yes to any criteria, transport to highest level TC available; if patient does not meet step 2 criteria, proceed to step 3
Step 3		Transport to TC for any of the following: falls >20 feet for adults, >10 feet or 2-3 times child's height; motor vehicle crash with partial or complete ejection of occupant; auto vs pedestrian/bicyclist thrown; motorcycle crash at speed >20 mph
	3 to 4	If yes to any criteria, transport to closest TC
Step 4		Consider transport to TC for the following: age >55 or <15, anticoagulation and bleeding disorders, burns, time-sensitive extremity injury, end-stage renal disease requiring dialysis, pregnancy, or provider judgment

*The Decision Scheme is an essential component of the trauma system, guiding EMS providers in transporting injured patients to the most appropriate facility, ensuring proper treatment, and thus reducing death and disability.

BP, Blood pressure; *GCS,* Glasgow Coma Scale; *TC,* trauma center.

Modified from Barclay L: *Guidelines issued for field triage of injured patients,* Medscape Medical News, 2009, available at www.medscape.com/viewarticle/587447. Accessed February 16, 2009.

TABLE 27-4

Laboratory Values: Arterial Blood Gases (ABGs)

NORMAL VALUES		
Pao_2	Pressure of oxygen in arterial blood	80-100 mm Hg
$Paco_2$	Pressure of carbon dioxide in arterial blood; measurement of how well lungs are discarding carbon dioxide (CO_2 level is controlled by lungs)	34-45 mm Hg
pH	Acidity or alkalinity of arterial blood; measurement of hydrogen ion concentration	7.35-7.45
HCO_3^-	Amount of bicarbonate in arterial blood; controlled by kidneys	21-28 mEq/L
O_2 saturation	Percentage of hemoglobin that is carrying oxygen	95-100%
ABNORMAL VALUES		**POSSIBLE CAUSE**
Pao_2	<50 mm Hg	Hypoxia
$Paco_2$	>45 mm Hg	Hypoventilation/CO_2 retention by lungs
pH	<7.35	Acidosis
	>7.45	Alkalosis
HCO_3^-	<22 mEq/L	Renal excretion of too much bicarbonate
	>26 mEq/L	Renal retention of too much bicarbonate

Modified from Pagana KD, Pagana TJ: *Mosby's diagnostic and laboratory test references,* ed 9, St Louis, 2009, Mosby.

EVIDENCE FOR PRACTICE

Assessing Neurovascular Status in Patients with Musculoskeletal Trauma

Trauma patients frequently present to the OR with fractures or other musculoskeletal injuries. A thorough assessment of the patient's neurovascular status is imperative to establish a baseline for nursing and surgical interventions.

ASSESSMENT TECHNIQUE	NORMAL FINDINGS
SKIN COLOR	
Inspect the skin distal to the injury.	There is no change in pigmentation compared with other parts of the body.
SKIN TEMPERATURE	
Palpate the area distal to the injury (the dorsum of the hands is the most sensitive to temperature).	The skin is warm.
MOVEMENT	
Ask the patient to move the affected area or the area distal to the injury (active motion).	The patient can move without discomfort.
Move the area distal to the injury (passive motion).	There is no difference in comfort compared with active movement.
SENSATION	
Ask the patient if numbness or tingling is present (paresthesia).	There is no numbness or tingling.
Palpate with a paper clip (especially in the web space between the first and second toes or the web space between the thumb and forefinger).	There is no difference in sensation in the affected and unaffected extremities. (Loss of sensation in these areas indicates perineal nerve or median nerve damage.)
PULSES	
Palpate the pulses distal to the injury.	Pulses are strong and easily palpated; there is no difference between the affected and unaffected extremities.
CAPILLARY REFILL (LEAST RELIABLE)	
Press the nailbeds distal to the injury until blanching occurs (or the skin near the nail if nails are thick and brittle).	Blood return (to usual color) is within 3 sec (5 sec for older people).
PAIN	
Ask the patient about the location, nature, and frequency of the pain.	Pain is usually localized and is often described as stabbing or throbbing. (Pain out of proportion to the injury and unrelieved by analgesics may indicate compartment syndrome.)

Modified from Murray CA: Interventions for clients with musculoskeletal trauma. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care,* ed 6, St Louis, 2010, Saunders.

BOX 27-1

Laboratory Values: Urinalysis (UA)*

NORMAL VALUES		ABNORMAL VALUES		In Trauma, May Indicate
Color	Amber yellow	Color	Dark or red	Presence of blood
Appearance	Clear	Appearance	Dark or red	Presence of blood
Specific gravity	1.005-1.030	Specific gravity	>1.030	Fluid volume deficit
pH	4.6-8.0	pH	Alkaline: >8.0	Alkalosis
Protein	Negative		Acidic: <4.6	Acidosis
Glucose	Negative	Glucose	Present	Diabetes
Ketones	Negative			Increased intracranial pressure
Microscopic findings		Protein	Present	Renal failure
◆ RBCs	0-2/high-power field (hpf)	Ketones	Present	Diabetes
◆ WBCs	0-4/hpf			Diarrhea and vomiting
◆ Epithelial cells	Few	Microscopic findings		
◆ Casts	0	◆ RBCs	>3/hpf	Kidney, ureteral, bladder trauma
◆ Crystals	0	◆ WBCs	>4/hpf	Urinary tract infection
◆ Bacteria	0	◆ Epithelial cells	↑	Renal tubular necrosis
◆ Yeast	0	◆ Casts	↑	Glomerular capsule trauma
		◆ Bacteria		Abnormalities not usually seen in early trauma

*A urinalysis is done to check for injury to the genitourinary system and for the presence of specific diseases.
Modified from Pagana KD, Pagana TJ: *Mosby's diagnostic and laboratory test references,* ed 9, St Louis, 2009, Mosby.

surgeon and does not insert the catheter. The patient may have a ruptured bladder or a urethral injury, either of which is commonly associated with a fracture of the pelvis. The surgeon may wish to perform a retrograde urethrogram to examine the bladder and urethra for the presence of tears or disruption. After catheter insertion, urine is obtained for a urinalysis and urine drug screen. The identification of specific drugs in the urine may assist in further diagnosis and treatment. The urine will also be tested to determine the presence of red blood cells (RBCs) (Box 27-1). Depending on the amount of hematuria present, a renal contusion or other renal injury may be present. In addition, a nasogastric tube may be inserted at this time.

The nurse obtains a brief history from the family or significant others when possible. This history is referred to as the "AMPLE" history and may be obtained even after the patient is transferred to the OR by the ED personnel. The history includes the following:

- ***A***llergies
- ***M***edications
- ***P***ast medical history
- ***L***ast meal, ***l***ast menstrual period (if appropriate)
- ***E***vents or ***e***nvironment leading to the accident or injury

If the history is obtained after the initiation of surgery, it is important to communicate it to the surgeon and the anesthesia providers.

Routine Laboratory Tests. Laboratory values aid the trauma team in evaluating the patient's status. Appropriate laboratory tests include a minimum of a complete blood count (CBC), hemoglobin and hematocrit (H&H) value, blood alcohol level (BAL), and a blood type and screen; other tests may be requested during evaluation. The results of the laboratory studies should be reviewed and communicated as appropriate (Box 27-2). An abnormal level of RBCs may signify dehydration, hypovolemia, or fluid overload (dilutional). An elevated white blood cell (WBC) count, indicating the presence of infection, may be related to inflammation, tissue necrosis, or immunocompromise. H&H values are also important to note. Caution is advised in evaluating an H&H drawn in the ED. The time delay between bleeding and a drop in the H&H value can be significant. It is only after hemodilution occurs (from shock compensation or crystalloid replacement) that hematocrit level drops. Frequently, abnormal values in the patient with blunt trauma alert the team to the possibility of internal bleeding.

BAL also assists the trauma team in their evaluation. If the patient's level is significantly high, the physical examination and response may be unreliable. In addition, the neurologic status of patients with high BALs is very difficult to assess. Abnormal clotting studies are of obvious significance in trauma patients. These results may be attributable to anticoagulant medication the patient is taking or the effects of profound hypothermia. Clotting times may also be prolonged in the presence of excessive alcohol ingestion or the use of anabolic steroids. Clotting times may decrease with the use of antihistamines and diuretics.

A blood type and screen shortens the time needed by the blood bank to obtain a crossmatch, if needed later. Most trauma centers have several units of type O–negative blood (universal donor) available in the event that a blood transfusion is required before a type and crossmatch (T&C) can be performed. Because of regional shortages of O-negative blood, O-positive blood can be used in male patients and adult female patients of non-childbearing age. Initially, trauma patients are fluid-resuscitated with warmed crystalloid solutions, such as lactated Ringer's solution or normal saline solution. If the patient's blood pressure responds, the diagnostic examination continues. However, if the hypotension returns, blood transfusions may be initiated and the patient may be transported immediately to the OR for exploratory surgery.

BOX 27-2

Laboratory Values: Blood and Serum Electrolytes

RED BLOOD CELLS (ERYTHROCYTES)

RBC values vary, depending on age, gender, and geographic location (in relation to sea level) of the patient.

Normal Values

Children	
Newborn	4.8-7.1 million/μl
2-8 wk	4-6 million/μl
2-6 mo	3.5-5.5 million/μl
6-12 mo	3.5-5.2 million/μl
1-6 yr	4-5.5 million/μl
6-18 yr	4-5.5 million/μl
Adults/Elderly	
Male	4.7-6.1 million/μl
Female	4.2-5.4 million/μl
Pregnant female	Decreased

Abnormal Value	Probable Cause
↑	Dehydration
↓	Hypovolemia
	Fluid overload (dilutional)

WHITE BLOOD CELLS (LEUKOCYTES)

A WBC count is obtained to identify the presence of an infection.

Normal Value

5000-10,000/μl (elevated in pregnancy)

Abnormal Value	Probable Cause
>10,900/μl	Infection/inflammation
	Tissue necrosis
	Immunocompromise

HEMATOCRIT (HCT)

A hematocrit value is obtained to determine the percentage of RBCs in whole blood.

Normal Values

Children	
Newborn	44%-64%
2-8 wk	39%-59%
2-6 mo	35%-50%
6-12 mo	29%-43%
1-6 yr	30%-40%
6-18 yr	3%-44%
Adult	
Male	42%-52%
Female	37%-47%
Pregnant female	>33%

Abnormal Values in Trauma	
↓	Hemodilution ◆ From compensated hypovolemia ◆ From excessive volume replacement
↑	Hemoconcentration

NOTE: When blood is lost acutely, the amount of hematocrit lost is in the same ratio as that of whole blood. Therefore the percentage of hematocrit in a whole blood sample would remain normal. It is only after hemodilution occurs (from shock compensation or crystalloid replacement) that the hematocrit value drops.

HEMOGLOBIN (HGB)

A hemoglobin value is obtained to measure the amount of hemoglobin in whole blood. The amount of hemoglobin determines the oxygen-carrying capacity of blood.

Normal Values

Children	
Newborn	14-24 g/dl
0-2 wk	12-20 g/dl
2-6 mo	10-17 g/dl
1-6 yr	9.5-14 g/dl
Adult	
Male	14-18 g/dl
Female	12-16 g/dl
Pregnant female	>11 g/dl
Elderly	Values slightly decreased

NOTE: When whole blood is lost acutely, the amount of hemoglobin that is lost is proportionate. It is only after hemodilution occurs (as a result of shock compensation or crystalloid volume replacement) that hemoglobin level drops.

PLATELETS (THROMBOCYTES)

A platelet count is obtained to test the amount of platelet function. Platelets play an essential role in coagulation. Particularly in vascular trauma, platelets are essential to hemostasis.

Normal Values

Newborn	150,000-300,000/μl
Infant	200,000-475,000/μl
Child	150,000-400,000/μl
Adult/elderly	150,000-400,000/μl

Abnormal Values	Probable Cause
↑	Splenectomy
	Living at high altitude
	Hemorrhage
↓	Disseminated intravascular coagulation

COAGULATION STUDIES: PROTHROMBIN TIME (PT, PRO TIME)

A prothrombin time is evaluated in trauma patients to measure clotting time (caused by factors I [fibrinogen], II [prothrombin], V, VII, and X). This is important in determining the blood's ability to clot.

Normal Value

11.0-12.5 sec

Abnormal Value	Probable Cause
↑	Deficiency of factors I (fibrinogen), II (prothrombin), V, VII, and X; 2.5× normal values means that there is a bleeding tendency.

NOTE: Clotting times may be prolonged in the presence of excessive alcohol ingestion or the use of anabolic steroids. Clotting times may decrease with the use of antihistamines and diuretics.

BOX 27-2

Laboratory Values: Blood and Serum Electrolytes—cont'd

COAGULATION STUDIES: ACTIVATED PARTIAL THROMBOPLASTIN TIME (APTT)

An APTT is obtained to screen for problems with intrinsic clotting factors (except factors VII and XIII). It can be used also to monitor the effectiveness of anticoagulation with heparin. This laboratory test measures the amount of time it takes for fibrin to form a clot. In the trauma patient it is used to determine the patient's tendency to bleed.

Normal Value

30-40 sec for the clot to form (after the clinical reagent is added)

Abnormal Value in Trauma	Possible Cause
>40 sec	Intrinsic factor deficiency

NOTE: Be sure to fill the laboratory tube completely because the tube contains anticoagulant and the ratio of blood to anticoagulant may be altered if the tube is not filled correctly, causing an inaccurate prolonged clotting time.

SERUM ELECTROLYTES: SODIUM (Na^+)

Sodium is one of the two major extracellular cations. It is the major cause of osmotic pressure in extracellular fluid. Sodium also plays a major part in both acid-base balance and neuromuscular function.

Normal Value

136-145 mEq/L

Abnormal Values	Possible Cause
>145 mEq/L (hypernatremia)	↓ Fluid intake/fluid loss ↑ Sodium intake
>136 mEq/L	↓ Sodium intake ↑ Sodium loss

SERUM ELECTROLYTES: POTASSIUM (K^+)

Because potassium is one of the two major cellular cations, it is essential for the maintenance of cellular osmosis. It plays a major role in the electrical conductivity of both cardiac and skeletal muscle. In addition, potassium plays a major role in both acid-base balance and kidney function.

Normal Value

3.5-5 mEq/L

Abnormal Values	Possible Cause
>5 mEq/L (hyperkalemia)	Major burns Renal failure Major crush injuries
<3.5 mEq/L (hypokalemia)	Hypovolemia

SERUM ELECTROLYTES: CHLORIDE (Cl^-)

Measurement of serum chloride concentration is important for the assessment of acid-base status. Chloride is a major extracellular anion that plays a role in the maintenance of oncotic pressure and thus blood volume and arterial pressure.

Normal Value

98-106 mEq/L

Abnormal Values	Possible Cause
>106 mEq/L (hyperchloremia)	Dehydration Renal failure Central nervous system (CNS) trauma with central neurogenic breathing
<98 mEq/L (hypochloremia)	Excess vomiting Excess gastric suctioning

Modified from Pagana KD, Pagana TJ: *Mosby's diagnostic and laboratory test references,* ed 9, St Louis, 2009, Mosby.

Many trauma centers are implementing massive transfusion policies (MTP) for the clinical management of patients experiencing massive hemorrhage and to coordinate interdisciplinary and interdepartmental resources. Nessen and colleagues (2008) define massive transfusion as the replacement of one or more blood volumes within a 24-hour period, or 50% of estimated blood volume in 3 hours or less. This volume is approximately equal to the transfusion of 10 units of red blood cells (RBCs). Current research (Malone et al, 2006) suggests that improved patient outcomes are associated with the use of packed RBC/plasma/platelet ratios of 1:1:1. This simple ratio not only is easy to use but also has the benefit of administration of higher plasma and platelet volumes.

Diagnostic Procedures

RADIOLOGY. Depending on the trauma center protocol, a blunt trauma radiographic series may be part of the resuscitative phase. This minimally includes a lateral view of the cervical spine and an anteroposterior (AP) view of the chest. In addition, the patient also undergoes lateral thoracic and lumbar spine films and an AP view of the pelvis. Any area with deformity, swelling, or pain may also be examined by x-ray. Trauma patients are always treated as if they have a cervical spine injury until proven otherwise. When reviewing the cervical spine films for cervical spine injury clearance, the clinician should consider any existing factors that place the patient at high risk for spine injury. These include age older than 65 years, a dangerous MOI, and paresthesias in the extremities. Patients with penetrating trauma injuries usually are transferred immediately to the OR for exploratory laparotomy.

If the resources are available, the trauma center protocol may also include a computerized tomography (CT) scan as a diagnostic or screening tool. Depending on the MOI, such as a fall, CT scans of the head and abdomen may be performed. Because injuries in blunt trauma are very difficult to diagnose, the CT scan is frequently done before patient transfer to the OR. A high index of suspicion is maintained for other injuries until proven otherwise. Bowel injuries may be missed during initial scanning. A CT scan of the brain revealing an injury incompatible with life may alter the course of definitive treatment for a patient.

A CT-angiogram may be indicated in diagnosis of vascular injuries. If the patient is hemodynamically stable, this test is of great value in determining the extent of the injury. It is particularly beneficial in the diagnosis of a ruptured thoracic aorta, in which extravasation of the dye at the area of aortic fixation to the chest wall is noted. Other uses include evaluation of penetrating wounds, especially in the extremity. Vessel injury can be noted and the need for surgical intervention determined.

TABLE 27-5

Comparison of DPL, FAST, and CT Scans

Diagnostic Peritoneal Lavage (DPL) Documents Bleeding	Focused Assessment with Sonography in Trauma (FAST) Documents Fluid	Computed Tomography (CT Scan) Documents Organ Injury
ADVANTAGES		
Early diagnosis	Early diagnosis	Most specific to injury
Performed rapidly	Noninvasive	92% sensitive
98% sensitive	Performed rapidly	98% accurate
Detects bowel injury	86-97% accurate	
	Repeatable	
DISADVANTAGES		
Invasive	Operator dependent	Increased cost and time
Low specificity	Bowel gas and subcutaneous air distortion	Misses diaphragm, bowel, and some pancreatic injuries
Misses diaphragmatic and retroperitoneal injuries	Misses diaphragm, bowel, and pancreatic injuries	

Modified from Emergency Nurses Association (ENA): *Trauma nursing core course,* ed 6, Des Plaines, Ill, 2007, Author.

OTHER DIAGNOSTIC TESTS. Cardiac monitoring is another component of the initial phase of trauma care and is particularly important in blunt trauma. Early detection of ventricular dysrhythmias may indicate a myocardial contusion, or bruising of the heart. An electrocardiogram (ECG) is obtained when indicated by the mechanism of injury or the patient's symptoms. Undiagnosed heart disease, as evidenced by an abnormal ECG, is noteworthy in a patient requiring operative intervention.

Focused assessment with sonography in trauma (FAST), used in the United States since the 1990s, may assist with diagnosis in difficult situations. FAST is a portable, noninvasive scan that can be used to determine the presence of free fluid in the chest or abdomen. The typical FAST scan consists of chest, pelvic, and four abdominal scans. The chest scan examines right and left chest views and can determine the presence of pericardial fluid. The upper right abdominal scan evaluates the hepatorenal area, the first area that shows the presence of air. The left upper scan examines the splenorenal area. The left and right paracolic gutters are also scanned. The pelvic scan assesses for free fluid near the bladder. FAST is also used in pregnant patients with blunt abdominal trauma; it is both faster and safer than a computerized tomography (CT) scan, which is contraindicated in the pregnant patient because of the use of iodinated contrast medium and ionizing radiation (Cunningham, 2008).

Although FAST is useful in diagnosing free fluid, it cannot determine damage to solid organs; therefore it complements rather than replaces other imaging scans. Diagnostic peritoneal lavage (DPL) may be performed to determine the presence of abdominal injury. This tool is of particular benefit when evaluation of the abdomen is difficult, such as when the patient is intoxicated, unconscious, or hemodynamically unstable. DPL can be performed in the ED, OR, PACU, or ICU. Nonetheless, retroperitoneal blood may be missed with a DPL, whereas the FAST approach may be quicker and visualize more structures, even pericardium; it is also less expensive and noninvasive. Thus FAST may be used with patients who are unstable and need a quick approach without the risk of a false-positive tap (Table 27-5).

Internal compartment pressures may be measured with an injury to the extremity as well as to the abdomen. Swelling of the muscles below the fascia covering may compromise circulation and result in the eventual loss of the extremity because of tissue necrosis. This is known as *compartment syndrome.* There are multiple compartments in the lower extremity that may be affected (Figure 27-4). Surgeons may measure compartment pressures with a manometer/stopcock/syringe or a commercial compartment pressure–measuring device. Normal compartmental pressures are less than 20 mm Hg. Pressures more than 30 mm Hg require a fasciotomy. Symptoms include severe pain, paresthesia, and a decrease in motor movement in the involved extremity, especially on passive movement (Table 27-6).

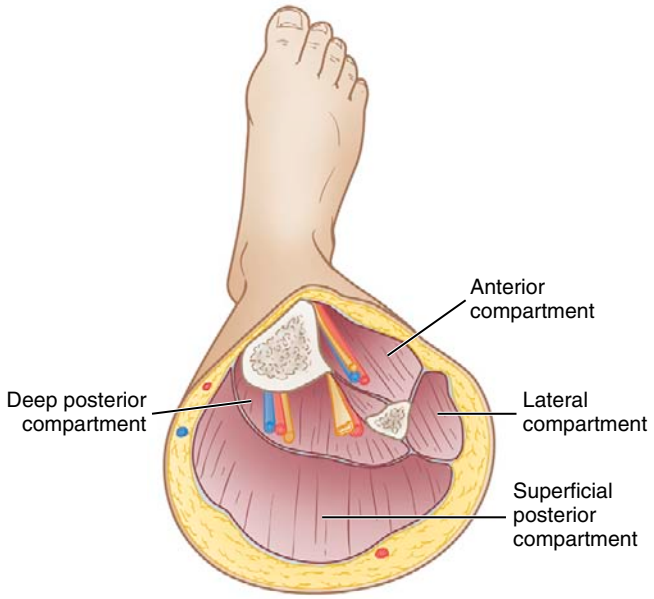


FIGURE 27-4 Compartments of the lower leg.

Massive intestinal edema may occur with trauma patients, causing compromise to internal organs and development of a different type of compartment syndrome. Abdominal compartment syndrome, also called abdominal hypertension, is characterized by increased intraabdominal pressure. Increased

TABLE 27-6

Signs and Symptoms Associated with Compartmental Syndromes

Compartment	Location of Sensory Changes	Movement Weakened	Painful Passive Movement	Location of Pain or Tenseness
LOWER LEG				
Anterior	First web space	Toe extension	Toe flexion	Along lateral side of anterior tibia
Lateral	Dorsum (top) of foot	Foot eversion	Foot inversion	Lateral lower leg
Superficial posterior	None	Foot plantar flexion	Foot dorsiflexion	Calf
Deep posterior	Sole of foot	Toe flexion	Toe extension	Deep calf—palpable between Achilles' tendon and medial malleoli
FOREARM				
Volar	Volar (palmar) aspect of fingers	Wrist and finger flexion	Wrist and finger extension	Volar forearm
Dorsal	None	Wrist and finger extension	Wrist and finger flexion	Dorsal forearm
HAND				
Intraosseous	None	Finger adduction and abduction	Finger adduction and abduction	Between metacarpals on dorsum of hand

Modified from Matsen FA: *Compartmental syndromes,* available at www.orthop.washington.edu/faculty/matsen/compartmental. Accessed May 14, 2009.

intraabdominal pressure (IAP) can have a negative impact on the respiratory, splanchnic, and cerebral functions. It contributes to sepsis or multiple organ failure seen in many trauma patients. Normal IAP is approximately 5 to 7 mm Hg; elevation to 25 mm Hg is often seen in patients with septic shock and correlates with high mortality (Vegar-Brozovic et al, 2008). IAP is graded from I to IV based on a 12 to >25 mm Hg scale. Adverse effects on organ function may be manifested as decreased cardiac output, oliguria, and hypoxia. Elevated intrathoracic pressure reduces left ventricular compliance, causing limitations in effective ventilation, often requiring ventilator support. Elevated IAP may cause an increase in intracranial pressure related to obstruction of cerebral venous blood outflow and increased intrathoracic and central venous pressure. Delay in treatment of IAP may lead to brain deterioration and damage.

Management involves a decompressive laparotomy. After a decompression, the greatest nursing priority is wound management. The swelling may render the abdomen difficult or impossible to close. If the abdomen is closed, intraabdominal pressure may rise to a level greater than 25 cm of H_2O, at which point it may lead to significant organ dysfunction (Kulaylat and Dayton, 2008). Intraabdominal pressure monitoring is accomplished with the use of a nasogastric tube in the stomach or a Foley catheter in the bladder. Simple water-column manometry is done at 2- to 4-hour intervals, although it is possible to connect a pressure transducer to a Foley catheter by way of the sampling port (Figure 27-5). By establishing a water column of urine in the Foley catheter with a clamp distal to the port, a pressure gradient is established. After zero-balancing the transducer, an 18-gauge needle is placed on the end of the pressure tubing and inserted into the sampling port. Using the pressure tubing and a 60-ml syringe, 50 to 60 ml of normal saline is then instilled into the Foley. On instillation of the saline, the waveform on the monitor is correlated to the existing bladder pressure. Normal intraabdominal pressure is zero or subatmospheric. A pressure of more than 25 cm of H_2O is considered diagnostic of abdominal compartment syndrome (Kulaylat and Dayton, 2008). Postoperatively, these patients are susceptible to fluid and heat loss. Continuous hemodynamic monitoring is essential in the critical care phase of treatment.

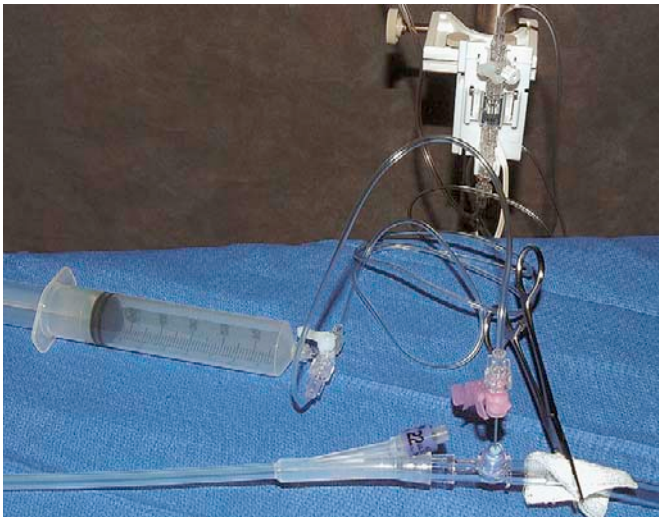


FIGURE 27-5 Setup for measuring abdominal compartment syndrome using a two-way Foley catheter and a pressure monitoring system.

Admission Assessment. The perioperative nurse may not obtain information concerning the trauma patient until the patient arrives in the OR for surgical intervention. If the patient's condition permits, the perioperative nurse should obtain a brief, precise report from the ED nurse that contains the following information: MOI, an AMPLE history (if available), condition on arrival (e.g., level of consciousness), availability of and prior administration of blood or blood products, spine clearance, injuries present, and any other pertinent information (e.g., family present, completion of secondary assessment). If the injury is life- or limb-threatening, implied

surgical consent is assumed (i.e., if the patient were able, consent would be given).

Additional data are collected as the perioperative nurse accompanies the patient to the OR. The status of the airway, as well as breathing patterns and circulatory condition, can be observed. The ED record also provides information concerning amount and type of intravenous (IV) fluid received, vital signs, core temperature, and laboratory and other diagnostic examinations performed. A quick visual and physical survey of the patient when the perioperative nurse is preparing the patient for the procedure enables identification of other sites of injury that might require attention (Patient Safety).

The patient's psychologic status can also be assessed. If the patient is conscious, the perioperative nurse is challenged to allay fear and anxiety. The trauma patient has endured a very frightening experience and is in need of support. The perioperative nurse is often the best member of the surgical team to communicate with the patient and explain the interventions occurring before anesthesia induction. A touch or handhold is an important aspect of this communication process, demonstrating the nurse's caring behaviors and offering comfort.

Nursing Diagnosis

Nursing diagnoses related to the care of trauma patients undergoing operative intervention might include the following:

- Anxiety and Fear (patient and family) related to unpredictable nature of condition
- Deficient Fluid Volume related to hemorrhage, fluid shifts, alteration in capillary permeability, alteration in vascular tone, or myocardial compromise
- Hypothermia related to rapid infusion of IV fluids, decreased tissue perfusion, and exposure
- Acute Pain related to effects of trauma/injury agents, experience during invasive procedures or diagnostic tests
- Risk for Aspiration related to reduced level of consciousness secondary to injury or concomitant substance abuse; impaired cough and gag reflex; trauma to head, face, or neck; and secretions and debris in airway

Outcome Identification

Outcomes identified for the selected nursing diagnoses could be stated as follows:

- The patient and family will experience decreasing anxiety and fear, as evidenced by orientation to surroundings, ability to verbalize concerns and ask questions to healthcare team, decreased fear-related behaviors (e.g., crying, agitation), and use of effective coping skills.
- The patient will have an effective circulating volume as evidenced by strong, palpable peripheral pulses; warm, dry skin of normal color; stable vital signs appropriate for age; maintenance of hematocrit level of 30 ml/dl or hemoglobin level of 12 to 14 g/dl or greater; and control of external hemorrhage.
- The patient will maintain a normal core body temperature, as evidenced by a core temperature measurement of 36.6° to 37.5° C (98° to 99.5° F) and warm, dry skin of normal color.
- The patient will experience relief of pain, as evidenced by diminishing or absent level of pain through patient's self-report, absence of physiologic indicators of pain (e.g., tachypnea, pallor, diaphoretic skin, increasing blood pressure), and ability to cooperate with care as appropriate.
- The patient will not experience aspiration, as evidenced by a patent airway; clear and equal bilateral breath sounds; regular rate, depth, and pattern of breathing; clear chest radiograph without evidence of infiltrates; and ability to handle secretions independently.

PATIENT SAFETY

Missed Injuries

The definition of a missed injury in trauma varies but is generally described as an injury not identified during the primary or secondary surveys or more than 24 hours after admission. Pfeifer and Pape (2008) identified patients with head injuries or a Glasgow Coma Scale score of 8 or less to be more likely to have a missed injury or delayed diagnosis. The literature review showed that the majority of errors occurred in the emergency department, intensive care unit, or OR. The injuries in the review were classified as minor, major, or life-threatening, with approximately 27% to 66% of missed injuries considered major and clinically significant (Pfeifer and Pape, 2008). The study also concluded that missed injuries result in significantly longer hospital stays and longer intensive care unit stays. Ekeh and colleagues (2008) studied diagnostic difficulties with blunt bowel and mesenteric injuries (BBMI) that cause delayed diagnoses even with computerized tomography (CT) scan, diagnostic peritoneal lavage, or FAST. They conclude that missed injuries are common in BBMI even with multislice CT capability.

Pfeifer and Pape (2008) reported that factors contributing to missed injuries include omission of radiographs of the specific area of injury, misinterpreted x-rays, clinical inexperience, assessment errors, interrupted diagnoses, and neighboring injuries. Howard and colleagues (2006) included patient-specific factors such as altered level of consciousness, intoxication, or sedation to the possible cause of missed injuries. Howard and colleagues stated that the most commonly missed injuries were extremity factures; they recommended increased focus on unconscious and/or intubated patients during the primary and secondary surveys. Howard and colleagues (2006) proposed the use of the tertiary survey to decrease the incidence of missed injuries. The tertiary survey, which includes a head-to-toe examination and review of all laboratory and radiologic studies, should be performed within 24 hours of admission. The conclusions of both studies call for adoption of the tertiary survey as the standard of care for all patients admitted to a level II trauma center. An unexpected outcome of the study by Howard and colleagues was the development of a culture of shared responsibility; nurses and therapists discovered injuries during their interactions with patients.

Modified from Ekeh AP et al: Diagnosis of blunt intestinal and mesenteric injury in the era of multidetector CT technology—are results better? *J Trauma* 65(2): 354-359, 2008; Howard J et al: Reducing missed injuries at a level II trauma center, *J Trauma Nurs* 13(3):89-95, 2006; Pfeifer R, Pape HC: Missed injuries in trauma patients: a literature review, *Patient Saf Surg,* 2008, available at www.pssjournal.com/content/2/1/20. Accessed May 16, 2009.

Planning

Because of the unexpected nature of trauma, planning perioperative care is of the utmost importance. Equipment, instruments, and supplies that have a high probability of use must be immediately available. Autologous blood salvage units should also be considered during patient care preparation, because blood salvage will be done if not contraindicated by the nature of the injury. A Sample Plan of Care for a trauma patient is shown below.

Implementation

Multiple Operative Procedures. Depending on the severity of the injuries, the multiple trauma patient may require many surgical interventions. Some of these procedures may be performed simultaneously. This is determined through a

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS

Anxiety and **Fear** (patient and family) related to unpredictable nature of condition

OUTCOME

The patient and family will experience decreasing anxiety and fear, as evidenced by orientation to surroundings; ability to verbalize concerns and ask questions to healthcare team; decreased fear-related behaviors (e.g., crying, agitation); and use of effective coping skills.

INTERVENTIONS

- Monitor the patient's level of anxiety by assessing the patient's state of alertness, ability to comprehend, and ability to comply with requests.
- Facilitate family's presence.
- Assist the family in identifying coping mechanisms; facilitate and support their use.
- Reassure patient and family during interactions by touch (when welcomed) and empathetic verbal and nonverbal communication.
- Explain perioperative environment to patient and what to expect to assist in reduction of anxiety.
- Discuss patient's postoperative appearance (i.e., drains, tubes, equipment) with the patient and family.

NURSING DIAGNOSIS

Deficient Fluid Volume related to hemorrhage, fluid shifts, alteration in capillary permeability, alteration in vascular tone, or myocardial compromise

OUTCOME

The patient will have an effective circulating volume as evidenced by strong, palpable peripheral pulses; warm, dry skin of normal color; stable vital signs appropriate for age; maintenance of hematocrit level of 30 ml/dl or hemoglobin level of 12 to 14 g/dl or higher; and control of external hemorrhage.

INTERVENTIONS

- Manage any uncontrolled bleeding by doing the following:
  - Applying direct pressure over bleeding site
  - Elevating extremities
  - Applying pressure over arterial pressure sites
- Ensure trauma profile laboratory work is complete.
- Verify that requested blood and blood replacement components are available in the OR.
- Prepare laboratory request slips as required; document time and type of analysis requested.
- Collaborate with anesthesia provider in monitoring cardiovascular changes suggestive of hypovolemia.
- Assist in accurate monitoring of intake and output during the surgical procedure.
- Administer blood and blood components as indicated.

NURSING DIAGNOSIS

Hypothermia related to rapid infusion of intravenous (IV) fluids, decreased tissue perfusion, exposure

OUTCOME

The patient will maintain a normal core body temperature, as evidenced by a core temperature measurement of 36° to 37.5° C (96.8° to 99.5° F) and warm, dry skin of normal color.

INTERVENTIONS

- Warm IV solutions and blood products using approved warming devices.
- Minimize body exposure during all phases of perioperative care.
- Use forced air–warming units and warm blankets to facilitate normothermia.
- Ensure irrigant solutions are warm.
- Monitor body temperature for signs of hypothermia, and report to anesthesia care provider.

NURSING DIAGNOSIS

Acute Pain related to effects of trauma/injury agents, experience during invasive procedures or diagnostic tests

OUTCOME

The patient will experience relief of pain, as evidenced by diminishing or absent level of pain through patient's self-report, absence of physiologic indicators of pain (e.g., tachypnea, pallor, diaphoretic skin, increasing blood pressure), and ability to cooperate with care as appropriate.

INTERVENTIONS

- Collaborate with anesthesia provider and surgeon regarding pain management therapy to increase the patient's level of comfort if condition permits.
- Assess nonverbal cues regarding level of pain and discomfort.
- If the patient is unable to provide verbal or nonverbal cues, assume that pain is present or that procedures will cause pain.
- Use a visual or numeric pain scale to assess pain levels and change in comfort if patient is conscious and able to respond.

NURSING DIAGNOSIS

Risk for Aspiration related to reduced level of consciousness secondary to injury or concomitant substance abuse; impaired cough and gag reflex; trauma to head, face, or neck; and secretions and debris in airway

OUTCOME

The patient will not experience aspiration, as evidenced by a patent airway; clear and equal bilateral breath sounds; regular rate, depth, and pattern of breathing; clear chest radiograph without evidence of infiltrates; and ability to handle secretions independently.

INTERVENTIONS

- Ensure operation of suction apparatus preoperatively, and maintain one open suction line solely for use by the anesthesia provider.
- Provide assistance with cricoid pressure under the direction of the anesthesia provider.
- Assist with placement of nasogastric or orogastric tube to evacuate stomach contents.

collaborative effort among the surgeons, anesthesia provider, and perioperative nurse. If a patient has sustained severe head and abdominal trauma, a surgeon will need to place an intracranial pressure (ICP) monitoring device. However, the abdominal exploration is also emergently indicated. Consequently, the severe condition of the patient may require performance of both of these procedures at the same time

Multiple procedures, either simultaneously or in succession, require a great deal of preparation by the perioperative nurse, surgical technologist, and the trauma team. The order of procedures is determined by the presence or absence of life threats. The usual order of priority is chest, abdomen, head, and extremities. However, this priority is determined for each individual patient's situation and adjusted accordingly. Performance of simultaneous procedures is preferable when physically possible. Anesthesia time is decreased for the critically ill patient, and definitive surgical interventions are accomplished more rapidly.

Increased Risk for Infection. Many trauma patients have wounds that are contaminated with roadside debris, dirt, grass, or automobile parts. Others have a perforated full stomach, and food particles are released into the peritoneum, increasing the risk of peritonitis. Consequently, many patients are at high risk for infection. Sterile technique may be compromised secondary only to immediate life threat. Pouring an antimicrobial solution across the surgical site may be the only surgical skin prep undertaken when an immediate life threat exists. The use of antimicrobial prophylaxis shortly before skin incision has become the standard of care for surgical procedures. Perioperative nurses are in a position to ensure the timely administration of antibiotics.

Wounds may need to be grossly decontaminated before the surgical skin prep. Sterile scrub brushes or a mechanical irrigation-under-pressure device may be used preoperatively and intraoperatively. Care must be exercised to remove as much contamination as possible, without creating further damage to the wound or body part. Perioperative personnel must wear personal protective equipment (PPE) during irrigation under pressure to prevent splashes and contamination from the lavage system. Traffic in the OR should be limited to essential personnel. Increased traffic in the room increases chances for contamination in an already compromised patient, as well as potentially interferes with the delivery of expedient care.

Procedure Preparation. Most level I trauma centers have a designated trauma OR that contains all equipment and supplies potentially needed for trauma patients. Many hospitals maintain an emergency abdominal procedure set, craniotomy procedure set, and chest procedure set either obtainable in the OR's sterile supply area or immediately available in the central supply department. This streamlines preparation for the surgical procedure and allows for the possibility of rapid preparation in those instances where the patient bypasses the emergency department on arrival and is transported directly to the OR.

Once the perioperative nurse is notified of the surgical procedure, OR determination is made in consultation with the anesthesia provider and surgeon. Considerations include the following:

- Equipment required by the surgeon or surgeons to perform the surgical procedure
- Room availability
- Room size (to accommodate equipment, staff, and multiple procedures)
- Need for additional staff
- Capability for autologous blood salvage
- Availability of emergency procedure supplies (including power equipment)
- Selection of OR bed

Additional diagnostic procedures are often required during multiple trauma procedures. A fluoroscopic electric OR bed provides increased flexibility in patient management. The bed can be rotated on its base to facilitate two teams operating at once. The fluoroscopic capabilities allow for additional radiographs and arteriograms as needed. The bed should easily transform into different positions, such as lithotomy or lateral rotation. If a fluoroscopic bed is not available, arrangements must be made in advance to perform diagnostic radiologic procedures intraoperatively.

Before transfer of the patient to the OR bed, the perioperative nurse must ascertain if the spinal column has been cleared by the surgeon or attending physician as free from injury. If the spine has not been cleared, the surgeon must be consulted before removal of the patient from the backboard. Safe transfer of the patient from the transport vehicle to the OR bed can be accomplished using the log-rolling technique.

Positioning of the patient is based on the surgical approach. Ascertaining the type and location of the wound (anterior or posterior) and type of operative procedure dictates the patient's position. For example, an aortic injury may be approached through a thoracotomy or a median sternotomy incision. The thoracotomy requires lateral positioning devices, and the sternotomy necessitates a supine position.

If several procedures are being performed, positioning may change intraoperatively. Changing the anesthetized patient's position is accomplished under the supervision of the anesthesia provider, with particular attention to maintenance of the airway. The patient is moved slowly, allowing for assessment of vital sign changes in response to the position movement. All precautions regarding positioning are reexecuted, with special attention given to the electrosurgical grounding pad. This pad may loosen during patient repositioning and require replacement to ensure adequate pad contact.

When the trauma patient is transferred to the OR, the extent of injury is not always known. The perioperative nurse should prep the patient from the suprasternal notch to the midthigh. This allows for rapid access to the chest to clamp the aorta should massive hemorrhage control be indicated; it also allows for exposure of the femoral arteries for potential cannulation and access to the thigh for harvesting a saphenous vein.

Established policies for counting sponges, instruments, and sharps should address surgical procedures of an emergent nature within the institution. Every attempt is made to verify appropriate numbers of counted items without compromising the timeliness of intervention in a life-threatening situation. If a preprocedural count is not performed, the perioperative nurse must document the occurrence and rationale used in accordance with established hospital policies and procedures. Some institutions require an x-ray examination postoperatively to examine the patient for the presence of a retained object. If counted sponges are intentionally left in the patient (e.g., in a damage control procedure at a level II, III, or IV center before transfer to a level I facility), the number and type of sponges

left in the wound should be documented on the perioperative nursing record (AORN, 2009). The operative dictation by the surgeon should also verify the presence of retained sponges, their type, and their number. This allows for accurate counts in subsequent procedures and prevents the potential for an inadvertent retained sponge.

In the presence of clotting difficulties or specific types of organ injuries with continuous oozing of blood, the surgeon may elect to pack the surgical site with laparotomy sponges and close the patient as a temporary measure. After a period of 24 to 48 hours, the patient returns to the OR for removal of the laparotomy sponges and primary closure if possible. In such instances the perioperative nurse must document and record accurately the number of sponges used for packing, as just noted. When the sponges are removed, the exact number is verified and the sponges are isolated and contained in accordance with established hospital policy and procedure.

Autotransfusion. Considering the high blood loss associated with traumatic injuries, autotransfusion has become a vital asset in trauma care. Preoperative blood loss that is associated with an isolated hemothorax is collected in a designated chest-drainage device for reinfusion within 4 hours to avoid bacterial contamination. Intraoperative blood loss is collected, filtered, and reinfused to the patient. This provides immediate volume replacement, decreases the amount of bank blood used, and reduces the possibility of transfusion reactions or risk of transfusion with bloodborne pathogens.

The autologous blood salvage unit requires specialized training for operation. Institutional policies vary regarding appropriate personnel designated for operation of the equipment. Capabilities for autotransfusion should be considered during procedure preparation, since additional qualified personnel may be required.

During autologous blood salvage the surgical technologist squeezes out additional blood and fluid from saturated sponges before discarding them from the surgical field. The blood salvage suction is used whenever possible to maximize the amount of blood salvaged. However, care must be taken to ensure that the blood collected in the salvage unit is free from contamination. For instance, if the abdomen is contaminated with free food particles or colonic perforation is present, the blood cannot be used. Similarly, once antibiotic irrigation is initiated, the blood salvage unit is not used.

Evidence Preservation. If the injury to the patient is a result of a violent crime, the team must give special attention to preservation of evidence during the course of patient care. Physical evidence (e.g., bullets, bags of powder, weapons, pills, and other foreign objects), trace evidence (e.g., hair and fibers), biologic evidence (e.g., body fluids and blood), and clothing are considered types of evidence to be preserved. Specific procedures on handling of evidence may differ by institution and law enforcement agencies.

Clothing must be handled properly. When clothing is removed from the patient, the person removing it should cut along the seams or around the bullet or stab wound holes. The shape of the hole may help identify the weapon used. Clothing is placed in paper bags, labeled appropriately, and given to law enforcement personnel. Plastic bags trap moisture and may facilitate growth of mold, which could destroy evidence. The transport vehicle sheet should also be handled in a similar manner, since evidence may be present. The nurse must ensure that descriptions of wound appearances, body markings consistent with gang or cult activity, and statements from the patient are accurately recorded.

The chain of custody for all evidence, including clothing, is followed. This process allows for identification of all people handling the evidence. Documentation must verify that the evidence has been in secure possession at all times. Records should be kept of all evidence discovered, including its site of origin and when and to whom the evidence was given. A system of documentation using receipts or a specific form should be established to ensure appropriate compliance.

Gunpowder residues, tissue, hair, or other valuable information may be present on the hands of a trauma patient. This evidence can be preserved by placing the patient's hands in a paper bag and securing it with tape. Washing the hands should be avoided until evidence is collected, or until directed to do so by the police.

Bullets and retained implements offer valuable evidence and may assist in identifying the assailant. The weapon firing the bullet and the bullet itself can be matched by the specific grooves and markings placed on the bullet when the gun was fired. Most bullets are composed of soft lead, and handling with metal instruments can interfere with the markings. Therefore the surgeon should avoid using metal instruments to handle bullets. Some of the newer exploding types of bullets can present a risk to perioperative team members during wound exploration. Care should be exercised to avoid sterile glove tears, since these types of bullets are extremely sharp. Once a bullet is removed, the surgical technologist should place it in dry, clean gauze in a plastic specimen container and pass it off the sterile field to the perioperative nurse. Using the chain-of-custody procedures, the perioperative nurse should label the container appropriately and dispose of the bullet according to established institutional policies.

Deep Vein Thrombosis Prophylaxis. Because of the prolonged immobilization anticipated for the trauma patient, along with the frequency of orthopedic or lower extremity surgery, trauma patients are at high risk for developing venous thromboembolic events (VTE). Placement of a sequential compression device (SCD) preoperatively is ideal. These pneumatic compression devices assist in decreasing the possibility of deep vein thrombosis (DVT), and their effect is optimized when applied before surgical intervention. Preoperative placement is subject to the physician's preference; clinical research regarding similar devices and demonstrated product effectiveness is ongoing. The incidence of DVT and pulmonary embolism (PE) in trauma patients varies widely according to current literature. Meier and colleagues (2007) conducted a meta-analysis of trauma literature that estimated 11.8% of trauma patients develop a DVT and 1.5% develop a PE. The incidences are higher where there is severe head injury, pelvic fracture, and older age.

Currently, in patients with traumatic brain injury, the only recommended prophylaxis is SCD because of concerns with the use of heparin leading to bleeding complications. Subsequently, an inferior vena cava filter (VCF) may be inserted in high-risk patients to prevent pulmonary embolus. Risk factors for PE include prolonged immobility, multiple pelvic and lower extremity fractures, previous history of PE, severe head trauma,

and incomplete spinal cord injury with paralysis. VCFs have success rates of 98% in preventing PE from lower extremity DVT (Meier et al, 2007). However, the placement of a VCF is associated with inferior vena cava obstruction and recurrent DVT. Contraindication to pharmacologic prophylaxis is generally limited to a short period after the initial trauma, and long-term vena cava filtration is rarely necessary (Research Highlight).

Anesthesia Implications. Depending on institutional protocol, the anesthesia team may be directly involved in resuscitation of the trauma patient immediately after arrival at the ED. The anesthesia provider maintains the airway and intubates the patient if necessary. A critically injured patient may be transferred directly to the OR, whereas some interventions may be performed in the ED of a trauma center. These interventions vary from insertion of an ICP monitor to an emergent exploratory thoracotomy.

However, if diagnostic evaluation can be accomplished without intubation and sedation, the patient may be conscious upon arrival in the OR. A trauma patient is assumed to have a full stomach; thus these patients are at high risk for aspiration and resultant pneumonia. Under the direction of the anesthesia provider, the perioperative nurse applies cricoid pressure (Sellick maneuver) (Figure 27-6). This pressure is maintained over the cricoid area until the cuff on the endotracheal (ET) tube is inflated and tube placement verified by the anesthesia provider. This type of intubation is often referred to as a "crash induction."

In addition, the patient may require intubation for protection of the airway before radiologic examination of the cervical spine. If the cervical spine is not cleared or if the radiographic screening examination is not performed before intubation, ET intubation is done while cervical spine precautions (i.e., in-line intubation) are maintained. The anesthesia provider may decide to use rapid-sequence intubation (RSI). RSI involves administration of 100% oxygen, an analgesic, and a neuromuscular relaxant; application of cricoid pressure; and insertion of a cuffed ET tube. Etomidate (Amidate) is the most commonly used induction agent (Emergency Nurses Association, 2007). It acts in about 1 minute and lasts about 5 minutes. It is often used in trauma patients because it does not cause an increase in ICP or worsening of hypotension. Succinylcholine (Anectine) is the most frequently used neuromuscular relaxant. The perioperative nurse can facilitate RSI by ensuring availability of all intubation and resuscitation equipment, assisting with monitoring devices, and confirming correct ET-tube placement (Box 27-3).

In injuries of the face where midface fractures are present, nasal intubation and nasogastric tube placement are avoided.

RESEARCH HIGHLIGHT

Early Placement of Optional Vena Cava Filters

Trauma patients are at increased risk for developing thromboembolic events such as deep vein thrombosis. Standard anticoagulant therapy may not be suitable for certain traumas, such as brain injuries. In this study, investigators evaluated 34 patients who had a prophylactic vena cava filter (VCF) implanted. Those included in the study were high-risk patients with contraindications to pharmacologic prophylaxis for more than 5 days because of traumatic brain injury. The OptEase VCF was used on all patients and was placed infrarenally. Of the patients, 27 (or 84%) had their filters retrieved with no related mortality. Five (16%) patients had VCFs that were permanently implanted. One patient developed early inferior vena cava occlusion and DVT occurred 14 days after VCF placement. One patient developed symptomatic pulmonary embolus 5 days after VCF retrieval. The researchers concluded that early VCF placement may benefit patients in whom pharmacologic intervention is contraindicated.

Modified from Meier C et al: Early placement of optional vena cava filter in high-risk patients with traumatic brain injury, *Eur J Trauma Emerg Surg* 33(4): 407-413, 2007.

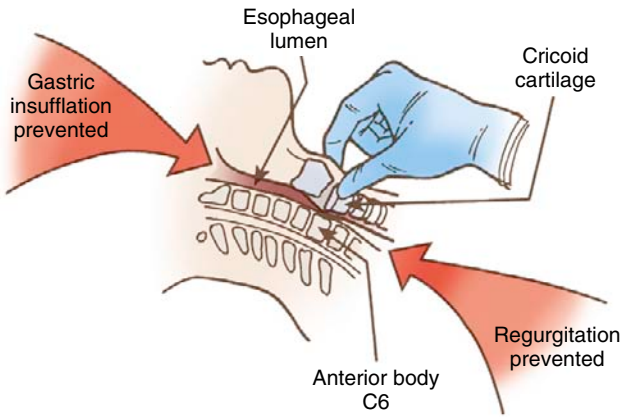


FIGURE 27-6 Application of cricoid pressure. Thumb and forefinger are used to depress cricoid cartilage, causing it to impinge on the lumen of esophagus and sealing it closed against the anterior body of C6. As a result, gastric insufflation secondary to positive-pressure ventilation (bag-valve-mask apparatus) from above, as well as regurgitation of stomach contents from below, is largely prevented. *C6*, Sixth cervical vertebra.

BOX 27-3

Rapid-Sequence Intubation Steps

Preparation	Assist anesthesia care provider as needed. Ensure all equipment is available.
Preoxygenation	Administer 100% oxygen.
Pretreatment	Assist anesthesia care provider in medication administration, as indicated (atropine, lidocaine, etomidate).
Paralysis with induction	Anesthesia is induced (midazolam, fentanyl), patient loses consciousness, and neuromuscular agent is administered (succinylcholine).
Protection and positioning	Use Sellick maneuver to provide cricoid pressure. Must be applied continuously and until anesthesia care provider asks to have pressure released to avoid aspiration.
Placement with proof	Inflate cuff; check placement with exhaled carbon dioxide detector and by listening to lungs with stethoscope.
Postintubation management	Secure tube, verify ventilator settings, and monitor per routine.

Modified from Emergency Nurses Association (ENA): *Trauma nursing core course,* ed 6, Des Plaines, Ill, 2007, Author.

Tube placement in the brain through a fracture of the cribriform plate is a well-known complication. To avoid this, oral ET intubation is the technique of choice. The anesthesia provider places an oral gastric tube to achieve stomach decompression. An oral intubation on a conscious patient is often necessary because anesthetics and muscle relaxants can result in the loss of any remaining airway in the presence of facial trauma.

Large-bore IV access used with rapid-infusion fluid warmers may be employed in the ED. These fluid warmers can deliver high volumes of crystalloid solution at body temperature. Use of the fluid warmer may continue during the intraoperative phase to facilitate volume replacement and help maintain normothermia. A number of factors may influence a trauma patient's response to fluid loss. These factors include age, severity of injury, type and location of injury, time lapse from injury to treatment, prehospital fluid therapy, prehospital use of a pneumatic antishock garment, and medications taken for chronic conditions. Fluid resuscitation should be initiated when early signs of blood loss are suspected. A classification system can be useful in determining the needs of the patient (Table 27-7).

Pregnancy. The normal physiologic changes that occur during pregnancy increase the challenge of evaluation and treatment when these individuals are victims of trauma. Cusick and Tibbles (2007) note that while the incidence of trauma in pregnant patients is low, it is still the leading cause of obstetric mortality. A trend noticed in this study identified more severe abdominal injuries and less severe head injuries in the pregnant patient. It is most important to remember that two patients are being treated. The key to resuscitation of the fetus is to resuscitate the mother. One of the first physiologic changes to note is that the pregnant trauma patient has a much larger circulatory volume (Table 27-8). The cardiac output may be increased by as much as 40%. Oxygen requirements are increased. Heart rate increases over the pre-pregnant state. The usual clinical indicators of hypovolemic shock are unreliable in the pregnant trauma patient (Table 27-9). The team must assume that the pregnant trauma victim is in shock until proven otherwise. Early aggressive treatment is essential. The uterus is enlarged and no longer a pelvic organ, and it elevates the bladder out of the pelvis as well. Supine position for the pregnant patient can result in a decrease in cardiac output as a result of compression of the inferior vena cava. If the patient is close to term, cardiac output can be reduced by as much as 30% as a result of compression on the inferior vena cava. Consequently, patients who are 20 weeks or more into their pregnancy should be placed in the left lateral decubitus position to avoid a hypotensive episode and maintain blood flow to the uterus and placenta. If this is not possible, manual displacement of the uterus by lateral abdominal pressure should be attempted. As a result of the physiologic changes just described, the pregnant patient is at risk for aspiration. Rapid-sequence induction, along with the Sellick maneuver, is the preferred method for intubation.

Ultrasound studies are conducted to determine viability of the fetus when possible. In the event of a ruptured uterus, a cesarean delivery and hysterectomy may be required if the fetus is viable. Neonatal resuscitation is of the utmost importance immediately on delivery of the fetus.

Pregnant patients requiring surgery also need fetal assessment performed intraoperatively. Any fetal movement should be noted. In addition, fetal monitoring is continuous. This includes fetal heart rate and uterine contractions. Fetal monitoring provides information on the condition of the fetus and the response to uterine contractions, if present. Fetal heart rate can usually be obtained after 10 weeks of gestation. Abnormalities in fetal heart rate can be an early sign of maternal compromise because the pregnant uterus is viewed as a nonessential peripheral organ in states of hypovolemic shock. The study by Cusick and Tibbles (2007) also noted that the presence of disseminated intravascular coagulation (DIC) was associated with fetal mortality. Personnel qualified in the interpretation of fetal heart rate patterns must be present. This expertise may be provided by the obstetric nursing staff.

TABLE 27-7

Estimated Fluid and Blood Losses Based on Patient's Initial Presentation*

	Class I	Class II	Class III	Class IV
Blood loss (ml)	Up to 750	750-1500	1500-2000	>2000
Blood loss (% blood volume)	Up to 15%	15%-30%	30%-40%	>40%
Pulse rate (beats/min)	<100	>100	>120	>140
Blood pressure	Normal	Normal	Decreased	Decreased
Pulse pressure	Normal or increased	Decreased	Decreased	Decreased
Respiratory rate (breaths/min)	14-20	20-30	30-40	>35
Urine output (ml/hr)	>30	20-30	5-15	Negligible
Central nervous system (CNS)/ mental status	Slightly anxious	Mildly anxious	Anxious, confused	Confused, lethargic
Fluid replacement (3:1 rule)	Crystalloid	Crystalloid	Crystalloid and blood	Crystalloid and blood

*The guidelines are for a 70-kg man. They are based on the 3:1 rule. This rule derives from the empiric observation that most patients in hemorrhagic shock require as much as 300 ml of electrolyte solution for each 100 ml of blood loss. Applied blindly, these guidelines can result in excessive or inadequate fluid administration. For example, a patient with a crush injury to the extremity may have hypotension out of proportion to his or her blood loss and require fluids in excess of the 3:1 guidelines. In contrast, a patient whose ongoing blood loss is being replaced by blood transfusion requires less than 3:1. The use of bolus therapy with careful monitoring of the patient's response can moderate these extremes.

Modified from American College of Surgeons: *ATLS program for doctors,* ed 7, Chicago, Ill, 2004, Author; Boswell SA, Scalea TM: Initial management of traumatic shock. In McQuillan KA et al, editors: *Trauma nursing: from resuscitation through rehabilitation,* ed 4, St Louis, 2009, Saunders.

TABLE 27-8

Maternal Adaptation During Pregnancy and Relation to Trauma

System	Alteration	Clinical Responses
Respiratory	↑ Oxygen consumption	↑ Risk of acidosis
	↑ Tidal volume	↑ Risk of respiratory mismanagement
	↓ Functional residual capacity	↓ Blood-buffering capacity
	Chronic compensated alkalosis	
	↓ $Paco_2$	
	↓ Serum bicarbonate	
Cardiovascular	↑ Circulating volume, 1600 ml	Can lose 1000 ml of blood
	↑ Cardiac output	No signs of shock until blood loss >30% of total volume
	↑ Heart rate	↓ Placental perfusion in supine position
	↓ Systemic vascular resistance (SVR)	Point of maximal impulse, fourth intercostal space
	↓ Arterial blood pressure	Heart displaced upward to left
Renal	↑ Renal plasma flow	↑ Risk of stasis, infection
	Dilation of ureters and urethra	↑ Risk of bladder rupture
	Bladder displaced forward	
Gastrointestinal	↓ Gastric motility	↑ Risk of aspiration
	↑ Hydrochloric acid production	Passive regurgitation of stomach acids if head lower than stomach
	↓ Competency of gastroesophageal sphincter	
Reproductive	↑ Blood flow to organs	Source of ↑ blood loss
	Uterine enlargement	Vena caval compression in supine position
Musculoskeletal	Displacement of abdominal viscera	↑ Risk of injury, altered rebound response; altered pain referral
	Pelvic venous congestion	↑ Risk of pelvic fracture
	Cartilage softened	Center of gravity changed
Hematologic	Fetal head in pelvis	↑ Risk of fetal injury
	↑ Clotting factors	↑ Risk of thrombus formation
	↓ Fibrinolytic activity	

Modified from Dorman KF: Obstetric critical care. In Lowdermilk DL, Perry SE, editors: *Maternity & women's health care,* ed 9, St Louis, 2007, Mosby.

TABLE 27-9

Signs of Hypovolemic Shock in Pregnancy

	Circulating Blood Volume Deficit	
	Early (20%)	**Late (25%)**
Pulse rate	<100 beats/min	>100 beats/min
Respiratory rate	12-20 breaths/min	>20 breaths/min
Blood pressure	Normal	Hypotensive
Skin perfusion	Warm, dry skin	Cool, ashen skin
Capillary refill time	<2 sec	>2 sec
Level of consciousness	Alert	Agitated, lethargic
Urine output	>30-50 ml/hr	<30-50 ml/hr
Fetal heart rate (normally 120-160 beats/min)	High, low, late decelerations	High, low, absent, late decelerations

Perimortem (postmortem) cesarean delivery may be performed in the event of the sudden death of the mother and the presence of a viable fetus.

Pediatric Trauma Patients. Special considerations related to the care of infants and children who have sustained a trauma are described in Chapter 25. Table 25-4 details a modified Glasgow Coma Scale for children.

Elderly Trauma Patients. As the number of adults older than 65 years continues to grow, so does the number of elderly patients requiring surgical intervention related to trauma. The physiologic effects of aging combined with the preinjury health status of many elderly patients significantly affect their ability to respond to initial treatment for traumatic injuries and subsequent surgical intervention. Consequently, the mortality for elderly trauma patients is significantly higher than that in younger patients with the same level of injury. Preexisting medical conditions, medication use, decreased physiologic reserves, and the physical and psychologic stress experienced during surgical interventions place elderly trauma victims at increased risk for perioperative complications (Plummer, 2009). (See Chapter 26 for the physical and psychologic changes that occur in elderly patients.)

Bariatric Trauma Patients. There has been a notable increase in admissions of bariatric patients in all healthcare facilities. Bariatric medicine is defined as the care of the extremely obese patient, as measured by body mass index (BMI). The World Health Organization (WHO) defines obese as a BMI greater than 30 and severely obese as a BMI greater than 40 (Muir and Archer-Heese, 2009). The obese patient often has several co-morbid conditions, including cardiac disease, hypertension, respiratory disease, diabetes, osteoarthritis, and stress incontinence. Because of their size and their decreased self-esteem the needs of bariatric patients are different from those of other patients. Societal prejudice against obesity is well established.

RISK REDUCTION STRATEGIES

Special Considerations for the Bariatric Trauma Patient

Bariatric trauma patients (e.g., those weighing more than 350 pounds) present special challenges to the surgical team. Morbidly obese trauma patients have an eight times greater risk of dying from their injuries than patients who are of normal body weight (Szczensiak, 2009). Several strategies must be developed to reduce risk to the patient and the healthcare team. The facility should be cognizant of the needs of bariatric patients and have policies and protocols established to facilitate effective and safe care.

Once the OR is notified of the arrival of a bariatric trauma patient, the perioperative nurse and surgical technologist must consider the planned procedure and the availability of necessary equipment, including a bariatric OR bed, foot board, and side extensions as well as long surgical instruments. A large blood pressure cuff will also be necessary for accurate blood pressure monitoring so that hemodynamic changes are quickly observed and treated.

As with all trauma patients, airway maintenance is a prime consideration. The bariatric patient often has a history of sleep apnea and is unable to lie flat for any length of time. The nurse should pad the head of the OR bed so that the patient's head is elevated as much as possible. In addition, the nurse should be prepared to assist the anesthesia care provider with intubation and also ensure that the difficult airway cart is available. The bariatric trauma patient is at increased risk for aspiration. The nurse can assist with airway protection by performing the Sellick maneuver at the anesthesia provider's direction.

Protection from positioning injury is a critical risk reduction strategy that the perioperative nurse should provide for the bariatric patient. Whenever feasible, it is best to have the patient move from the transport vehicle to the OR bed; if not, adequate personnel should be available to assist with the transfer and positioning so that both the patient and the surgical team can avoid injury. The increased adipose tissue of the bariatric patient does not protect the patient from pressure sores; the nurse must pad all bony prominences and pressure points well. Pillows collapse easily under a heavy load, so foam supports should be used. Shear injury can easily occur; therefore the nurse must check the patient's position and remove blankets or other materials under the patient if they are preventing a smooth surface.

All trauma patients are at increased risk for DVT. Bariatric patients have an even greater risk for developing this complication. The nurse should obtain the appropriate size of stockings and compression sleeves; these must be placed carefully, without any folds.

Skin breakdown, tissue injury, and dermatitis between the obese patient's layers of adipose tissue are very common. The perioperative nurse must retract skin folds while prepping to ensure the area is clean and well-prepped. If a limb is to be prepped, help should be obtained; another person or a sling may be used. Because one leg is 16% of body weight, it may weigh as much as 62 pounds; if not held securely, the weight of the limb can cause knee or ankle dislocation.

Care must also be taken in the placement of the ESU dispersive pad. Because of the increased amount of adipose tissue, the nurse may consider applying two dispersive pads to prevent the concentration of electrical current in a single area.

The bariatric trauma patient is at increased risk for retention of foreign bodies related to the size of the abdominal and other cavities. The perioperative nurse and surgical technologist must scrupulously count all sponges and instruments on the surgical field.

Finally, the nurse must have self-awareness and insight into any personal prejudice against the obese and act as an advocate for the patient. Comments about the patient's weight are not appropriate, and the nurse plays a role in reminding members of the team to monitor their verbal and nonverbal communications when providing care for bariatric patients.

Modified from Bell S: Current issues and challenges in the management of bariatric patients, *J Wound Ostomy Continence Nurs* 32(6):386-391, 2005; Ide P et al: Perioperative nursing care of the bariatric surgical patient, *AORN J* 88(1):30-58, 2008; Muir M, Archer-Heese G: Essentials of a bariatric patient handling program, *Online J Issues Nurs* 14(1), 2009; Szczensiak SL: Trauma in the bariatric patient. In McQuillan KA et al, editors: *Trauma nursing: from resuscitation through rehabilitation,* ed 4, St Louis, 2009, Saunders.

Studies show that nurses are often less attentive to the needs of the obese patient and are often worried about the possibility of personal injury related to positioning the patient. Sharma (2005) states that diagnosis can be very difficult in the absence of routine symptoms; CT and MRI scans are often not possible because of the limitations of the equipment. The use of ultrasonography may be limited because of distortion caused by the thickness of the abdominal wall. There are many strategies that the perioperative nurse may use to decrease risk for this patient group (Risk Reduction Strategies).

Invasive Emergency Department Interventions. If a patient has shown a very recent deterioration of vital signs, either en route to the hospital or on arrival at the ED, the surgeon may elect to perform an emergency thoracotomy in the ED. A left-sided approach is usually performed because this allows rapid access to the heart for external cardiac massage and exposure of the great vessels for clamping in the event of severe blood loss (Figure 27-7). The incision can be extended

FIGURE 27-7 Emergency exploratory thoracotomy performed in the emergency department.

RAPID RESPONSE TEAM

The Ohio State University Medical Center (OSUMC) conducted a 2-week trial of the in-house "stat" nurse position. Nurses accepted into this position need prior experience in critical care with a demonstrated ability for critical thinking. At OSUMC the role of the stat nurse includes assisting with patient transport to and from diagnostic tests, helping nurses perform difficult intravenous starts, responding to cardiac arrest and trauma calls, assisting with procedural sedation, and serving as a clinical resource for staff. The stat nurse, typically a non–emergency department (ED) professional, rarely takes the lead in patient care but rather acts as an assistant to the ED nurse. In a trauma situation, the stat nurse serves as an extra hand by setting up needed equipment, transporting blood specimens to the laboratory, and comforting family members as needed. The ability to provide an experienced critical care nurse in the trauma setting has had a positive impact on both patient care and staff morale.

Modified from Sinclair TD: The role of the rapid response nurse: hospital wide and in trauma resuscitations, *J Trauma Nurs* 13(4):175-177, 2006.

to the right side by cutting across the sternum. This procedure can be used to gain control in hemorrhage of the great vessels, to access the heart, or, in a grave situation, as a final effort to save a life. The procedure is used more often in penetrating injuries where a laceration to a ventricle or other potentially treatable, life-threatening injury may be present.

Because of the perioperative nurse's knowledge of surgical instrumentation and procedures, his or her assistance in this procedure in the ED is often required. In some facilities, perioperative nurses may assist the rapid response team in this role (Rapid Response Team box). Rapid access to the heart and great vessels is the goal. The patient is then transported to the OR for additional interventions once hemorrhage is controlled.

In a similar fashion, an exploratory laparotomy can be initiated in the ED to control abdominal hemorrhage, especially when a splenic rupture is suspected and the patient is severely compromised.

If all other techniques of airway access are unsuccessful, the surgeon performs a cricothyrotomy. The surgeon makes a vertical incision through the skin, and incises the cricothyroid membrane. An ET or tracheostomy tube can be inserted through the membrane to create an airway. In the event a tube is not immediately available, a large-bore needle can be inserted into the membrane and the catheter left in place. This provides a temporary airway access measure but is inadequate to effectively ventilate the patient without a jet oscillating ventilator.

Successive Surgical Interventions. Often the multiple trauma patient requires a multitude of surgical procedures—either specialty-related or as a stepwise progression in the primary treatment of the initial injury. Initially the trauma patient is critically ill and requires intensive care facilities. When surgery is scheduled, the perioperative nurse may need additional assistance in transport of the patient as transport monitoring of the ECG, arterial line, and blood pressure is performed. Oxygen administration and mechanical ventilation with an Ambu bag are necessary for the intubated patient. Acalculous cholecystitis is often a secondary complication of the trauma patient's postoperative course that requires cholecystectomy. Fixation of initially undiscovered fractures, debridements, secondary wound closures, flap constructions, and other reconstructive procedures make up the majority of follow-up procedures. Depending on the patient's condition, some procedures may be performed after discharge on an outpatient basis (Ambulatory Surgery Considerations).

AMBULATORY SURGERY CONSIDERATIONS

Outpatient Follow-up Procedures

Because of the extensive nature of some traumatic injuries, many trauma patients need further surgeries. Often follow-up procedures are performed on an outpatient basis. The perioperative nurse's care and planning for these patients must include an awareness of the physiologic and psychologic effects of the previous trauma. Preoperative teaching should include an assessment of the knowledge acquired by the patient and caregiver(s) from previous admission as well as the coping strategies they have been using. Maintaining the same routine as much as possible will help with the psychologic adjustment to yet another procedure. Pain assessment by the perioperative nurse is critical and must consider the patient's current medication use, including the duration of use as well as the medication's effectiveness. It is imperative to consider that this procedure will likely change the focus and severity of the pain and that additional or different medications may be necessary postoperatively.

Modified from Association of periOperative Registered Nurses (AORN): Preoperative patient care in the ambulatory setting guideline. In *Perioperative standards and recommended practices,* Denver, 2009, The Association.

Evaluation

The evaluation of the patient should reflect the effectiveness of the interventions. Did the patient remain free from untoward complications? Was there progress toward the expected outcomes as described in the perioperative plan of care? The following are examples of evaluation statements in relation to the sample plan of care:

- The patient demonstrated a decreased level of anxiety; he or she verbalized less apprehension, maintained eye contact, and was able to comply with requests even though anxiety persisted.
- The patient remained hemodynamically stable; fluid resuscitation was undertaken, blood pressure and pulse rate measurements were adequate considering the patient's status, and the H&H values were within acceptable ranges.
- The patient achieved and maintained normothermia in the OR.
- The patient reported reasonable relief from pain during preparatory maneuvers in the OR.
- The airway was maintained, and induction of anesthesia proceeded without complication.

On completion of the procedure or procedures, the perioperative nurse is afforded an opportunity to further assess the trauma patient as well as evaluate the plan of care implemented. If the patient sustained numerous injuries and remains critically injured, the PACU may be bypassed and the patient may be transferred directly to the ICU. The perioperative nurse should accompany the patient, along with the anesthesia provider, to the ICU. Once the anesthesia report is given, the perioperative nurse can provide a wealth of information to the critical care nurse. At this point, family members may have been contacted or are present, allowing more specific medical history information to be obtained. However, the mechanism of injury and events surrounding the trauma are still significant. A high index of suspicion remains during postoperative care of the patient sustaining multiple injuries. Attention can be diverted from a less significant injury in the presence of a highly visible or obvious trauma. Once the obvious trauma undergoes intervention, pain or discomfort from other injuries becomes more apparent. In the care of a patient with neurologic deficit, physical assessment and continued evaluation are essential because patient self-report is nonexistent.

The nurse should also report the status of progress in the secondary assessment. Any additional laboratory work or interventions that have yet to be completed should be discussed. It is imperative in a thorough examination to view the back of the patient in an effort to locate all injuries.

Additional diagnostic procedures may be required after completion of the surgical procedure if the patient's condition is stable. The perioperative nurse may be requested to accompany the patient to the diagnostic department with the anesthesia provider. In addition, respiratory care personnel may assist in patient transport and maintenance of the airway.

Patient and Family Education and Discharge Planning

Traumatic injury to a family member or significant other occurs without warning. Patients may be traveling or visiting out of town or state at the time of injury. Families or friends involved in a motor vehicle collision may be triaged to several different facilities based on severity of injury or age. A family member or significant other may not be contacted until several hours or even days after the injury. Sometimes the patient's identity either is unknown or must be kept confidential to prevent further harm. Both the patient and the family member are truly victims of traumatic injury. Consequently, patients and family members are in a time of crisis.

Some families may handle the crisis with ease, whereas others become dysfunctional. Coping strategies may be inappropriate at times as the patient and family attempt to reestablish patterns of function. A family system already taxed before the event may be overwhelmed with the additional stress of a sudden traumatic event. On the other hand, family members may wish to be present during resuscitation efforts. Family presence requires a facilitator to explain procedures and the accompanying sights, sounds, and smells that may occur. Nurses base their decisions on medical concerns, which may be very different than patient and/or family concerns. In trauma situations, nurses do not know their patient's preferences and may even be unaware that differences in opinion exist. Care may be improved when understandable terms are used to explain the situation, to provide realistic expectations, and to relay when clinicians will be available to answer questions (Murray, 2008).

The perioperative nurse must be prepared for a variety of responses, both from the patient and from the family or significant others. Interaction with the patient before surgical intervention may be impossible because of the severity of the injury, prior intubation, or hemodynamic instability. The perioperative nurse will need to offer brief, simple instructions and explanations if the patient is conscious. These may include the following:

- Background noise as caregivers prepare for emergent intervention
- Perception of cold within the OR room
- Placement of safety and restraining straps, armboards, warming devices, and pneumatic compression stockings, for example
- Invasive interventions, such as additional IV access or arterial line monitoring

A reassuring touch or holding the patient's hand may be the only communication possible. Touch, placement of warm blankets, a gentle squeeze of the hand, and softly spoken words of reassurance are important comfort measures.

In accordance with hospital policies and procedures, the perioperative nurse may call the surgical waiting room with periodic updates on the patient's condition. The information shared is subject to the surgeon's discretion and is usually concise in nature, such as, "At this time the extent of injury is unknown; his/her condition is critical." When implemented, these contacts with family members are appreciated because frequently they were unable to see or speak with the patient before surgery.

All of the patient's injuries and possible subsequent complications may not be known at the time of operative intervention. The multiply injured patient frequently requires rehabilitation or an extended stay in a skilled nursing facility before discharge to home. In addition to coping with physical changes, some patients may experience posttraumatic stress disorder (Research Highlight). Continued therapy, such as neuropsychology (for cognitive impairment) or occupational and physical therapy, may be provided on an outpatient basis. Consequently, information regarding recovery and rehabilitation is limited on admission to the hospital. Many facilities have access to or provide support groups for patients and families related to the type of injury and its subsequent lifelong effects (Patient and Family Education).

End-of-Life Care

Unfortunately, some accidental injuries result in death. Many facilities have a chaplain or social worker available to assist family members during this time of crisis. These caregivers assist in the initial family contact and provide immediate support. Providing end-of-life care for patients and family is relevant, even in trauma situations. Trauma is different in that the patient and family do not have a prior relationship with the healthcare team. This makes it difficult for the team to know and/or understand the wishes and values of the patient and family. Jacobs and colleagues (2005) believed that there was a need to develop guidelines for end-of-life care that incorporates aspects of trauma into a model. The American Trauma Society (ATS) sponsored a Trauma Leadership Forum (TLF) to identify specific problems related to trauma and end-of-life issues.

RESEARCH HIGHLIGHT

Propranolol and the Prevention of Posttraumatic Stress Disorder

Posttraumatic stress disorder (PTSD) may be defined as the reexperiencing of a traumatic event that is accompanied by symptoms. Most research to date has been focused on treatment to reduce symptoms but currently some researchers are studying prevention of PTSD with the use of drugs to blunt its effects. Medications such as propranolol (a beta-blocker) have been shown to attenuate the memory of emotions associated with traumatic events. Current treatments include various forms of psychotherapy, but these methods can take months or even years to help the patient and are not routinely effective. There is a period shortly after a trauma in which the memory is encoded in the brain; the strength of the memory is directly related to the release of stress hormones such as adrenaline. Some research has shown that administration of a beta-blocker for a time before or after the trauma effectively decreases the strength of the memory. However, debate exists regarding the ethics of eliminating or decreasing a person's memory. In one study, participants were given a placebo or a beta-blocker and then asked to watch some stories. The placebo group had much stronger memory and response to the emotional story but both groups had equal recall of the emotionally neutral story. The future may see the use of beta-blockers in the ED to treat patients recently involved in a traumatic event but the ethical concerns about the risks and benefits of pharmacologic intervention need to be addressed first.

Modified from Henry M et al: Propranolol and the prevention of post-traumatic stress disorder: is it wrong to erase the sting of bad memories? *Am J Bioeth* 7(9):12-20, 2007.

PATIENT AND FAMILY EDUCATION

Psychoeducation for Survivors of Trauma

Psychoeducation that focuses on long-term effects of trauma helps by making symptoms understandable and manageable for the survivor and helps to minimize responses. The knowledge that a stress response is autonomic makes it more understandable and may give the survivor a sense of control over these responses. Education about the physiologic basis for symptoms such as mood instability, flashbacks, and depression allows the survivor to realize they are symptoms and not personal failings. Trauma education for the healthcare team assists them in assessing a person's behavior more accurately, intervening more appropriately, and showing more empathy. A second goal is to help family members understand normal responses, offer coping strategies, and identify responses that may indicate more help is required. Phoenix (2007) discusses three phases of response to traumatic events. The first, the impact phase, occurs at the scene and includes feelings of disorientation and responsibility for the event. During phase 2, or the immediate postevent phase, the survivors may experience denial, shock, flashbacks, and/or nightmares. Intense anger is normal at this phase and awareness of this may help survivors and their families avoid conflict or misunderstanding. Phase 3 is the prolonged recovery phase, during which memories should become less extreme over the first few months after the event. Nurses can assist survivors and their families by providing them with a range of coping strategies. Individual or group support systems, including spiritual, assist all involved toward recovery.

Modified from Phoenix BJ: Psychoeducation for survivors of trauma, *Perspect Psychiatr Care* 43(3):123-131, 2007.

A result of one of the forums was TELOS (Trauma End-of-Life Optimum Support), the primary goal of which is to standardize care given to trauma victims and their families from incident through the dying process. Healthcare professionals are obligated to support healthy survival as well as peaceful dying. According to Jacobs and colleagues (2005), "Even if the healing for certain patients is death, the dying process leading to ultimate healing, ought to be supported with compassion, care, comfort, and respect." This standard prompts the healthcare team, from the ED through the OR, to support the patient and family with honesty and truthfulness.

Critical Incident–Stress Debriefing

When the end result of a traumatic injury is death, it can be particularly difficult for the perioperative team, since most surgical interventions are of a curative or restorative nature. In many emergency medical systems, a critical incident–stress debriefing team exists. It is composed of mental health professionals and specially trained volunteers who are also professionals and peers in the healthcare field. Police officers, firefighters, paramedics, ED nurses, and ICU nurses may also be on the team. In the event of a particularly tragic death of a patient, the team can be contacted, and a meeting with that patient's care providers is arranged. The benefit of this team is enhanced when intervention is timely for the care providers. Opportunity for them to discuss their feelings and emotions is provided and encouraged as each provider discusses feelings related to personal participation in the care of the patient. Gray and Litz (2005) emphasize that critical incident–stress debriefing teams enhance coping mechanisms and can provide a healthy professional growth from what may otherwise be considered a tragedy.

Surgical Interventions

DAMAGE CONTROL SURGERY

Damage control surgery is a well-recognized surgical strategy that sacrifices complete, immediate repair to adequately address the physiologic impact of trauma and surgery. Damage control surgery is a series of operations performed to accomplish definitive repair of abdominal injuries with consideration of the patient's physiologic tolerance. The focus is on control of hemorrhage and contamination to stop bleeding and control any intestinal, biliary, or urinary leak into the abdominal cavity. Indications for the potential need for damage control surgery include hemodynamic instability, hemorrhagic shock, coagulopathy, hypotension, tachycardia, tachypnea, inaccessible major anatomic injury, concomitant major injury, and altered mental status.

Abdominal packing is the foundation principle of damage control surgery, first reported in the early twentieth century. Later reports detailed survival of patients with severe liver injuries that were packed. In 1981 a report described operative

management that included initial abandonment of laparotomy, use of intraabdominal packing, correction of coagulopathy and metabolic acidosis, and later reoperation for definitive repair (Germanos et al, 2008). The term "damage control" was first used in 1993 along with a detailed approach. The components are stop bleeding, close perforations; continue resuscitation, emphasizing correction of coagulopathy, acidosis, and hypothermia; plan reoperation for definitive repair.

There are five decision-making stages for damage control.

- *Stage 1*—Patient selection and decision to perform damage control: The emphasis is on early recognition for potential damage control surgery, including rapid transport to the hospital and early decisions related to control of hemorrhage.
- *Stage 2*—Operation and intraoperative reassessment of laparotomy: This consists of control of hemorrhage and contamination with rapid packing and temporary abdominal closure.
- *Stage 3*—Physiologic restoration in the intensive care unit: The focus here is restoration of physiologic status, which may include rewarming and fluid replacement.
- *Stage 4*—Return to OR for definitive procedures: The focus is on removal of packing, repair of injuries, and closure. Indications for emergency reoperation include massive ongoing bleeding, evidence of bowel leak or ischemic organ, and presence of abdominal compartment syndrome.
- *Stage 5*—Abdominal wall closure/reconstruction: It is not always possible to close the abdominal wall in stage 4, necessitating further repair.

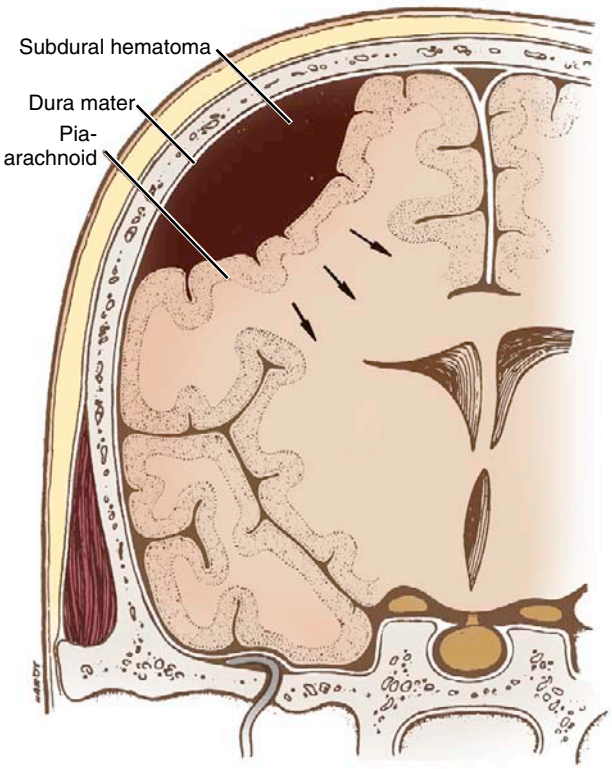


FIGURE 27-8 Subdural hematoma causing increased intracranial pressure with shifting of tissue.

INJURIES OF THE HEAD AND SPINAL COLUMN

Trauma to the head is responsible for half of all trauma deaths. Brain injury occurs either as a direct result of the trauma to the tissue or as a complication. Often, forces of energy from the impact are tolerated by the rigid skull, but the soft tissue of the brain is traumatized, resulting in the formation of subdural (Figure 27-8), epidural, or intracerebral hematomas. Blood clots are classified by their location in the brain and range from mild to life-threatening. A clot under the skull but on top of the dura is an epidural hematoma, which often results from a tear in an artery under the skull. A clot under the skull and dura but outside the brain is a subdural hematoma, often resulting from a tear in a vein or from a cut on the brain itself. An injury to the brain itself, a contusion, is an intracerebral hematoma, a result of a skull fracture or other blood clot causing swelling inside the brain. In addition, cerebral swelling can result in herniation of the brain despite treatment (Figure 27-9).

A baseline neurologic examination is extremely important. The pupils are examined, and the presence or absence of posturing is noted. The Glasgow Coma Scale (see Table 20-3) provides a universally accepted mechanism to assess the baseline data for the trauma team. However, in the presence of alcohol or drug intoxication or chemical paralysis, the scale cannot be used. For patients with a score of 8 or less, intubation with controlled ventilation is the immediate treatment of choice. In the highly combative patient, intubation may also be performed to allow adequate assessment of the extent of injury.

Previously, ICP hyperventilation was routinely used to decrease ICP in the initial management of patients with neurologic deterioration. No studies have shown improved outcomes for these patients, and other methods of assessment have shown that hyperventilation can cause significant constriction of cerebral vessels and may reduce cerebral blood flow to an ischemic level. One study has shown long-term improvement when hyperventilation was not used. Occasionally, hyperventilation may be necessary with persistently high ICP unresponsive to other treatment modalities.

An osmotic diuretic, such as mannitol, can be used in the treatment of ICP. Osmotic effects take place in 15 to 30 minutes (Hodgson and Kizior, 2009) and instigate an osmotic gradient to extract water from neurons. Osmotic diuretics such as mannitol have proven benefits in lowering ICP without reducing cerebral blood flow. They are given by bolus administration to create an acute reduction phase in ICP. These agents are excreted in the urine and cause a rise in serum and urine osmolality. Patients with serum osmolalities higher than 320 mOsm/kg (Kulaylat and Dayton, 2008) are at risk of acute tubular necrosis. Hypovolemia should be avoided with the infusion of isotonic fluids as necessary. Because such agents act quickly, fluid intake and output and the potential for fluid and electrolyte imbalances mandate close hemodynamic monitoring (Surgical Pharmacology). Elevating the head of the bed 30 degrees and keeping the patient's head midline (to promote venous drainage) can also be beneficial.

Skull fractures usually do not require operative intervention when there is no displacement and the fracture is linear. Depressed fractures or the presence of bone in the brain frequently requires elevation and debridement (Figure 27-10). Hematoma evacuation is based on its location as well as the size and number of hematomas present. Before performing a craniotomy or drilling a burr hole, the CT scan, the neurologic

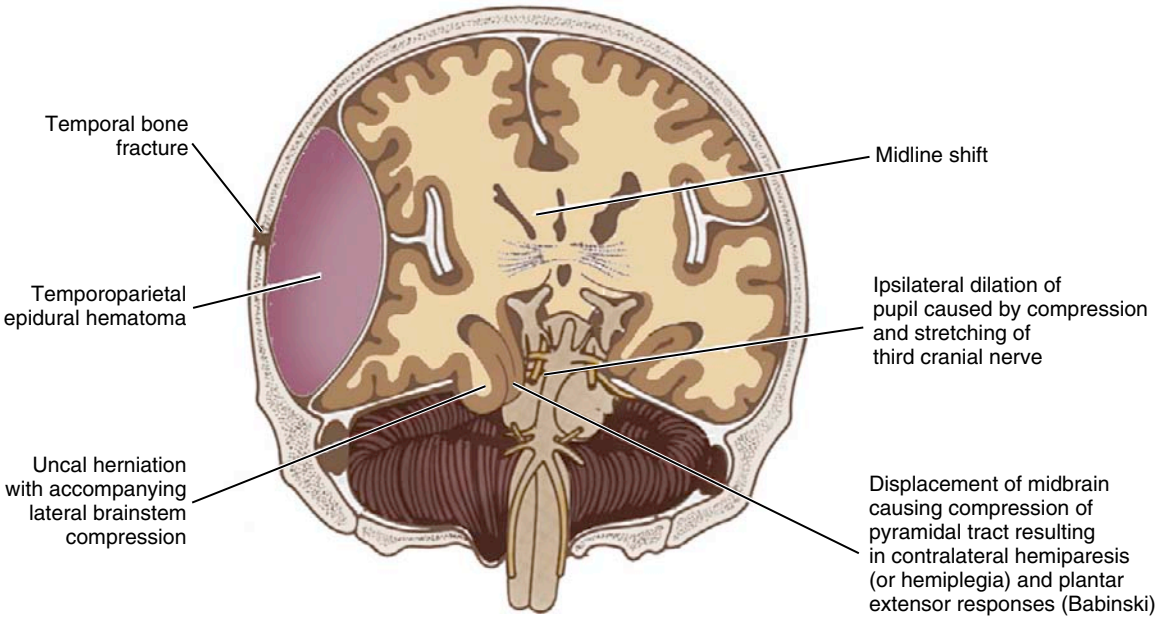


FIGURE 27-9 Cross section showing herniation of lower portion of temporal lobe (uncus) through tentorium caused by temporoparietal epidural hematoma. Herniation may occur also in cerebellum. Note mass effect and midline shift.

SURGICAL PHARMACOLOGY

Commonly Used Medications and Head Trauma

Trauma patients may have situations arise with the diagnosis of head trauma that require immediate attention at the scene, in the emergency department, and in the OR and ICU. With injury to the brain, swelling may occur quickly, requiring a host of aggressive decisions to manage increasing intracranial pressure (ICP). Increased ICP may result in changes in the patient's stability that make survival a priority, including instituting mechanical ventilation, monitoring intraventricular stability, and administering medications necessary to maintain hemodynamic stability. Familiarity with the medications frequently used with head trauma patients is vital.

Medication	Usual Dosage	Nursing Implications	Rationale for Use
BENZODIAZEPINES			
Midazolam (Versed)	0.05-0.1 mg/kg IV, may be repeated prn, not to exceed 6 mg for infants or 10 mg for children	Monitor patient for hypersensitivity. Monitor for hypotension, cardiorespiratory depression.	Use for sedation with patients having increased ICP, especially if on mechanical ventilation Adverse reactions can occur if patient not ventilated
Lorazepam (Ativan)	*Adult:* 4 mg/kg IV over 2-5 min, repeat in 10-15 min prn, not to exceed 8 mg/12 hr *Pediatric:* 0.05-0.1 mg/kg IV over 2-5 min, may be repeated in 10-15 min	Assess for continuing seizure activity. Monitor for hypotension, cardiorespiratory depression, CNS depression.	Long-acting benzodiazepine; used as anticonvulsant for immediate control of seizure activity
ANTICONVULSANTS			
Phenytoin (Dilantin)	*Adult:* Loading dose for status epilepticus: 15-20 mg/kg IV once or in divided doses, followed by 100-150 mg dose at 30-min intervals *Pediatric:* Loading dose 15-20 mg/kg IV once or in divided doses	Assess patient for seizure activity, description and duration of activity. Assess patient for hypotension during administration and do not exceed 50 mg/min for IV infusion. Monitor for interaction with other medications because it interacts and may precipitate in presence of some medications or fluids.	Prophylactic measure for patients at increased risk for seizure activity following head trauma May act on motor cortex to inhibit spread of seizure activity Preferred to phenobarbital because it does not cause as much CNS depression

Commonly Used Medications and Head Trauma—cont'd

Medication	Usual Dosage	Nursing Implications	Rationale for Use
DIURETICS			
Furosemide (Lasix)	*Adult:* 20-80 mg IV; may increase dose, not to exceed 600 mg/day *Pediatric:* 1-2 mg/kg IV every 6-12 hr	Monitor for hypotension. Note extent of diuresis. Watch for changes from initial assessment.	Loop diuretic helpful in decreasing ICP Influences CSF formation by affecting sodium-water movement across blood-brain barrier and shows preferential excretion of water over solute in distal tubule
Mannitol (Osmitrol)	*Adult:* 1.5-2 g/kg IV as 20% solution over 30 min *Pediatric:* 0.5-1 g/kg IV initial dose; 0.25-0.5 mg/kg IV every 4-6 hr	Careful evaluation of cardiovascular status: sudden increase in extracellular fluid may lead to fulminating CHF. If used every 4-6 hr, serum osmolality should be monitored and dose held if it exceeds 320 mOsm/kg.	Osmotic diuretic that lowers blood viscosity and produces cerebral vasoconstriction with normal cerebral blood flow; ICP decrease occurs subsequent to decrease in cerebral blood volume
BARBITURATES			
Thiopental (Pentothal sodium)	*Adult:* 75-250 mg/kg IV; repeat prn *Pediatric:* Induction 4-7 mg/kg IV	Monitor for myocardial depression, decreased cardiac output, and hypotension. Contraindicated with severe hypovolemia, unstable hemodynamics, inability to manage airway.	Use as an adjunct in management of elevated ICP Facilitates transmission of impulses from thalamus to cortex of brain, resulting in imbalance in central inhibitory and facilitatory mechanisms
Phenobarbital (Luminal)	*Adult:* 300-800 mg followed by 120-240 mg/kg IV at 20-min intervals until seizures controlled or total dose of 1-2 g administered *Pediatric:* Loading dose 15-20 mg/kg IV in single or divided doses	Monitor respiratory and cardiac function during loading dose; may cause drowsiness.	Adjunct for seizure control in patients with head trauma
NEUROMUSCULAR BLOCKERS			
Vecuronium (Norcuron)	*Adult:* 0.1 mg/kg IV *Pediatric:* Loading dose 0.08-0.1 mg/kg IV	Effect should be titrated to peripheral nerve stimulator. Concomitant administration of steroids may result in prolonged blockade despite withdrawal of agent.	Therapy directed at controlling ICP with multiple medications, including neuromuscular blockers Used as adjunct to sedative or hypnotic agent Facilitates endotracheal intubation and mechanical ventilation
Cisatracurium (Nimbex)	*Adult:* 0.10-0.2 mg/kg bolus; maintain at 2.5-3 mcg/kg/min *Pediatric:* 1 yr-23 mo: 0.15 mg/kg over 5-10 sec 2 yr-12 yr: .1-.15 mg/kg over 5-10 sec Infusion 3 mcg/kg/min; may titrate to 2 mcg/kg/min	Monitor blood pressure, heart rate, peripheral nerve stimulation, muscle twitching, and blood gases.	Used for control of refractory ICP, mechanical ventilation, and ease of endotracheal intubation Used as adjunct to sedative or hypnotic agent
SEDATIVE/HYPNOTIC/ AMNESIC			
Propofol (Diprivan)	100-200 mcg/kg/min *For general anesthesia:* *Adult:* 5 mcg/kg/min IV infusion for 5 min; titrate in 5-10 mcg/kg/min increments for desired sedation. Maintain at 5-50 mcg/kg/min or possibly higher	Monitor for hypotension, respiratory depression, decreased cerebral blood flow. Elderly or debilitated patients have increased risk of cardiorespiratory effects including hypotension, apnea, airway obstruction, and/or oxygen desaturation. May be used in pediatrics but with caution secondary to propofol infusion syndrome	Sedation for mechanically ventilated patient; titrated to achieve desired level of sedation Short-acting agent used for induction of general anesthesia; provides no analgesia

Modified from Association of periOperative Registered Nurses: *AORN drug information handbook for perioperative nursing,* Denver, 2006, AORN Lexi-Comp; Hodgson BB, Kizior RJ: *Saunder's nursing drug handbook,* St Louis, 2009, Saunders.

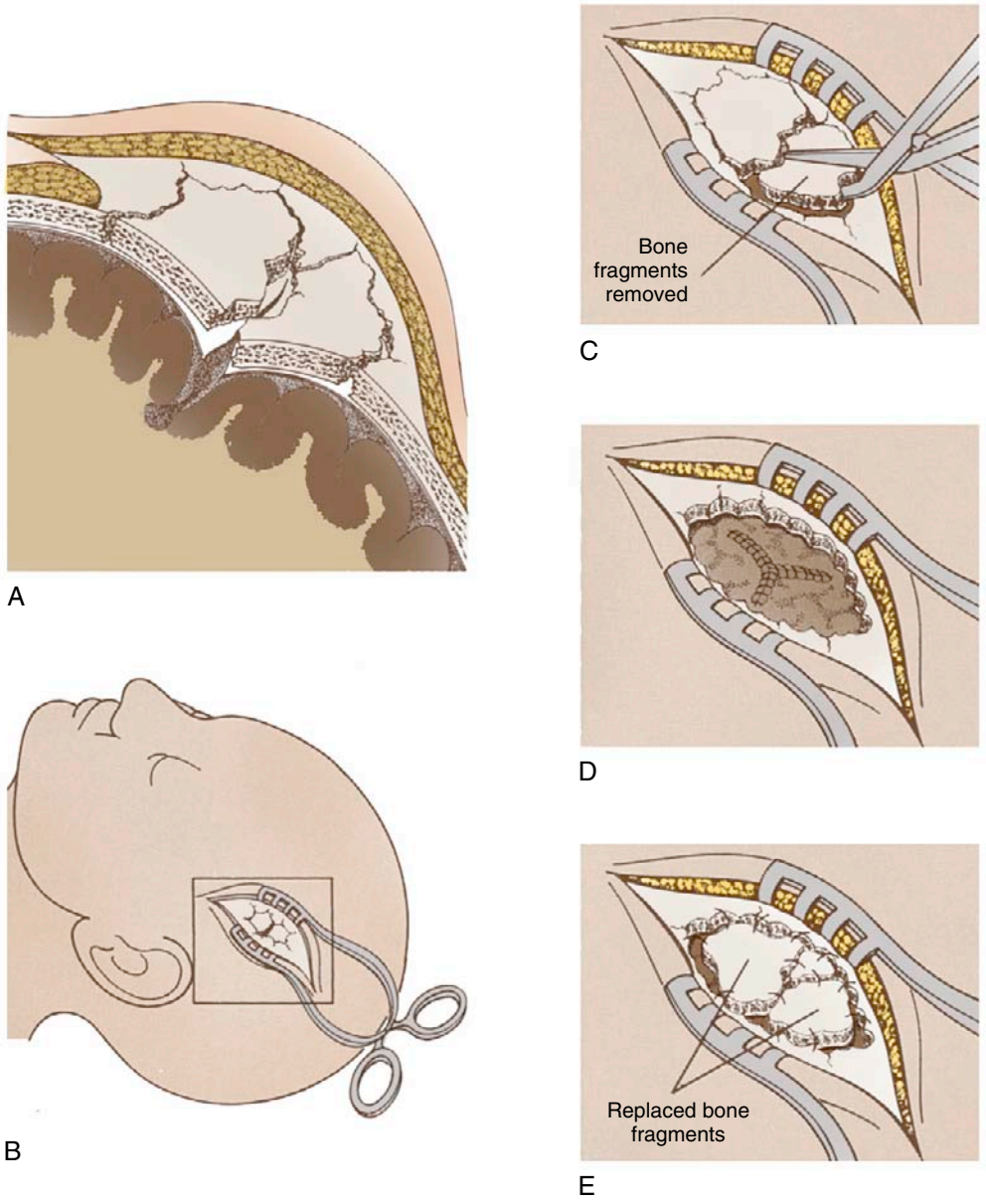


FIGURE 27-10 Treatment of compound depressed fracture of skull. **A**, Depressed skull fracture and scalp injury. **B**, Incision to expose fracture and remove the portion of the scalp that is devitalized. **C**, Removal of impacted bone by burr hole to locate and identify normal dura, followed by resection of bone fragments. **D**, Watertight closure of dura after brain debridement. **E**, Replacement and fixation of bone fragments.

status of the patient, the morbidity or mortality associated with the procedure, and the presence of other injuries or underlying medical problems, if known, are evaluated. An ICP monitor may be placed in the patient who is at risk for increased ICP. Chapter 20 discusses neurosurgical procedures.

The patient with a cervical spine injury at or near C3 to C5 is at great risk for respiratory difficulties because this is the area of diaphragmatic innervation. There is also the possibility of swelling above the area of injury, and the perioperative nurse should be alert for the potential of respiratory distress even if it is not initially present. A 24- to 48-hour dose of methylprednisolone (Solu-Medrol), calculated by body weight, is considered to decrease initial cord swelling.

The standard indicators of possible cord injury are absence of rectal tone and bradycardia in the presence of hypotension. The body's normal response is to increase heart rate in the presence of decreased blood flow or hypotension. These responses are not present in injury of the spinal cord, and vagal control results in bradycardia.

Injuries involving the spinal cord can range from complete transection, without hope of recovery, to a contusion of the cord. Fractures or dislocation of a vertebra can result in the

protrusion of small pieces into the spinal canal. This is known as a *burst fracture*. Several vertebrae may be fractured or have fractured components. Generally, in compression fractures, if the loss of vertebral height is more than 20%, surgical treatment may be indicated. Spinal bracing can be considered an option if the compression is less than 20% and no neurologic signs or symptoms are present. Cerebral arteriography may be used to screen patients with cervical vertebral fractures for blunt vertebral artery injuries (BVIs). Patients who sustain blunt trauma with unilateral headache or posterior neck pain, particularly if it is sharp, sudden, and severe, should be screened for BVIs and treated with anticoagulant therapy if not contraindicated (Inamasu and Guiot, 2006).

Treatment of spinal column fractures can involve surgery. Stabilization of the fracture may be necessary, depending on the severity of the injury. For cervical spine fractures, traction may be used initially to reduce the fracture, followed by surgical intervention as soon as the patient's condition permits. Internal fixation devices are discussed in Chapter 19.

INJURIES OF THE FACE

Motor vehicle crashes account for about 60% of maxillofacial injuries. Mandibular fractures alone are highly associated with assault as the MOI. In the patient who presents with facial injury, the airway must be secured. This requires ensuring patency and removing any items that pose the threat of aspiration. If a midface fracture is present, the anesthesia provider avoids nasogastric tube placement and nasotracheal intubation. A tracheostomy may need to be performed before initiation of the operative procedure. Control of scalp or facial hemorrhage can be achieved through a pressure dressing until surgical intervention is possible, since exsanguinations can occur. Treatment of the fracture may be delayed until the immediate life threats have been successfully managed. Goals of operative intervention are to reduce and immobilize the fracture, prevent infection, and restore facial cosmesis and function.

Facial fractures can be categorized into Le Fort I, II, or III (Figure 27-11). A Le Fort I fracture is the most common maxillary fracture. It involves a horizontal interruption of the anterior and lateral wall of the maxillary sinus. Le Fort II is a pyramidal fracture along the maxilla and lacrimal bones and through the infraorbital rim. Le Fort III is otherwise known as *craniofacial disjunction*. The midface is completely disengaged from the cranial base, resulting from a fracture across the frontomaxillary sutures. Specific information regarding these injuries is in Chapter 21.

INJURIES OF THE EYE

Injuries to the eye can result from blunt or penetrating types of trauma. Penetrating objects in the globe are stabilized and not removed until the patient is in the OR. These injuries threaten loss of vision because of the injury itself, inflammation, or infection. Blunt injury to the eye can result in hematomas and accompanying fractures. A blow-out fracture is the result of a blunt force to the eye that pushes soft tissue through the thin bony orbital floor. The patient has recession of the eye into the orbit and loses the ability to gaze upward. Surgical repair is often indicated. Chapter 17 discusses ophthalmic procedures.

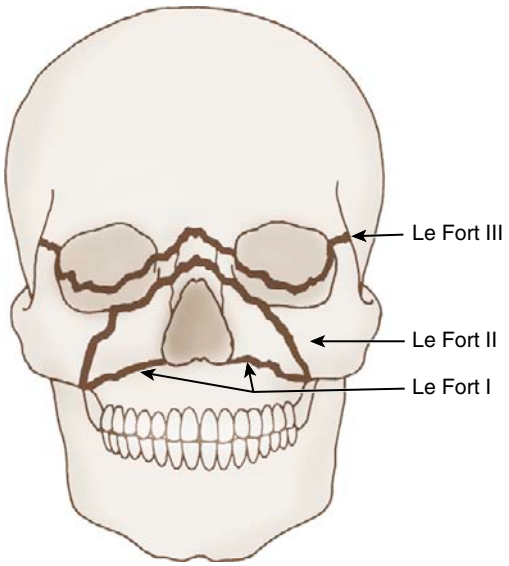


FIGURE 27-11 Le Fort classification of maxillary fractures.

INJURIES OF THE NECK

Injury to the neck and soft tissue structures is most commonly a result of penetrating trauma. The neck can be divided into three zones with respect to injury and consequence. Zone I is the base of the neck below the clavicles. Anatomic structures located in this region are the great vessels and aortic arch, innominate veins, trachea, esophagus, and lungs. Zone II is the area in the middle of the neck between the clavicles and the mandible. Structures located in this area include the carotid artery, internal jugular vein, trachea, and esophagus. Zone III is located between the angle of the mandible and the base of the skull. The primary target of evaluation in these injuries is vascular structures.

Zone II injuries may necessitate an otorhinolaryngology specialist. Penetrating injuries to the larynx and trachea can be primarily repaired. Blunt force to the larynx can result in a fracture and impose immediate airway obstruction. These patients require immediate tracheotomy followed by repair of the fracture when it is unstable or displaced. Chapter 18 provides specific information concerning otorhinolaryngologic procedures.

INJURIES OF THE CHEST AND HEART

Trauma to the chest area is the primary cause of death in approximately 25% of trauma victims. Blunt trauma is most often associated with high-speed motor vehicle crashes. Penetrating traumas may be associated with violent crimes. Penetrating injuries at or immediately below the nipple line or level of the scapular tips are evaluated for both chest and abdominal involvement. Diaphragmatic injury is also a possibility.

Deceleration injury, such as that occurring from a fall or from striking the steering wheel in a motor vehicle crash, may cause contusions of the chest wall, fractures of the ribs or sternum, contusions of the heart or lungs, or rupture of the aorta and other major vessels. Rib fractures are also associated with a hemothorax or pneumothorax. A flail-chest segment may result when two or more adjacent ribs are broken in two or more places. This results in paradoxical chest wall movement

as a result of loss of bony support; that is, the affected segment of the chest wall will move in the opposite direction. If respiratory distress and diminished breath sounds are present, a chest tube is indicated immediately; an autotransfusion chest drainage device is also considered. Chest tube output must be closely monitored intraoperatively because accumulation of 1000 to 1500 ml of blood is an indication for chest exploration. Penetrating wounds, as a result of either gunshot or stab injuries, may cause hemothorax and pneumothorax as well. Lacerations or perforation of the lung, heart, great vessels, trachea, esophagus, and bronchus is possible.

Myocardial contusion usually involves the right ventricle and can be evidenced by dysrhythmias on patient arrival or shortly thereafter. The patient is monitored on a telemetry unit, and surgical intervention is not required. Rupture of a heart valve can occur, depending on the timing of the contusion in relation to the phase of the cardiac cycle. If valve rupture has occurred, surgical repair is necessary. Heart sounds should be evaluated during the secondary assessment to document the presence or absence of murmurs. Heart valve rupture can occur as a late complication of myocardial contusion. Pericardiocentesis is performed for signs and symptoms of pericardial tamponade (Figure 27-12), which include jugular venous distention, muffled heart sounds, and a narrowing pulse pressure. Patients may present to the OR for a pericardial window either emergently or during the recovery phase.

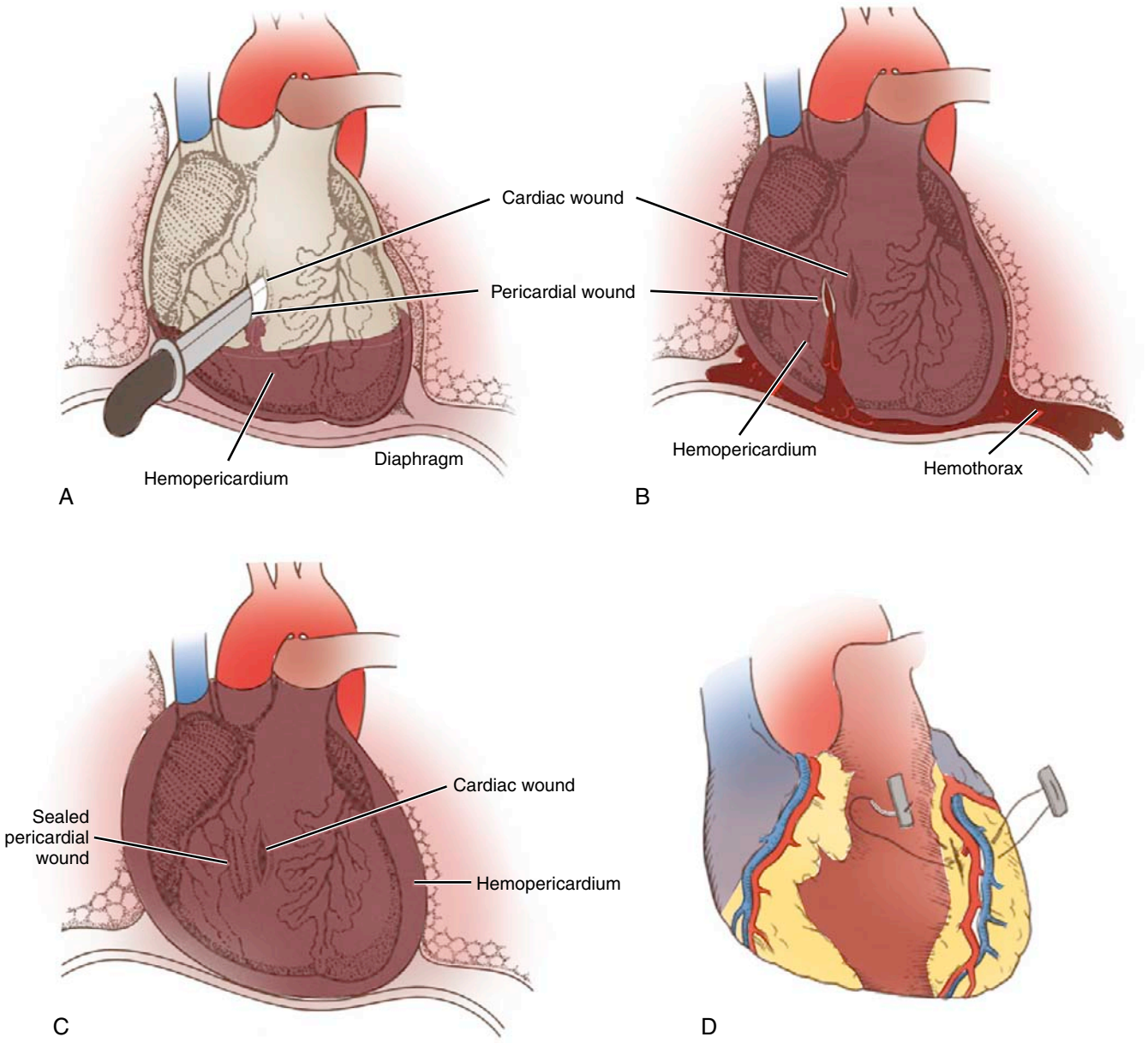


FIGURE 27-12 **A**, Cardiac injury with pericardial disruption. **B**, Bleeding from heart through pericardial tear into pleural space. **C**, Self-sealing of pericardial wound resulting in pericardial tamponade. **D**, Sutured cardiac wound.

An emergency thoracotomy may be indicated in the patient with penetrating trauma to the chest in full arrest or pulseless electrical activity on ECG. If a laceration to the heart is suspected and the patient is rapidly deteriorating, a thoracotomy may be performed in the ED. The laceration may be primarily repaired and the patient transferred to the OR for irrigation, wound debridement, and closure. Otherwise, surgical intervention is initiated in the OR. Wounds located across the mediastinum accompanied by hemodynamic instability, massive penetrating lung injuries, and disruption of the trachea, bronchus, or esophagus also require surgical intervention. Rupture of the thoracic aorta is another injury requiring surgical intervention and includes the use of extracorporeal bypass. This injury is an obvious life threat but may be difficult to diagnose. An arch aortogram is indicated in trauma patients who may have sustained such an injury. Rupture of the thoracic arch is associated with first rib or sternal fractures. Chapters 22 and 24 provide additional information about associated surgical procedures in thoracic and cardiac surgery, respectively.

INJURIES OF THE ABDOMEN

The spleen is the most common organ injured in blunt trauma, and the liver, because of its large size, is the most common organ injured in penetrating trauma. Historically, initial efforts were aimed at performing splenectomy with splenic injury. However, because of the role of the spleen in the body's defense against infection, the surgeon makes every effort to control hemorrhage in the spleen and avoid its removal. Treatment is determined by the condition of the spleen and of the patient. Injury to the spleen occurs with deceleration injuries, resulting in fracture of the organ because of its multiple fixation points. Splenic injury may be associated with fractures of the left tenth through twelfth ribs. The patient may exhibit left shoulder pain (Kehr's sign), upper left quadrant tenderness, abdominal wall muscle rigidity, spasm or involuntary guarding, and/or signs and symptoms of hemorrhage and hypovolemic shock. Splenic injuries (Table 27-10) range from laceration of the capsule to ruptured subcapsular hematomas or parenchymal laceration. The most serious injury is a severely fractured spleen or vascular tear, producing massive blood loss and splenic ischemia. Rupture of the spleen can be immediate or delayed. Splenic lacerations may be treated nonoperatively by close monitoring and bed rest or operatively for lacerations of a more severe nature. The surgeon creates a midline incision, which allows for exposure of all abdominal contents. Topical hemostatic agents are also used with success, as well as suturing and the argon laser in some instances. In some cases, angiographic embolization may be attempted. A laceration involving the splenic hilum or complete shattering of the organ usually results in splenectomy.

The severity of hepatic injury ranges from controlled hematoma to severe vascular injury of the hepatic veins or hepatic avulsion (Table 27-11). Because liver tissue is so friable and has an extensive blood supply as well as blood storage capacity, hepatic injuries often result in profuse hemorrhage and require surgical control of bleeding. The patient usually exhibits upper quadrant pain, abdominal wall muscle rigidity, involuntary guarding, rebound tenderness, hypoactive or absent bowel sounds, and signs of hemorrhage or hypovolemic shock. Nonoperative treatment is indicated in minor capsular and subcapsular injuries. This can be accomplished with bed rest and close monitoring. Topical hemostatic agents and suturing are used in management of minor injuries. Fibrin glue is also used in some institutions as a topical hemostatic agent. More severe injuries with active expanding hematomas or lobe disruption require surgical exploration and may necessitate hepatic resection or ligation of associated vasculature. With massive hemorrhage, control of bleeding is the primary concern. Packing with laparotomy sponges may be indicated, along with manual compression of the organ if intraoperative hypotension becomes severe. A pressure dressing may be applied and the wound closed temporarily until associated coagulopathies, hypothermia, and hemodynamic instability can be corrected. The patient is usually returned to the OR within 24 to 72 hours postoperatively or when his or her condition permits further exploration and removal of the sponges.

Injuries to the gastrointestinal system are also associated with abdominal trauma. Bowel injuries may be missed on abdominal CT scan during the initial diagnostic period. The small bowel is frequently injured because deceleration may

TABLE 27-10

Splenic Injury Scale

Grade	Type of Injury	Description of Injury
I	Hematoma	Subcapsular: <10% of surface area
	Laceration	Capsular tear: <1 cm parenchymal depth
II	Hematoma	Subcapsular: 10%-50% of surface area; intraparenchymal: <5 cm in diameter
	Laceration	Capsular tear: 1-3 cm; parenchymal depth that does not involve a trabecular vessel
III	Hematoma	Subcapsular: >50% of surface area or expanding; ruptured subcapsular or parenchymal hematoma; intraparenchymal hematoma; >5 cm or expanding
	Laceration	>3 cm parenchymal depth or involving parenchymal vessels
IV	Laceration	Laceration involving segmental or hilar vessels, producing major devascularization (>25% of spleen)
V	Laceration	Completely shattered spleen
	Vascular	Hilar vascular injury that devascularizes spleen

Modified from Hoyt DB et al: Management of acute trauma. In Townsend CM et al, editors: *Sabiston textbook of surgery,* ed 18, Philadelphia, 2008, Saunders.

TABLE 27-11

Liver Injury Scale

Grade	Type of Injury	Description of Injury
I	Hematoma	Subcapsular: <10% of surface area
	Laceration	Capsular tear: <1 cm parenchymal depth
II	Hematoma	Subcapsular: 10%-50% of surface area; intraparenchymal: <10 cm in diameter
	Laceration	Capsular tear: 1-3 cm parenchymal depth; <10 cm in length
III	Hematoma	Subcapsular: >50% surface area of ruptured subcapsular or parenchymal hematoma; intraparenchymal hematoma: <10 cm or expanding
	Laceration	>3 cm parenchymal depth
IV	Laceration	Parenchymal disruption involving 25%-75% of hepatic lobe or 1-3 of 8 Couinaud segments
V	Laceration	Parenchymal disruption involving >75% of hepatic lobe or >3 of 8 Couinaud segments within a single lobe
	Vascular	Juxtahepatic venous injuries (i.e., retrohepatic vena cava/central major hepatic veins)
VI	Vascular	Hepatic avulsion

Modified from Hoyt DB et al: Management of acute trauma. In Townsend CM et al, editors: *Sabiston textbook of surgery,* ed 18, Philadelphia, 2008, Saunders.

lead to shearing, which causes avulsion or tearing. The most commonly affected areas of the small bowel are areas relatively fixed or looped. Associated with any perforation of the gastrointestinal tract is a chance for peritonitis and sepsis or compartment syndrome from increased pressure. Crystalloid resuscitation and capillary leakage contribute to tissue swelling. The resulting abdominal edema creates a pressurized compartment that must be explored to render relief to the compromised organs.

If the abdomen is difficult to close, alternative wound closure techniques may be used to prevent the occurrence of abdominal compartment syndrome. One such method is to use a silo-bag closure, in which heavy plastic is trimmed to fit and sutured to skin edges (Figure 27-13). A sterile absorbent drape may also be placed inside the abdomen to absorb fluid.

In the event of a penetrating injury, the trajectory of the missile or the implement is examined, and organs within the area are considered potentially injured. Exploration is indicated, and the components of the gastrointestinal system are thoroughly examined for any perforations, contusion, hemorrhage, or compromise of vasculature, such as a mesenteric hematoma. Once the injury is identified, suturing, stapling, or segmental excision may be indicated. Chapter 10 discusses gastrointestinal surgery and Chapter 11 addresses surgery of the liver, biliary tract, pancreas, and spleen.

Diagnostic laparoscopy is frequently used for direct visualization of abdominal organs to decrease the need for open abdominal exploration. This procedure allows the surgeon to effectively evaluate the presence of any injury and develop an appropriate plan of treatment in the stable patient. However, there is some concern that bowel injuries may not always be identified. Some therapeutic interventions may also be performed through the laparoscope so that the more invasive open approach is avoided. Increased intraabdominal pressure required in laparoscopic insufflation may create an adverse ventilatory effect. In the presence of abdominal vein injury with low pressures, CO_2 could leak into the vasculature and result in CO_2 emboli to the heart or lungs. Tension pneumothorax may be created in patients with a diaphragmatic injury. Consequently, indications for these procedures in the trauma setting continue to be evaluated.

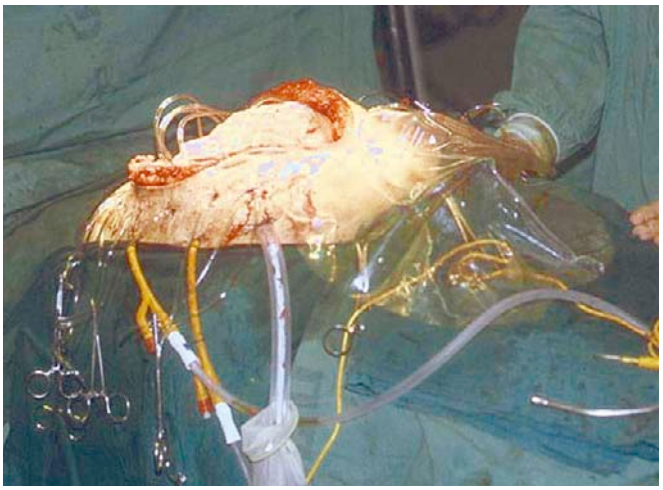


FIGURE 27-13 Alternative technique using plastic for temporary closure of the abdomen.

INJURIES OF THE GENITOURINARY SYSTEM

Laceration of the kidney is closely associated with fracture of the ribs and transverse vertebral processes (Table 27-12). Because the kidney is retroperitoneal, the presence of bleeding may not be observed on diagnostic peritoneal lavage. Renal contusions often produce hematuria. Gross clots may also be seen in more serious injury, but it should be noted that hematuria is not present in a complete avulsion injury. Management of renal contusions can be nonoperative with monitoring of hematuria. Lacerations involving the collecting system, severe crush injuries, or pedicle injuries necessitate surgical intervention (Figure 27-14). Nephrectomy may be indicated with severe injury of the pedicle or massive hemorrhage.

Rupture of the bladder and urethral injury are most often associated with pelvic fractures. Both blunt trauma and penetrating trauma are causative factors. The type of bladder injury is a direct result of the amount of urine present in the bladder at the time of injury. Blunt forces applied to a full bladder result in an intraperitoneal rupture. This type of rupture is closely associated with alcohol consumption because of alcohol's

TABLE 27-12

Renal Injury Scale

Grade	Type of Injury	Description of Injury
I	Contusion	Normal urinalysis except possible microscopic or gross hematuria
	Hematoma	Subcapsular, no parenchymal laceration
II	Hematoma	Perirenal, confined to renal retroperitoneum
	Laceration	>1 cm depth of renal cortex
III	Laceration	>1 cm parenchymal depth of renal cortex
IV	Laceration	Extends through cortex, medulla, and collecting system
	Vascular	Involves main renal artery or vein
V	Vascular	Completely shattered kidney Includes avulsion of renal hilum, which devascularizes kidney

Modified from Emergency Nurses Association (ENA): *Trauma nursing core course,* ed 6, Des Plaines, Ill, 2007, Author.

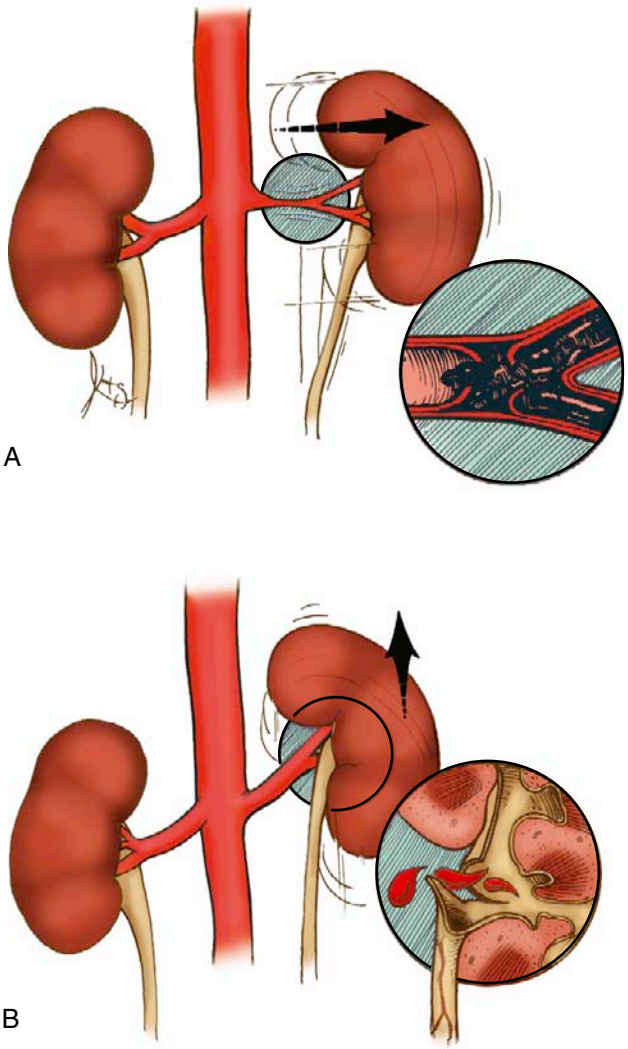


FIGURE 27-14 Renal injuries. Acceleration-deceleration injury may produce disruption of the (**A**) renal artery and the (**B**) ureteropelvic junction.

FIGURE 27-15 Complete urethral injury as demonstrated on urethrogram.

diuretic effect. Pelvic fracture is associated with an extraperitoneal bladder rupture. Most often these patients present with gross hematuria. A small extraperitoneal rupture may be managed by urinary catheter drainage. A large extraperitoneal rupture and intraperitoneal rupture require surgical intervention. A suprapubic cystostomy tube may be placed, and the bladder is repaired. Pelvic fracture reduction and fixation are also performed.

Urethral injuries require exploration and primary repair. These types of injuries are more common in the male because the male urethra is longer and less protected than the female urethra (Figure 27-15). A fall or straddle type of injury is usually responsible. This injury is detected by the presence of blood at the urinary meatus. In these instances an indwelling urethral catheter should not be inserted. Blood at the urinary meatus may indicate a tear in the anterior urethra. A retrograde urethrogram may be performed to evaluate for extravasation of urine and potential injury. Suspicion of a pelvic fracture raises the index of suspicion of a concomitant urethral injury. Chapter 14 provides additional information on urologic procedures.

SKELETAL INJURIES

Trauma to the skeletal system usually results in contusion or fracture. After stabilization of the patient, radiographs are taken of any body part that is distorted, edematous, painful, or highly suspicious for fracture or dislocation. Treatment of fractures is aimed at restoring function with a minimum of complications. Immobilization of fractures can be accomplished by casting, bracing, splinting, application of traction, or hardware fixation. Femur fractures in particular can be associated with a high risk of hemorrhage and require traction before surgical repair. Closed and open reductions, application of internal

and external fixators, and some types of traction may be performed in the OR. The perioperative nurse involved in care of the trauma patient must have a working knowledge of orthopedics. Fractures must be repaired in a timely manner to avoid untoward complications; however, immediate life threats are corrected first. Open fractures are at an increased risk of infection. Chapter 19 contains information on the surgical procedures used in fracture management.

Pelvic fractures may pose an additional challenge to the perioperative team. Fractures within the pelvic ring are associated with significant internal blood loss and shock. Systemic peripheral vascular resistance is increased. A method to quickly minimize or tamponade blood loss in severe pelvic fractures is the application of a pneumatic antishock garment (PASG) or PASG trousers to provide stabilization of the fracture and reduce associated hemorrhage. The use of PASG trousers may be effective in patients who are 20 to 40 minutes away from the hospital and have unstable pelvic fractures and decompensated shock (Salomone et al, 2005). If a pneumatic garment is applied, the patient may be transported to the OR with the trousers still inflated. The perioperative nurse must be familiar with deflation procedures. The attending anesthesia provider directs deflation in collaboration with the surgeon. Blood pressure and other vital signs are closely monitored. The abdominal compartment is deflated first. Deflation continues slowly while IV fluids are infused to maintain blood pressure. A 5 mm Hg drop in blood pressure requires fluid resuscitation of approximately 200 ml before deflation of the next compartment. If the patient remains stable, each leg compartment is deflated slowly, one at a time.

Some trauma centers apply external fixator devices in the ED during initial resuscitation. A pelvic C-clamp, sheet wrap, or a commercially available support binder may be used for initial stabilization of pelvic fractures. Severe hemorrhage associated with the fracture may be controlled by arterial embolization performed in the radiology department if surgical intervention for fracture fixation must be delayed.

Soft tissue injuries of an extremity are subject to compartment syndrome. This is a result of swelling of the soft tissues and muscles encased in the fascia. With a significant amount of swelling, pain is increased and the surrounding circulation may be compromised. The patient may experience a decrease in motor and sensory function. This injury must be treated surgically by a fasciotomy. Incising the fascia allows space for tissue swelling. Several days later, the patient returns to the OR for closure, which may require skin grafting for complete coverage.

HYPOTHERMIA

When trauma is involved, hypothermia often begins at the time of injury, related to heat loss through conduction and convection. A core body temperature of 32° C (89.6° F) is associated with a nearly 100% mortality rate (Moore, 2008). Moore (2008) reviewed a study designed to determine if trauma nurses check the patient's temperature during the secondary assessment. Only 40% of the patients had their temperature checked and of these 33% were hypothermic. Starting hypothermia prevention at the trauma scene and continuing measures to prevent hypothermia throughout surgery and into the ICU continue to be the recommended best practice.

For purposes of definition, generalized hypothermia is considered to be present when the core temperature is below 36° C (96.8° F). (See Chapter 9 for discussion of the prevention of inadvertent hypothermia in adult surgical patients.) Hypothermia can be classified into three types. *Mild hypothermia* is a core temperature between 32° and 36° C (89.6° and 96.8° F). These patients may appear gray and are cool to the touch. Some alterations in level of consciousness can be present. If the patient's clothing is wet, the nurse should remove it and cover the patient with warm blankets. Treatment is aimed at passive rewarming of the patient by means of warm ambient room temperature, warm fluids, and infrared radiant energy lights. *Moderate hypothermia* is characterized as core temperatures between 30° and 32° C (86° and 89.6° F). Warmed fluids are given by IV line and also by gastric or peritoneal lavage. In addition, a warming blanket, such as a forced air–warming device, may be used. Immersion in a Hubbard tank filled with warm water has also been successful. An irritable myocardium may cause dysrhythmias to be present. Shivering may or may not be present. If the patient is intubated, warmed, humidified gases can be administered. *Severe hypothermia* is diagnosed in the patient with a temperature below 30° C (86° F). The heart rate and the respiratory rate are greatly decreased. This patient is comatose, often appears deceased, and requires active rewarming processes. It is advisable to warm the core first to avoid complications associated with rewarming. This can best be accomplished by using cardiopulmonary bypass (CPB), which directly warms internal vital organs, including the heart. The patient should be handled gently during transfers to avoid further tissue injury and stimulation of an irritable myocardium.

In the trauma patient, hypothermia may be potentiated by hypovolemia, hypotension, and shock. Cold hemoglobin cannot release oxygen to tissue as readily as normothermic hemoglobin and decreased circulating volume related to hemorrhage reduces oxygen delivery to the tissues. The combination of hypothermia, acidosis, and coagulopathy is known as the trauma triad of death (Solheim, 2008). The three parts of the triad have a complex relationship; each may be influenced by the other and often results in high mortality if not interrupted. In hypoperfusion, cells burn glucose for energy (lactic acidosis), which increases total blood acidity (metabolic acidosis). Hypoperfusion may also halt the coagulation cascade (coagulopathy), thus triggering the triad. Hypothermia also affects other body systems already compromised by the trauma. At a core temperature of less than 30° C (86° F), atrial fibrillation is common; when the core temperature is below 25° C, the heart automatically converts to ventricular fibrillation (Moore, 2008). Cerebral blood flow is highly sensitive to hypothermia and the patient may appear to be dead. Resuscitation measures are ceased if the patient is rewarmed to at least 35° C (97° F) and cardiac functions remain nonexistent.

THERMAL INJURIES

Heat and cold exposure injuries require prompt initial management in the ED setting. Some institutions transfer pediatric burn patients and severely burned adult patients to a burn center for treatment once the patients' conditions are stabilized. In addition to treatment of the site of injury to decrease further tissue damage, fluid management is of the utmost importance in

these patients. After hemodynamic stabilization of the patient, burn and frostbite wounds usually require a series of procedures. These patients may have multiple surgical debridement procedures before skin grafting and cosmetic interventions. Restoration of function is important. Circumferential burns may restrict the neurovascular structures during eschar formation. Chest burns with eschar may restrict movement of the chest wall and ventilatory function. An escharotomy (incision of the eschar) may be performed to alleviate the constriction. If necessary, this procedure may be performed at the bedside and the perioperative team may be asked to assist.

ORGAN AND TISSUE PROCUREMENT

As previously noted, trauma primarily affects young people. In the event that resuscitation efforts or surgical interventions are not successful, the patient may be declared dead. Depending on the cause of death and preexisting medical conditions, the patient may be an organ-donor candidate. Both federal and state laws mandate that local organ-procurement facilities are notified of potential donors and that families are informed that organ donation exists as an option. Organ-donation agencies can be contacted early and will assist in assessing the potential donor, as well as providing a protocol for donor management once the patient is declared dead. Brain death criteria for organ donation began around 1968, attributed to the Harvard Ad Hoc Committee on Brain Death. Most organ donations in this country are from patients who experience brain death. In 1980 the Uniform Declaration of Death Act offered an additional option: cardiopulmonary death, defined as irreversible cessation of circulatory and respiratory function. This may present an ethical dilemma to some perioperative nurses. With brain death, the physician declares the patient dead in the intensive care unit (ICU) and the family is offered an opportunity to say goodbye. The patient arrives in the OR on a ventilator, which is deactivated when the organs have been retrieved. In cardiopulmonary death, the physician accompanies the patient to the OR, the ventilator is deactivated, the staff wait for cessation of circulatory and respiratory function, and death is declared at that time (Saver, 2007). Definitions of brain and cardiopulmonary death are not uniform throughout the United States. The perioperative nurse should be familiar with the state's definitions of brain and cardiopulmonary death and the institution's criteria for the declaration.

Once a patient is declared dead and becomes a potential organ donor, the patient's family does not incur any financial costs acquired from that point. The patient is not disfigured in any way that will interfere with bereavement rituals.

A transplantation coordinator assists in managing the organ-donor patient in the ICU setting until the procurement teams arrive. The perioperative nurse must prepare for the organ-procurement procedure. The harvesting of organs and tissue may take several hours and additional members of the perioperative team. Different organ-procurement agencies will provide a surgical team, but additional scrub and circulating personnel are needed. The transplantation coordinators actively seek tissue and organ recipients during the harvest procedure. Most organ-transplantation agencies contact the institution and provide follow-up information regarding the ultimate success of the transplantation procedures and information about the recipients.

The heart is removed first, followed by the lungs, pancreas, liver, and kidneys. Tissue dissection is performed in such a manner as to allow for optimal organ transplantation. Sterile technique remains important. In addition, traffic control is of concern during these procedures. Traffic should be limited to essential personnel. Bone, skin, and corneas can also be removed. Some procurement agencies remove bone and corneas in the morgue rather than in the OR.

REFERENCES

Association of periOperative Registered Nurses (AORN): Counts-sponges, sharps and instruments recommended practice. In *Perioperative standards and recommended practices*, Denver, 2009, The Association.

Barclay L: *Guidelines issued for field triage of injured patients*, 2009, Medscape Medical News, available at www.medscape.com/viewarticle/587447. Accessed February 16, 2009.

Born CT: Blast trauma: the fourth weapon of mass destruction, *Scand J Surg* 94(4):279–285, 2005.

Cunningham AR: FAST scan: ultrasound's role in trauma, *Radiol Technol* 79(5):455–457, 2008.

Cusick SS, Tibbles CD: Trauma in pregnancy, *Emerg Med Clin North Am* 25:861–872, 2007.

Emergency Nurses Association: *Trauma nursing core course*, 6th ed, Des Plaines, Ill, 2007, Author.

Germanos S et al: Damage control surgery in the abdomen: an approach for the management of severely injured patients, *Int J Surg* 6:246–252, 2008.

Gray MJ, Litz BT: Behavioral interventions for recent trauma: empirically informed practice guidelines, *Behav Modif* 29(1):189–215, 2005.

Hodgson BB, Kizior RJ: *Saunder's nursing drug handbook*, St Louis, 2009, Saunders.

Inamasu J, Guiot BH: Vertebral artery injury after blunt cervical trauma: an update, *Surg Neurol* 65(3):238–245, 2006.

Jacobs LM et al: A plan to improve end-of-life care for trauma victims and their families, *J Trauma Nurs* 12(3):73–76, 2005.

Kulaylat MN, Dayton MT: Surgical complications, In Townsend CM et al, editors: *Sabiston textbook of surgery*, ed 18, Philadelphia, 2008, Saunders.

Malone D et al: Massive transfusion practices around the globe and a suggestion for a common mass transfusion protocol, *J Trauma* 60 (6 Suppl):S91–96, 2006.

Meier C et al: Early placement of optional vena cava filter in high-risk patients with traumatic brain injury, *EurJ Trauma Emerg Surg* 33(4): 407–413, 2007.

Moore K: Hypothermia in trauma, *J Trauma Nurs* 15(2):62–64, 2008.

Muir M, Archer-Heese G: Essentials of a bariatric patient handling program, *Online Journal of Issues in Nursing* 14(1), 2009.

Murray MA: A question of evidence: decision-making in palliative care nursing, *Int J Palliat Nur* 14(1):45–46, 2008.

Nessen S et al: Acute resuscitation and critical care: massive blood transfusion in patient with hemoperitoneum. In Nessen S et al: War surgery in Afghanistan and Iraq a series of cases, 2003-2007, USA, 2008, Department of the Army.

Plummer E: Trauma in the elderly. In McQuillan KA et al, editors: *Trauma nursing: from resuscitation through rehabilitation*, ed 4, St Louis, 2009, Saunders.

Salomone JP et al: Opinions of trauma practitioners regarding prehospital interventions for critically injured patients, *J Trauma* 58(3):509–515, 2005.

Saver C: Being prepared for donation after cardiac death, *OR Manager* 23(10):18–21, 2007.

Sharma AM: Managing weighty issues on lean evidence: the challenges of bariatric medicine, *CMAJ* 172(1):30–31, 2005.

Solheim J: *The trauma triad of death: hypothermia, acidosis, and coagulopathy,* 2008, available at www.ena.org/conferences/annual/2008/handouts/218-c.pdf. Accessed March 15, 2009.

Vegar-Brozovic V et al: Intra-abdominal hypertension: pulmonary and cerebral complications, *Transplant Proc* 40:1190–1192, 2008.

CHAPTER 28

Interventional Radiology

KATHLEEN A. GROSS

Interventional radiology (IR) is the medical specialty devoted to advancing patient care through the innovative integration of clinical and imaging-based diagnosis and minimally invasive therapy (Society of Interventional Radiology [SIR], 2005). Interventional radiology procedures offer many advantages for the appropriate patient and are commonly performed because they are less invasive when compared to surgical procedures.

The specialty of radiology is subdivided into many modalities—namely, diagnostic radiology, computed tomography (CT), positron emission tomography (PET), nuclear medicine, ultrasound, interventional radiology, and magnetic resonance imaging (MRI). Procedures vary from diagnostic procedures to therapeutic and/or palliative procedures. Today, combinations of imaging are frequently employed in the imaging environment. Imaging studies, including CT, MRI, diagnostic imaging, and interventional radiology, play an important role in the determination of patient care and treatment. The interventional radiologist uses all available information to determine a minimally invasive treatment approach.

The list of reasons for IR continues to grow as less invasive means are preferred by patients, providers, and payors. An interventional procedure is performed by a team of healthcare providers, namely, the interventional radiologist(s), radiology nurse(s), and interventional radiology technologist(s). Interventional radiologists may work collaboratively with other specialists, including vascular surgeons, urologists, or gastroenterologists, to perform a procedure. Anesthesia providers may also be involved in the periprocedural care of the patient. The specialty of IR is certified by the American Board of Medical Specialties. Notable milestones in IR are noted in the History box.

RADIOLOGY NURSING

Introduction to Radiology Nursing

Records show that nurses worked in radiology departments as early as 1911 at the Massachusetts General Hospital. In 1935 the Johns Hopkins Hospital established a radiation department, staffed by two technologists and one registered nurse, and a diagnostic department, staffed by one nurse (Po, 2005). Advances in technology, alterations in practice, changes in patient acuity, establishment of regulatory mandates, and trends for nurses to become more involved in imaging areas led to an increase in the need for radiology nurses and supported the evolution of the specialty.

The practices of radiology nurses, whether performed at a free-standing clinical site or in a hospital, should be in accordance with the standards of radiology nursing established by the American Nurses Association and the Association for Radiologic and Imaging Nursing (ARIN) as well as other established guidelines for nursing. Every nurse should practice within his or her scope of professional practice as guided by the state board of nursing, national association, regulatory agencies, and institutional policies and procedures.

Patient safety is paramount to the practice of radiology nursing. The emphasis for the interventional radiologist to be involved in longitudinal patient care (American College of Radiology [ACR], 2005) helps to support the roles and value of nursing in the imaging areas. While there is no specific academic educational preparation for the role of radiology nursing to date, prior experience in critical care nursing, emergency nursing, or postanesthesia care unit nursing is of great value to the practice of radiology nursing. Specific radiologic nursing competencies should be current for all activities performed. Orientation with a preceptor and continuing on-the-job training is essential. Certifications in advanced cardiac life support (ACLS) and pediatric advanced life support (PALS) are recommended.

The nurse must possess strong critical thinking skills and knowledge to make quick, accurate patient assessments and initiate treatments per the radiologist. Although the ability to work independently is key to this role, the nurse must be capable of working with a team of imaging professionals to meet the needs of the patient. Intellectual curiosity, self-study, and involvement are key to becoming a more qualified, competent radiology nurse. Nursing initiative has always been an important attribute in advancing the specialty of radiology nursing throughout its history.

Facilities

Most interventional radiology procedures are performed in the hospital setting with patients registered as either inpatients or outpatients. There are also some free-standing interventional radiology centers in the United States. The number of clinics designed for preprocedure and postprocedure care for interventional radiology patients is increasing. Facilities designated for interventional radiology have specific requirements for radiographic equipment, patient precare and postcare areas, medical/surgical supplies and nonradiographic equipment, staffing, and physiologic monitoring equipment (Figure 28-1) (ACR, 2005).

A few interventional procedures, such as venous line placement, thoracentesis, paracentesis, or simple percutaneous drainage, may be performed at the bedside in critical care areas using ultrasound guidance if the acuity of the patient or other

HISTORY

Milestones in Radiology

In 1895 Wilhelm Röentgen, a physics professor at the University of Würzberg, Germany, discovered "X-Light" or x-rays as they are known today. Physicists, physicians, and photographers became involved in this new discovery. The popular press also spread the word about "the new light." Poetry was written about this new phenomenon and cartoons appeared in popular literature. An evacuated glass tube with an anode and cathode and a generator were all that were needed to produce an image; thus "bone portraits" became popular in studios that were established in larger cities. The operator became known as a "skiagrapher." The x-ray pictures were known as "skiagrams."

X-rays were rapidly integrated into the medical field. X-rays were used to locate bullets in soldiers during the British River Wars on the Nile in 1896. The first angiographic study was done by Haschek and Lindenthal in Vienna in 1896. This postmortem exam was performed using an injection of mercury compounds. Grubbé used x-rays to treat cancer in 1896. The medical use of x-rays lead to other discoveries, such as x-ray epilation and other harmful effects, including erythema, dermatitis, loss of digits, and death. By 1898 lead was being used for protection and limits to exposure were in use. Rooms especially designed for taking x-rays were found in many hospitals in the United States by 1905. Ventriculography was developed in 1918, pneumoencephalography in 1919, and arteriography in 1927. Dyke is known as the first neuroradiologist and practiced in New York in 1930. In 1904 Hickey introduced the term "radiograph" and talked about the "interpretation" of the radiograph in a standardized manner.

As the field of interventional radiology evolved, the following milestones were observed:

1964
Angioplasty
1966
Embolization therapy to treat tumors and spinal cord vascular malformations by blocking blood flow
1967
The Judkins technique of coronary angiography, the technique still most widely used around the world today
Closure of the patent ductus arteriosus, a heart defect in newborns in which there is a vascular opening between the pulmonary artery and the aorta
Selective vasoconstriction infusions for hemorrhage, now commonly used for bleeding ulcers, gastrointestinal (GI) bleeding, and arterial bleeding
1969
The catheter-delivered stenting technique and prototype stent
1970s
Percutaneous removal of common bile duct stones, occlusive coils
1972
Elective arterial embolization for GI bleeding, which was adapted to treat massive bleeding in other arteries in the body and to block blood supply to tumors
1973
Embolization for pelvic trauma
1974
Selective arterial thrombolysis for arterial occlusions; now used to treat blood clots, stroke, DVT, for example
Transhepatic embolization for variceal bleeding
1977-1978
Embolization technique for pulmonary arteriovenous malformations and varicoceles
1977-1983
Bland embolization and chemoembolization for treatment of hepatocellular cancer and disseminated liver metastases
1980
Cryoablation to freeze liver tumors
Development of special tools and devices for biliary manipulation
1980s
Biliary stents to allow bile to flow from the liver, saving patients from biliary bypass surgery
1981
Embolization technique for spleen trauma
1982
TIPS (Transjugular Intrahepatic Portosystemic Shunt) to improve blood flow in damaged livers from conditions such as cirrhosis and hepatitis C
Dilators for interventional urology, percutaneous removal of kidney stones
1983
The balloon-expandable stent (peripheral) used today
1985
Self-expandable stents
1990
Percutaneous extraction of gallbladder stones
Radiofrequency ablation (RFA) technique for liver tumors
1990s
Treatment of bone and kidney tumors by embolization
RFA for soft tissue tumors, for example, bone, breast, kidney, lung, and liver cancer

Modified from Society of Interventional Radiology: *Milestones pioneered by interventional radiologists,* available at www.sirweb.org/about-us/historyIR.shtml. Accessed January 2, 2009.

factors limit the ability to transport the patient to a procedure area for imaging. Interventional magnetic resonance imaging (iMRI) procedures and intraoperative MRI procedures require strict attention to safety issue (see www.acr.org for information on MRI safety).

Radiology Nurse Roles and Responsibilities

The role of the nurse varies according to the individual site and modality in which the nurse practices, as well as the level of expertise of the nurse (e.g., radiology nurse generalist or radiology advanced practice registered nurse).

Nursing roles and responsibilities in the imaging areas are multifold (Box 28-1). Many of these responsibilities revolve around the Joint Commission National Patient Safety Goals. The nurse functions as a provider, role model, patient advocate, and resource in the radiology area. The nurse documents patient care and events. One of the most common aspects of the nurse's role is that of providing sedation and analgesia for diagnostic and therapeutic procedures. Competency in this role should be verified and in accord with current standards. The nurse often assumes responsibility for risk management, performance improvement, and continuing education within

the area. All the roles of the nurse are directed at improving patient outcomes in the radiology area. On-call responsibilities are often assumed with the position of radiology nurse.

Nursing Care of the Interventional Radiology Patient

Assessment. In addition to the standard assessment techniques used with all perioperative patients, nurses caring for patients in IR settings must review information about the patient's renal status and obtain a thorough history that would uncover any other contraindications or any risk factors for the use of contrast media. This information may not be easily obtainable in an emergency situation or when the patient is unconscious or unable to communicate effectively, which can result from a variety of factors. The history should note any circumstances that would increase the patient's risk of a reaction, such as any history of prior reaction, asthma, or significant heart disease. Seafood allergy should no longer be considered a risk factor (Beaty et al, 2008) (Research Highlight). The elderly often have co-morbidities that need to be considered before contrast media use. The very young patient may be at higher risk for a reaction. Other conditions that may place the patient at risk include sickle cell disease, myasthenia gravis, and severe debilitation. The emotional status of the patient is considered relevant to the occurrence of adverse reactions and may affect the severity of reactions. Thyroid disease may increase the risk of delayed hyperthyroidism. Patients who have undergone interleukin II therapy may experience a delayed flulike syndrome. The radiologist should be notified of any patient with thyroid cancer because the use of contrast media may be contraindicated in these patients.

FIGURE 28-1 Angiographic procedure in radiology suite.

Preprocedure medication assessment is essential in the interventional radiology setting. If preprocedure telephone calls are made to outpatients, it is helpful to request the patient to provide a list of medications, including dosage (or actual containers that can then be returned to a family member), so that an accurate list can be obtained for medication reconciliation on the day of the procedure. All over-the-counter medications and herbal supplements should also be included in the medication assessment. Particular attention should be given to any prescription, over-the-counter, or herbal medications that influence prolongation of coagulation. When the nurse obtains the patient's medical history, special attention is directed to medications that may increase the risk of reaction to contrast media, such as beta-adrenergic blocking agents, which may place the patient at risk for a reaction or increase the severity of a reaction. Calcium channel blockers may interfere with the correction of hypotension should a contrast medium reaction occur. Metformin and medications containing metformin should be discontinued at the time of the study and withheld for 48 hours (Box 28-2) because of the increased risk for lactic acidosis when combined with contrast media. Renal function should be assessed before the resumption of metformin or any of the metformin combination drugs.

BOX 28-1

Interventional Radiology (IR) Nurse Duties

In addition to standard perioperative nursing duties, nurses practicing in the IR setting perform the following activities. NOTE: This list is not exhaustive. The role of the radiology nurse will vary according to expertise, practice developments, and facility.

- Participate in radiation safety measures for patient and staff.
- Understand occupational radiation exposure concepts/monitoring.
- Practice ALARA.
- Practice the principles of MRI safety.
- Practice the principles of radionuclide exposure/protection.
- Conduct a targeted assessment relative to the examination/procedure (e.g., NPO status, distal pulses, neurologic assessment, ability to lie prone if applicable).
- Screen patient for any procedure contraindications (e.g., abnormal clotting studies, renal insufficiency, or MRI contraindications) and communicate findings.
- Assess patient for contrast administration (e.g., premedications, contraindications, risk factors).
- Assist with hemostasis (use hemostasis devices or monitor arterial closure by device).
- Transfer patient to same or higher level of care with appropriate hand-off communication.
- Insert PICC lines and perform other procedures (if credentialed and competency is current).
- Know safe handling of chemotherapy agents if used for procedures.
- Have a basic understanding of special equipment (e.g., radiofrequency ablation equipment, Doppler ultrasound devices, electrosurgical devices).

Modified from the *RNCB survey of radiologic nursing practice,* Radiological Nursing Certification Board, 2008.

RESEARCH HIGHLIGHT

Seafood Allergy and Contrast Media Reactions

Allergies to seafood and shellfish have long been considered a contraindication to the use of iodinated contrast media in radiologic procedures. Research has shown that in patients with true allergies to seafood and shellfish the IgE-mediated response is to the actual proteins within the fish—not to the iodine content of the fish. Despite these findings, some physicians continue to consider this type of allergy as increasing the risk of contrast media reactions.

Researchers conducted a survey to determine if radiologists considered seafood allergy a risk factor for contrast media reaction. They surveyed 231 radiologists and interventional cardiologists at 6 Midwestern universities. The survey consisted of 8 yes/no questions about how practitioners assessed for seafood allergy and the actions they took in relation to administration of contrast media in the presence of seafood allergy.

The response rate to the survey was 48.9% (113 respondents). Analysis of the survey results indicated that 69% of responders inquire about a history of seafood allergy before contrast media administration and 37.2% of responders would withhold contrast media or recommend premedication on the basis of a history of seafood allergy.

While this survey was informal and therefore limited in terms of validity of results, it did corroborate the misconception about the relationship between seafood allergy and contrast media reaction. More than one third of the responders noted that they would either withhold contrast media or premedicate the patient if a history of seafood allergy was present; approximately two thirds of the responders still question patients about seafood allergy as part of the pre–radiology assessment. This study demonstrates there is a need for continuing education for physicians about the relationship between seafood allergy and contrast media administration.

Modified from Beaty AD et al: Seafood allergy and radiocontrast media: are physicians propagating a myth? *Am J Med* 121:158e1-158e4, 2008.

BOX 28-2

Medications Containing Metformin

- Actoplus Met (pioglitazone and metformin HCl)
- Advandamet (rosiglitazone maleate and metformin HCl)
- Fortamet (extended release metformin HCl)
- Glucophage, Glucophage Forte, or Glucophage XR (metformin HCl)
- Glumetza (metformin HCl extended release)
- Glucovance (glyburide metformin HCl)
- Glybofen (metformin and glyburide)
- Janumet (sitagliptin phosphate and metformin)
- Metaglip (glipizide and metformin HCl)
- PrandiMet (repaglinide and metformin HCl)
- Riomet (metformin HCl liquid)

Modified from Hodgson BB, Kizior RJ: *Saunders nursing drug handbook 2010,* St Louis, 2010, Saunders; Skidmore-Roth L: *Mosby's drug guide for nurses with 2010 update,* ed 8, St Louis, 2010, Mosby.

The patient's height and weight, a brief history of the present illness, and significant past history, including renal or clotting problems and allergies (including latex, contrast medium allergy, or tape allergies), are obtained. Any history or suspected problems with sleep apnea should be noted and further action taken if needed, including possible anesthesia service consultation by the radiologist. Anxiety related to the procedure can be addressed. Anxiety may be related to the procedure diagnosis and not necessarily the procedure. Claustrophobia can be a significant issue for patients undergoing procedures such as CT or MRI, or any interventional radiology procedure in which sterile draping around the head, face, and neck is needed. Reassurance that sedation and analgesia will be available may help to significantly allay fears. The value of complementary or alternative (CAM) therapies, such as verbal relaxation techniques, music distraction, and therapeutic presence, should not be overlooked. The nurse provides clear verbal instructions (and written instructions, if time allows) regarding preprocedure lab work or special studies; the time, date, and place to arrive on the day of the procedure; NPO status; medication list instructions (as described in the previous paragraph) or actual containers (per institution policy); insurance information; advance directives; and a contact number should further questions or needs arise. Patients should be advised how to take certain medications (e.g., blood pressure or cardiac medications) the morning of the procedure, usually with only a sip of water. Patients with diabetes should be given clear instructions about how to manage their morning serum glucose levels. Some medications may be held for 48 hours before and up to 24 hours after myelography. It is sometimes necessary for patients to provide copies of x-rays/CT scans/MRI films and/or reports on the day of the procedure, and if this is the case patients should be reminded to have these available. Patients should also be notified of the need for transportation home after the procedure, if applicable. The availability of amenities within the facility should be explained to the patient/family member, as well as an anticipated time of confinement. Facility brochures with parking instructions and information sheets can be mailed to patients if time allows. Special needs or anticipated problems can be ascertained and corrective or preventive action initiated at the time of the preprocedure phone call. Gaining the patient's trust and cooperation is essential to a successful procedure. All preoperative preparation is aimed at making the patient's procedure day experience be as stress-free as possible. Baseline vital signs including a pain assessment should be done on admission and documented. The patient's current weight should be verified. Procedure tables vary according to weight limits. When in doubt or the patient's stated weight is not believable, an actual weight should be obtained. This should be done with sensitivity, especially in regard to the obese patient. Accurate weight assessment is also important for medication dosages, especially in the pediatric population. If angiography is to be performed, initial pulse assessments (presence/absence and quality) should be performed and marked. This may necessitate the use of a portable or handheld Doppler device. Intravenous access should be obtained for most procedures. Intravenous access is needed both for administration of periprocedural medications and hydration fluids and for treatment of untoward reactions such as vagal responses, allergic reactions, or hemorrhage. A nursing neurologic assessment, including notation of difficulty with speech, visual disturbances, facial weakness, and any motor or sensory loss in the extremities, should be

completed before neuroangiography procedures. This assessment is used for comparison during the procedure and during the recovery period along with distal pulse assessment. Timing of preprocedure antibiotics should be according to the guidelines of The Joint Commission and other facility and professional association established guidelines.

Patient teaching should include some basic information about the procedure table and room. Interventional procedure tables and CT tables are narrow and not well-padded. The nurse informs the patient that the room lights may be turned off or dimmed when imaging is complete and that monitoring and equipment sounds may be heard throughout the procedure, especially when only light sedation and analgesia is needed. Patients should also be informed that personnel may leave the room briefly during the acquisition of some images but that the patient will be observed and voice communication will be maintained during this time.

The American College of Radiology (2007a) *Practice Guideline on Informed Consent for Image-Guided Procedures* states consent should be obtained for many invasive procedures requiring the insertion of needles or catheters, for any incisional procedures, and for those procedures requiring sedation. The document further notes that consent for intravenous contrast medium may be omitted but this decision should be obtained based on state law, institutional and departmental policy, and surrounding community practice. Radiation-induced cancer risk is not generally part of the consent because of the necessity of the procedure, but the radiologist should be ready to answer the patient's questions (Marx, 2008). For procedures involving high-risk radiation exposure (e.g., certain stent placements, transjugular intrahepatic portosystemic shunt (TIPS), neurologic and visceral embolizations), the patient should be specifically informed of the risk of skin injury from radiation (Marx, 2008).

Nursing Diagnosis. Nursing diagnoses related to the care of patients undergoing IR procedures might include the following:

- Risk for Impaired Comfort
- Anxiety related to the procedure
- Deficient Knowledge related to procedure and postprocedure period
- Ineffective Breathing Pattern related to pain or conscious sedation
- Ineffective Tissue Perfusion related to sedation, procedural fluid imbalance, or postprocedure bleeding
- Risk for Injury related to radiation exposure

Outcome Identification. Outcomes for the selected nursing diagnoses could be stated as follows:

- The patient will experience relief of pain, verbalize relief of pain, and demonstrate less autonomic responses to pain.
- The patient will verbalize decreased anxiety.
- The patient will verbalize understanding of the procedure and postprocedure expectations.
- The patient's airway will be maintained and oxygen saturation will be within normal limits.
- The patient will maintain vital signs within acceptable limits, maintain peripheral pulses as expected, and demonstrate no evidence of excessive bleeding.
- The patient's skin remains intact, is nonreddened, and is free from blistering.

Planning. Planning care for the patient undergoing an IR procedure consists of the standard elements of perioperative care as well as special considerations for radiation exposure and safety. A Sample Plan of Care for a patient undergoing an interventional radiology procedure is shown on p. 1221.

The use of fluoroscopy (real-time radiography) with ionizing radiation allows for visualization of catheters and guidewires during interventional radiology procedures. The potential benefit of the specific procedure should always be weighed against the risks of radiation exposure. Appropriate utilization is a desired goal (Table 28-1). The linear-no-threshold (LNT model) risk model's presumption is that any radiation is hazardous and the risk increases with exposure. This concept may not apply to doses less than 100 millisievert (mSv) per year (yr) as the risk to health is considered so minimal. Injuries from radiation are described as stochastic or deterministic (Box 28-3).

Today there is growing professional interest and concern about radiation exposure because of the increased incidence of radiation-induced skin injury cases documented by the U.S. Food and Drug Administration. New interventional procedures may require prolonged fluoroscopic guidance (e.g., percutaneous transluminal coronary angioplasty, vertebroplasty, endograft repair of abdominal aortic aneurysms, and uterine artery embolization), and repeated interventional procedures may make the patient more vulnerable to injury (Table 28-2). The radiation risk to the patient involves more than skin dosage. Different tissues vary in their sensitivity to radiation. Cataract development may be influenced by exposure to radiation.

Pregnancy is a contraindication for radiation exposure (unless unusual life-threatening exception exists). Fetal radiation dose calculation may be required to assess fetal vulnerability in the case of discovery of an unknown or undisclosed patient pregnancy. The risk from radiation exposure is the greatest during organogenesis and the first trimester. Children are more sensitive to radiation than adults. Personnel should inform their employer if they are pregnant, and appropriate radiation protection actions should be taken.

All staff members are responsible for patient and staff safety. Everyone receives natural background radiation. Geographic location can affect the amount received. In the x-ray suite, lights to signal "x-ray in use" should be at room entrances. The room doors should be closed during procedures with the exception of necessary brief exits or entrances. Staff should be familiar with the location of the emergency stop button for radiation exposure. Sources of x-ray exposure in the procedure room include primary radiation (through imaged area), secondary radiation (scatter), and leakage radiation. When the operator remembers to control the dose to the patient he/she also controls the dose received by the operator (Klein et al, 2009). The "As Low As Reasonably Achievable" (ALARA) principle should be used. The obese patient may need a higher radiation dose in order to obtain quality images (Uppot, 2007). The Health Physics Society Position Statement entitled *Ionizing Radiation-Safety Standards for the General Public* (2009) states "The Health Physics Society supports the establishment of an acceptable dose of radiation of 1 mSv/y (100mrem/y) above the annual natural radiation background. At this dose the risk of radiation-induced health effects are either nonexistent or too small to be observed."

SAMPLE PLAN OF CARE

NURSING DIAGNOSIS
Risk for Impaired Comfort

OUTCOME
The patient will experience relief of pain, verbalize relief of pain, and demonstrate less autonomic responses to pain.

INTERVENTIONS
- Assess characteristics of pain: location, severity on a scale of 1-10, type, frequency, precipitating factors, relief factors.
- Eliminate factors that precipitate pain.
- Offer analgesics per physician's orders.
- Teach patient to request analgesics before pain becomes severe.
- Explore nonpharmacologic methods for reducing pain/promoting comfort.

NURSING DIAGNOSIS
Anxiety related to the procedure

OUTCOME
The patient will verbalize decreased anxiety.

INTERVENTIONS
- Monitor the patient's level of anxiety by assessing the patient's state of alertness, ability to comprehend, and ability to comply with requests.
- Facilitate family's presence.
- Assist the family in identifying coping mechanisms; facilitate and support their use.
- Reassure patient and family during interactions by touch (when welcomed) and empathetic verbal and nonverbal communication.
- Explain IR environment to patient and what to expect to assist in reduction of anxiety.
- Discuss patient's postoperative appearance (e.g., drains, tubes, equipment) with the patient and family.

NURSING DIAGNOSIS
Deficient Knowledge related to the procedure and postprocedure pain

OUTCOME
The patient will verbalize understanding of the procedure and postprocedure expectations.

INTERVENTIONS
- Assess patient's desire to learn.
- Assess preferred learning mode (e.g., auditory, visual) and literacy level.
- Provide orientation to the preprocedure unit, procedural area, and postprocedure unit.
- Provide health teaching and written instructions.
- Plan and share necessity of learning outcomes with patient.

NURSING DIAGNOSIS
Ineffective Breathing Pattern related to pain or conscious sedation

OUTCOME
The patient's airway will be maintained and oxygen saturation will be within normal limits.

INTERVENTIONS
- Note risk factors for respiratory compromise.
- Assess for signs/symptoms of respiratory distress.
- Administer oxygen as ordered.
- Monitor respiratory rate, pulse oximetry, and capnography (when available) parameters.

NURSING DIAGNOSIS
Ineffective Tissue Perfusion related to sedation, procedural fluid imbalance, or postprocedure bleeding

OUTCOME
The patient will maintain vital signs within acceptable limits, maintain peripheral pulses as expected, and demonstrate no evidence of excessive bleeding.

INTERVENTIONS
- Monitor patient's vital signs and assess cardiac rhythm.
- Assess peripheral pulses.
- Observe for signs of bleeding.
- Assess the patient for the underlying cause and contributing factors.
- Correct the underlying cause.
- Maintain patency of all IV and other invasive lines.
- Provide psychosocial support for patient and family members.

NURSING DIAGNOSIS
Risk for Injury related to radiation exposure

OUTCOME
The patient's skin remains intact, is nonreddened, and is free from blistering.

INTERVENTIONS
- Implement protective measures to prevent injury caused by radiation sources.
- Minimize time of exposure to radiation.
- Maximize distance from radiation source if possible.
- Evaluate patient for signs and symptoms of radiation injury.

Staff education on radiation exposure and protection is essential. Personnel should be familiar with the three principles of radiation protection: time, distance, and shielding. Fluoroscopy time should be limited as much as possible. Digital subtraction angiography (DSA) and cineangiography produce high dose-rates. Fluoroscopy time is often noted by equipment that produces an audible sound after 5 minutes of fluoroscopy and staff should be aware of this warning. Some equipment may have a feature that shows actual fluoroscopy time on a screen. Last-image-hold is a technique that radiologists can use to limit fluoroscopy time. Loop-replay will also allow for review of an image without additional exposure time. The "road map" technique, or roadmapping, is of value during interventional procedures. Pulsed fluoroscopy reduces the absorbed dose. Collimators are used to reduce the area of exposure. Changing the angle of the x-ray beam is also an important way to reduce the amount of radiation to a specific area by changing the beam's entry point. Multimodality guidance (e.g., ultrasound with fluoroscopy for nephrostomy or venous access procedures) can be used to limit radiation exposure (Dendy, 2008).

Distance is key to providing protection during fluoroscopy because radiation exposure follows the inverse square law. (For example, the exposure at 2 meters from the source will be only one fourth as much as the exposure at 1 meter's distance.) Another important concept to follow is that "The patient should be positioned as far from the x-ray tube and as close to the image intensifier as possible for optimal image quality and

TABLE 28-1

Radiation Units of Measure

Measured Quantity	SI Unit	Conventional Unit	Equivalents
Dose: amount of energy absorbed per unit mass	Gray (Gy)	Rads (1 Gy = 100 rads)*	1 Gy = 1 J/kg
Dose equivalent: amount of biologic damage from a radiation dose (= dose × "quality factor"†)	Sievert (Sv)	Rem (1 Sv = 100 rem)	Sv = Gy × QF†
Activity: radioactive emission per unit mass	Becquerel (Bq) = 1 disintegration/sec	Curie (Ci) = 3.7×10^{10} disintegrations/sec	1 Ci = 3.7×10^{10} Bq

*For external β-ray, γ-ray, or x-ray exposure, 1 rad = 1 rem.
†Quality factor (QF) adjusts for the amount of biologic damage caused by a given radiation type: the QF of x-rays, γ-rays, and β-rays is 1; the QF of α-radiation is 20 for internal exposure; and the QF of neutrons ranges from 3 to 20 depending on the energy. Particulate radiation, such as α-radiation and neutrons, is more densely ionizing per unit length of tissue exposed than nonparticulate radiation, such as x-rays and γ-rays. The former, more injurious forms of radiation (e.g., α, neutrons) are assumed to have a high linear energy transfer (LET), while x-rays and γ-rays are referred to as low LET radiation.
Modified from Chambers JA, Purdue GF: Radiation injury and the surgeon, *J Am Coll Surg* 204:128-139, 2007.

BOX 28-3

Glossary of Common Interventional Radiology Terms

Angiography: An x-ray exam of the arteries and veins to diagnose blockages and other blood vessel problems; uses a catheter to enter the blood vessel and a contrast agent (x-ray dye) to make the artery or vein visible on the x-ray.
Balloon angioplasty: Opens blocked or narrowed blood vessels by inserting a very small balloon into the vessel and inflating it. Used by IRs to unblock arteries in the legs or arms, kidneys, brain, or elsewhere in the body.
Biliary drainage and stenting: Uses a stent (small mesh tube) to open up blocked ducts and allow bile to drain from the liver.
Biologic variation: Differences between individuals in threshold dose or degree of response to radiation; may be idiopathic or due to underlying disease; different portions of patient's skin also differ in radiosensitivity.
Centipoise (cps): a unit of measure that describes the viscosity of a liquid
Chemoembolization: Delivery of cancer-fighting agents directly to the site of a cancer tumor while depriving the tumor of its blood supply; currently being used mostly to treat cancers of the endocrine system and liver cancers.
Contrast media: Substance used to enhance the contrast and visibility of blood vessels, fluids, and other structures in the body during medical imaging.
Deterministic effect: Radiation effect characterized by a threshold dose; injury does not occur unless threshold dose is exceeded; once threshold dose is reached, severity of injury increases with increasing dose; examples include hair loss and cataracts.
Dose fractionation: Delivery of radiation over time (e.g., days or weeks); occurs in interventional radiology when same patient has multiple procedures on different days.
Embolization: Delivery of clotting agents (e.g., coils, plastic particles, gel, foam) directly to an area; used to stop bleeding or to block blood flow to a problem area, such as an aneurysm or a fibroid tumor in the uterus.
High-osmolality contrast media (HOCM): Composed of salts that dissociate into cations (sodium or meglumine) and anions (diatrizoate, iothalamate, or metrizoate).
Ionic: Ions held together by a bond.
Low-osmolality contrast media (LOCM): Not composed of salts; does not dissociate.
Osmolality: Number of particles in solution per kilogram of water; concentration of osmotically active particles.
Radiofrequency ablation: Use of radiofrequency (RF) energy to kill cancerous tumors.
Stochastic effect: Radiation effect in which probability of occurrence increases with increasing dose; severity of effect is independent of total delivered dose; example is radiogenic cancer.
Threshold dose: Minimum radiation dose at which a deterministic effect can occur (threshold will vary somewhat among individuals).
Transient erythema: Mild observable skin reaction to radiation; has threshold dose of 2 Gy and resembles a sunburn; subsides by 48 hours after exposure and is frequently not noticed by patient.

Modified from Society of Interventional Radiology: *Common IR terms fact sheet,* available at www.sirweb.org/news/newsPDF/facts/Common_IR_Terms_fact_sheet.pdf. Accessed June 4, 2009; Miller DL et al: Minimizing radiation-induced skin injury in interventional radiology procedures, *Radiology* 225: 329-336, 2002.

minimal radiation dose" (Mauro et al, 2008.) Magnification of an image decreases the area exposed but causes an increase in dose to the area viewed (Marx, 2008). Hands should be kept away from the beam. Nonessential personnel should stand at least 6 feet away from the patient when fluoroscopy is in use. Nurses should attempt to provide nursing interventions when the beam is off if possible and limit close-proximity exposure for urgent patient needs only.

Shielding is the third method of protection. Lead aprons with a minimum of 0.5 mm of lead should be worn by staff for protection. Maternity aprons are available. Proper care of lead aprons is essential to extend the life of the apron, to provide maximum protection to the user, and to protect the patient from contaminants such as blood and body fluids. Thyroid shields are used to reduce radiation exposure to the thyroid gland (Figure 28-2). Lead aprons and thyroid shields should

TABLE 28-2

Potential Clinical Effects of Radiation Exposures to the Skin and Eye Lens

	Effects	Threshold Dose (Gy)	Time of Onset
Skin	Early transient erythema	2	2-24 hr
	Main erythema reaction	6	≈1.5 weeks
	Temporary epilation	3	≈3 weeks
	Permanent epilation	7	≈3 weeks
	Dermal necrosis	>12	>52 weeks
Eye	Lens opacity (detectable)	>1-2	>5 years
	Lens/cataract (debilitating)	>5	>5 years

Modified from International Commission on Radiological Protection: Avoidance of radiation injuries from medical interventional procedures, ICRP publication no. 85, *Ann ICRP* 30:7-67, 2000. In NIH publication no. 05-5286; *Interventional fluoroscopy reducing radiation risks for patients and staff,* March 2005.

FIGURE 28-2 Radiation protection devices, including protective apron, thyroid shield, and dosimeter.

be stored by hanging them vertically or they can be laid flat, if appropriate, when not in use. They should not be folded. Cracks in the lead decrease protection from radiation exposure (Box 28-4). Institutional policies and procedures for monitoring of lead aprons should be followed, including a labeling system that allows for tracking and routine maintenance. Lead aprons can contribute to musculoskeletal injury and low back pain (Risk Reduction Strategies box). Leaded eyeglasses provide protection against cataract development for the equipment operator and personnel adjacent to the operator. Sterile lead gloves are available for use but may not be used for a variety of reasons, including cost and comfort. Institutional policies should be followed during radioactive "seed" implants,

BOX 28-4

Care of Lead Aprons

- Hang apron by both shoulders.
- Handwash apron with mild soap and water; rinse with a damp cloth. Aprons should be kept clean and free of dry blood and other fluids.
- Hang to air-dry.
- Check apron for defects as required by State Radiation Control Boards. This is usually an annual requirement.
- Do not fold lead apron over chair.
- Do not lay apron over processor or any other source of heat.
- Do not puncture the apron with any sharp objects.
- Do not put the lead apron through the laundry or clean it with chemicals.
- Do not throw the apron on the floor or crinkle it in any way.
- Take care when having the lead apron repaired.
- Have the apron repaired by a professional in the lead business because someone unfamiliar with the proper technique can ruin the apron by sewing through the lead and thus rendering it unsafe.

Modified from *Care of lead aprons: Davis lead aprons,* available at www.apronco.com/servcare.htm. Accessed February 3, 2009.

RISK REDUCTION STRATEGIES

Preventing Occupational Low Back Pain in the Imaging Environment

- Wear lightest apron available that meets shielding requirements.
- Do not borrow an apron that is not sized appropriately for height and shape.
- Obtain a two-piece apron that shifts some weight off the shoulders to the hips, or use a belted apron or one with an internal frame to take weight off the shoulders.
- Use overhead or mobile x-ray barriers whenever possible to reduce exposure and need for apron use.
- Place shielding around the patient to reduce scatter radiation and need to wear apron.
- Maintain an upright posture; avoid bending forward or sideways.
- Avoid maintaining one position for a long time.
- Use antifatigue pads on the floor; wear well-padded shoes.
- Maintain optimal neck position, neutral to slightly flexed.
- Avoid trunk twisting when reaching for objects.
- Consider arrangement of IR room, tables, monitors, other equipment.
- Ensure there is sufficient staff to assist with patient transfers on and off the procedure table. Obtain assistive transfer devices and encourage staff to use them.
- Practice healthy living habits, attempting to maintain a work environment that minimizes stress.

Modified from Naito NA: *Occupational back pain in the interventional radiologist,* Society of Interventional Radiology Annual Meeting Program, New Orleans, La, 2005.

including a "Radioactive" warning sign on the room door and use of lead aprons by personnel.

Fixed shielding (in walls or doors), table-side lead apron drapes, ceiling-suspended lead acrylic shields, and movable lead acrylic shields provide additional protection for staff.

EVIDENCE FOR PRACTICE

Strategies to Manage Radiation Dose to Patients and Operators

IMMEDIATE	LONG-TERM
OPTIMIZE DOSE TO PATIENT	
Use proper radiologic technique: ◆ Maximize distance between x-ray tube and patient. ◆ Minimize distance between patient and image receptor. ◆ Limit use of electronic magnification. Control fluoroscopy time: ◆ Limit use to necessary evaluation of moving structures. ◆ Employ last-image-hold to review findings. Control images: ◆ Limit acquisition to essential diagnostic and documentation purposes. Reduce dose: ◆ Reduce field size (collimate) and minimize field overlap.	Include medical physicist in decisions: ◆ Consider machine selection and maintenance. ◆ Incorporate dose-reduction technologies and dose-measurement devices in equipment. ◆ Establish a facility quality improvement program that includes an appropriate x-ray equipment quality assurance program, overseen by a medical physicist, which includes equipment evaluation/inspection at appropriate intervals.
MINIMIZE DOSE TO OPERATORS AND STAFF	
Keep hands out of the beam. Use movable shields. Maintain awareness of body position relative to the x-ray beam: ◆ Horizontal x-ray beam: operator and staff should stand on the side of the image receptor. ◆ Vertical x-ray beam: the image receptor should be above the table. Wear adequate protection: ◆ Wear protective, well-fitted lead apron. ◆ Wear leaded eyeglasses.	Improve ergonomics of operators and staff: ◆ Train operators and staff in ergonomically good positioning when using fluoroscopy equipment; periodically assess their practice. ◆ Identify and provide the ergonomically best personal protective gear for operators and staff. ◆ Urge manufacturers to develop ergonomically improved personal protective gear. ◆ Recommend research to improve ergonomics for personal protective gear.
DOSIMETRY RECORDS AND FOLLOW-UP	
Measure and record patient radiation dose: ◆ Record fluoroscopy time. ◆ Record available measurements: dose area product (DAP), cumulative dose, skin dose. ◆ Inform patients who have received high doses to examine the x-ray beam entrance site for skin erythema. Develop methods to quantify late effects: ◆ Design medical records to clearly document the number and types of interventional procedures received by the patient. ◆ Maintain a database of all patients with procedure and dose information. ◆ Review dose information to identify patients with high doses (>2 Gy) for follow-up.	

Modified from *Interventional fluoroscopy: reducing radiation risks for patients and staff,* NIH publication no. 05-5286, March 2005.

Patient shielding should be considered. All patient body parts not being imaged (e.g., hands) should be out of the field of view during fluoroscopy.

Personnel radiation monitoring is an important part of radiation exposure safety. Optically stimulated luminescence (OSL) personal radiation dosimeters are typically used on the trunk (under the apron) and at the collar level (outside the apron). Personal radiation dosimeters should not be left on aprons as this would cause inaccurate readings when an apron or thyroid shield is worn by other than the intended user. Monitors are usually exchanged and monitored on a monthly basis. Staff should be aware of and strictly follow the institution's policies and procedures and governing laws (Evidence for Practice).

Implementation. To provide effective perioperative care of the patient undergoing an IR procedure the nurse implements those actions that relate to the patient's nursing diagnoses and contribute to achievement of identified outcomes. During this phase of care the nurse will obtain and use appropriate equipment and supplies and perform interventions related to patient positioning, prepping, monitoring, and medication administration.

EQUIPMENT. In addition to x-ray equipment (e.g., ultrasound devices) other essential equipment includes power injectors for precise timing and rate of injection of contrast media (Figure 28-3), torque devices to guide catheters, and vascular closure devices to assist hemostasis. Tourniquets are needed for peripherally inserted central catheter (PICC) line placement and venography procedures. Portable handheld Doppler devices or other ultrasound equipment may be required for vascular procedures. An electrosurgical unit may be used during procedures where a pocket is created for device insertion. Other special equipment is needed for procedures such as inferior vena cava filter placement, diskography, kyphoplasty, and radiofrequency ablation. Laser equipment may be used for angioplasty cases. Laser safety includes education of staff, use of protective equipment, and special preparation of the procedure room. Any equipment that is used for interventional MRI (iMRI) procedures should meet the current MRI safety standards and be nonferrous (nonmagnetic).

FIGURE 28-3 Power injector used to deliver contrast medium.

FIGURE 28-4 Catheters and guidewires.

SUPPLIES AND INSTRUMENTATION. A variety of specialty items are used for IR procedures. A Seldinger needle (18 gauge, 2¾ inches) is commonly used for groin access. A finer needle (or micropuncture set) is used when other considerations exist, such as when there is increased risk for bleeding, axillary or brachial artery puncture is planned, or a pediatric case is being performed. The radiologist may have a specific preference based on other factors. Minor instrument trays may be used to create pockets for implantable devices.

A sheath is commonly inserted at the arterial or venous puncture site. The sheath has several functions. Most importantly, it is used to protect the puncture site and vessel from damage. This is especially true in interventional procedures that involve multiple guidewire and catheter exchanges. Heparinized saline flush may be infused through the sidearm (port) of the sheath. For thrombolysis procedures or when a sheath is left in place for another pending procedure, it may be sutured to the skin and covered with a sterile dressing per the radiologist's preference.

Guidewires are available in a variety of lengths, diameters, and stiffness (Figure 28-4). A 0.035-inch J or straight wire is often used. There are steerable and nonsteerable guidewires as well as introducing and exchange guidewires. Guidewires may have a hydrophilic coating. There are guidewires with long, floppy tips that allow access past difficult vessels. The type of guidewire selected will depend on its purpose and the preference of the radiologist. Guidewires can be dislodged during catheter exchange and caution should be used at this time. Guidewires have a right and wrong end for insertion.

Catheters are available in a variety of lengths and shapes, each with a specific advantage (see Figure 28-4). Catheters are sized by the French system. Flow rates will vary among the catheter types and sizes. A pigtail catheter can deliver a larger amount of contrast medium because of additional side holes, as compared to the standard catheter with one end hole. Multihole straight catheters are available. Catheters can be referred to as selective or nonselective. Examples of selective catheters include the Cobra, Berenstein, Headhunter, and Simmons (Sidewinder) catheters. Microcatheters (co-axial catheters) are used for access to very small vessels. Catheters may also have balloons that can be inflated for angioplasty purposes. Meticulous catheter technique is needed to prevent inadvertent air in the line and coagulation of blood in the catheter. Before an injection is done, the placement of the catheter tip is often verified by using fluoroscopy. A test injection using a small amount of contrast material may be done. The type of contrast dye and its volume and flow rate are determined by the radiologist before injection.

Pressure bags, used with high-pressure tubing and connectors, are needed for vascular interventional procedures. Three-way stopcocks are placed on the flush line. A Tuohy-Borst adaptor is used to form a seal around guidewires and catheters. The Tuohy-Borst sidearm can be used as a port for injection. Vascular snares are devices that are used to retrieve foreign bodies. Heparinized saline flush bags and a closed system for discard of flush, contrast medium, or blood will also be needed for a procedure. Stents and catheters equipped for balloon angioplasty may be needed for vascular procedures. Percutaneous mechanical thrombectomy devices will be used in cases in which pharmaceutical thrombolysis cannot be done or as an adjunct treatment for thrombolysis. This will also be used for some dialysis graft interventions.

Coils, embolic agents, or sclerosants may be needed for procedures designed to occlude a vessel. Because tube tracts frequently need to be dilated for initial tube placement, dilators of all sizes are needed. Urinary, biliary, or other drainage tubes may be held in place by sutures or by a variety of commercial tube holders. Drainage bags, stopcocks, and connecting tubing are needed for drainage catheter placement. Drainage bags with leg straps may be used. Some patients with nephrostomies will also prefer to have a larger drainage bag for use overnight. A variety of suture materials will be needed for pocket closure following device placements such as a portacath or cardiac device. Sterile specimen containers and sterile slides should be available for biopsy or drainage procedures. Solutions and fixatives for specimen storage should be available. Chest tubes, collection systems, and wall suction are needed for pneumothorax interventions. Vacuum bottles will be needed for paracentesis or thoracentesis procedures.

MEDICATIONS. Medication assessment, administration, monitoring, and performance improvement often constitute a large part of the nurse's productive time. An accurate medication history is essential to providing safe patient care. A variety of medications are administered in the IR setting. The perioperative nurse must be familiar with the medications used in this setting including their indications, dosages, and side effects.

Anticoagulants. The diagnostic or therapeutic procedure may necessitate the administration of heparin or other anticoagulant or antiplatelet medications (e.g., aspirin, dipyridamole, ticlopidine) because vascular injury can lead to thrombus development. Heparin is often used to prevent acute thrombosis and ischemic episodes. Heparin's short half-life makes it a good choice for periprocedural anticoagulation. Its effect can be reversed with protamine sulfate. The nurse notes the time heparin is given because the anticoagulation status of the patient will influence when a repeat dose may be needed or when an arterial sheath can be safely removed. An activated coagulation time (ACT) may be determined to evaluate the need for additional intraprocedural heparin administration in certain cases or to assess the effectiveness of anticoagulation before a sheath is removed. The perioperative nurse may be involved in point-of-care testing for the ACT. An intravenous infusion of heparin may be started for thrombolysis or angioplasty cases. Standard mix bags of heparin are practical and convenient to use. Heparin is a high-alert medication—the concentration of heparin should be checked. For example, premix bags with 25,000 units of USP heparin in 500 ml of 0.45% normal saline (0.45NS) may be used for the intravenous infusion of heparin during thrombolysis or angioplasty cases. Heparin flush premix bags (e.g., 1000 units of USP heparin in 500 ml of 0.9NS) may be used for sheath or catheter flushing and should not be confused with other concentrations. The thrombin inhibitor bivalirudin (Angiomax) may be used during stent procedures instead of heparin.

After most venous access lines are placed, heparin is instilled. The specific type of line (e.g., dialysis catheter, portacath, triple-lumen central line, or PICC) will dictate the amount and strength of heparin needed. Manufacturer guidelines for the device and hospital policy for line management should be followed. Certain types of lines, such as Groshong catheters, may not require heparin. Low-molecular-weight heparin (LMWH), heparin, or other medications may be used for venous thromboembolism prophylaxis following the procedure.

Heparin is contraindicated in the patient with hypersensitivity or the patient with bleeding. Thrombocytopenia and heparin-induced thrombocytopenia (HIT) can develop. Aspirin or other antiplatelet drugs can be given to prevent embolic or ischemia events caused by coagulation problems. A wide variety of platelet aggregation inhibitors, anticoagulants, and vitamin K antagonists are used.

Thrombolytics. Small amounts of a thrombolytic drug can be instilled into portacaths and aspirated to ensure patency of the device. Intravascular thrombolytic agents are used to dissolve a thrombus so normal vascular patency can be achieved. Thrombolytic drugs activate the conversion of plasmin to plasminogen and break down fibrin. Thrombolytic drugs work best on a fresh clot. Thrombolytic drugs cause a systemic lytic state and hemorrhage is a possible complication. The patient should be screened for both relative and absolute contraindications for thrombolytic therapy. During thrombolytic infusion procedures the patient should be monitored in a critical care setting.

Vasodilators and Vasoconstrictors. Nitroglycerin, a short-acting vasodilator, is used to prevent or treat vascular spasm caused by the wire or catheter during interventional procedures (e.g., percutaneous transluminal angioplasty). It is prepared as a 100-mcg dose and administered directly into the affected vessel by the radiologist. Papaverine delivered as a bolus and then by infusion has been used for nonocclusive mesenteric ischemia. Tolazoline hydrochloride (Priscoline) is another vasodilator that has been used intraarterially during angiography.

Vasopressin (Pitressin), a vasoconstrictor, may be given as an intraarterial infusion for gastrointestinal bleeding. Vasopressin has an antidiuretic hormone (ADH) effect.

Miscellaneous Medications. Amobarbital sodium (Amytal) is used during cerebral arteriography in Wada's test to evaluate neurologic function.

Because of its platelet inhibition properties, aspirin is often given before and after a percutaneous transluminal angioplasty procedure. Aspirin may also be administered after endovascular laser treatment.

Chemotherapy agents are used during transcatheter liver chemotherapy procedures. The pharmacy from which the chemotherapy agents are prepared should know in advance of the need and approximate time of need. Imaging staff members should be aware of chemotherapy handling and disposal precautions and follow facility policies and procedures.

Diphenhydramine (Benadryl) is used for a variety of reasons, including as a sedative adjunct, as a treatment for contrast reaction urticaria, and, in rare circumstances, as a local anesthetic.

Glucagon is used to decrease peristaltic activity of the bowel during angiography and during gastrointestinal tube placement. The lyophilized form of glucagon needs to be reconstituted with the diluent provided just before use. Glucagon 1 mg is given intravenously. (NOTE: Glucagon is supplied in 1- and 10-mg vials. Be careful not to confuse the two.)

The antioxidant *N*-acetylcysteine (Mucomyst) is an off-label use medication for the prevention of contrast-induced nephropathy, although this has not been conclusively proven effective. It is usually administered 600 mg twice daily on the day before the procedure and on the day of the procedure. Other regimens have been recommended.

Radioisotopes may be given via a lumbar puncture. Staff from the nuclear medicine department should be notified when the patient is scheduled for the procedure.

Secretagogue, 10% calcium gluconate, may be given during diagnostic angiography for gastrinomas or insulinomas.

Thrombin (Gentrac, Inc., Middleton, Wisc, for Johnson & Johnson; or Jones Medical Industries, St Louis, Mo) may be used for direct percutaneous injection for pseudoaneurysm repair. With ultrasound guidance this may be used in combination with direct pseudoaneurysm compression.

EMBOLIC AND SCLEROSING AGENTS. Embolic materials induce mechanical obstruction within a vessel and formation of thrombus via platelet activation and activation of the patient's clotting mechanism. The size of the vessel to be embolized and the need for embolization to be permanent or temporary will affect the choice of agent. Some clinical indications for use of embolic agents include upper and lower gastrointestinal bleeding, pelvic embolization (e.g., posttrauma, uterine fibroid embolization, postpartum hemorrhage), severe hemoptysis, pseudoaneurysm, arteriovenous (AV) fistula, and preoperative solid organ embolization (e.g., renal, splenic). An inflammatory response may be initiated with certain agents. Nontarget embolization is a possible complication. Postembolization syndrome (PES) is expected in some situations, such as after uterine fibroid embolization.

Embolic agents can be categorized by the nature of their occlusive action, either temporary or permanent. Temporary agents include absorbable gelatin sponge, Gelfoam sponge powder, starch microspheres, oxidized cellulose, and collagen fiber preparations. Gelfoam may be cut into small pledgets or "torpedoes" and injected via a catheter, or cut into small pieces and mixed with saline and contrast medium to form a "Gelfoam slurry" for injection via a catheter. Gelfoam activates platelet aggregation and the clotting cascade. It also causes inflammation of a vessel wall. Collagen fiber preparations cause mechanical obstruction in a vessel or inflammation to occur. Gelfoam may be used for the purpose of devascularization before surgery or for control of bleeding. Gelfoam may be placed into a needle tract following a biopsy to prevent bleeding from the biopsy site.

A vascular plug or coils may be used. Coils may consist of Dacron fibers to promote thrombosis. Coils may be used in combination with another material such as Gelfoam. Coil size is very important to prevent migration from the intended site. Coils are usually packed tightly to prevent recanalization of the vessel. Surgical silk and polypropylene suture material have been used for embolization but the lack of radiopacity is a drawback. Permanent nonreabsorbable materials for small vessel use include polyvinyl alcohol particles or sponges, trisacryl gelatin microspheres, particulate agents, and tissue adhesives. Cyanoacrylate glue and coils have been used for embolization of brain arteriovenous fistulas. Ethiodol, an oil-based contrast agent, is sometimes used during embolization procedures to allow visualization of the extent of the embolization. Thrombin activates the conversion of fibrinogen to fibrin. It may be used to treat iatrogenic pseudoaneurysms following femoral artery catheterization.

Sclerosing materials cause direct destruction of the vascular endothelium. Examples include absolute alcohol, sodium tetradecyl sulfate, and ethylene–vinyl alcohol co-polymer. Chemical pleurodesis for pleural effusions has been accomplished with tetracycline. Doxycycline suspended in saline or contrast medium has been used for sclerotherapy of seromas. Sclerosing agents may involve a "dwell" time followed by drainage. Injection of a sclerosant into a pocket may cause discomfort for the patient and a local anesthetic may be injected. The topical antiseptic povidone-iodine has been used as a sclerosing agent to eradicate persistent pockets. After catheter drain placement and initial treatment in the interventional radiology department, outpatients are often given instillation, dwell time, and drainage instructions.

ANALGESIA AND SEDATION. While some simple interventional procedures, such as PICC line placement, can be performed using only a local anesthetic, most interventional procedures require sedation and analgesia. In addition to the normal perioperative assessment parameters, the nurse providing care in the IR setting should be familiar with the patient's American Society of Anesthesiologists (ASA) status (see Chapter 4) and be able to assess additional factors specific to the risk of developing complications related to sedation (Patient Safety).

The nurse works under the direction of a radiologist credentialed for sedation and analgesia administration per the institution's policy and procedure. Advanced cardiac life support (or pediatric advanced life support in the event of a pediatric case) should be a requirement for all providers. Pharmacologic antagonists, medications, and intravenous fluids to correct vasovagal or other blood pressure problems as well as resuscitation medications should be readily available. Oxygen and suction and resuscitation equipment should also be readily available before the patient is given medications for sedation and analgesia.

Physiologic monitors (continuous electrocardiography, blood pressure [BP], pulse oximetry, and capnography, if available) with audible alarms should be in place when sedation and analgesia are given. Pulse oximetry can be used to monitor the patient's respiratory status but it should not be the sole indicator of respiratory status. Respiratory rate and ventilation are both important vital signs to monitor for the prevention of oversedation or untoward response. Capnography is an

PATIENT SAFETY

Nursing Assessment and Actions for the Patient Receiving Intravenous (IV) Moderate Sedation/Analgesia

A primary responsibility of the nurse providing care in the IR setting is the administration of sedation and analgesia. In addition to being familiar with the agents used for sedation, the nurse must be well versed in assessment and in the actions to take if complications related to the agents occur.

Before administering sedation agents the nurse should assess the following about the patient:

- Relevant physical examination findings
- Current medications
- Allergies and sensitivities
- Current medical problems such as hypertension, diabetes, cardiopulmonary disease, liver disease, and renal disease
- History of sleep apnea
- Smoking history
- Alcohol intake history
- Recreational drug use
- Presenting medical problems
- Baseline vital signs
- Level of consciousness
- Emotional state
- Communication ability
- Perceptions of sedation/analgesia and the procedure itself

STEPS TO FOLLOW WITH INADVERTENT DEEPENING OF SEDATION WITH LOSS OF AIRWAY

- Check patient; stimulate patient quickly to affirm deepening of sedation with loss of airway.
- Call for help early (rapid response team or code blue team). Use all available members of the team to correct situation.
- Provide supplemental oxygen/increase oxygen flow (if apneic or inadequate respirations, provide bag-valve-mask ventilation). (Ensure oxygen is flowing to patient.)
- Improve head position (per advanced life support guidelines).
- Use oral or nasal airway (trained provider).
- Provide bag-valve-mask ventilation (with oxygen source).
- Consider reversing sedation and analgesia.
- Insert protected airway device, laryngeal mask airway, endotracheal tube (by trained provider).

Modified from Shabanie A: Conscious sedation for interventional procedures: a practical guide, *Tech Vasc Interv Radiol* 9:84-88, 2006; Association of periOperative Registered Nurses (AORN): *Perioperative patient care in the ambulatory surgery setting,* Denver, 2007, The Association.

excellent adjunct to monitor the patient's respiratory status especially in procedures where ventilatory function assessment is compromised, such as when the patient is in a prone position. Careful observation of the patient, knowledge of all the procedure-related events, and trending of all vital signs are key to successful sedation and analgesia in the imaging setting.

Supplemental oxygen should be started before the initiation of sedation (Shabanie, 2006). The provider should be familiar with both the risks and benefits of oxygen use. The team should be knowledgeable about fire potential in the radiology area when oxygen is in use and be aware when other elements of the fire triangle are present.

Sedation and analgesia help to allay fear and facilitate patient cooperation throughout the procedure. Anxiety can enhance pain perception and lead to undesired physiologic responses, as well as movement during the procedure. Imaging procedures require that a patient lie quietly on the procedure table to prevent motion artifact on the images. Breathing instructions may be given to the patient just before filming in certain situations. Therefore analgesia and sedation need to be adjusted to the procedure. For example, if respiration control is desired, the patient should be awake enough to cooperate but comfortable enough to tolerate the procedure. Some procedures, such as a diskogram, require that a patient be able to communicate the amount of pain felt with each disk injection and rate it in comparison to the usual pain. If the patient is oversedated, he or she may not be able to respond or the response may not be accurate. During the course of some procedures, the radiologist may need to perform a more painful maneuver, such as tract dilation before tube advancement during percutaneous nephrostomy tube or drainage tube placement. These maneuvers may require additional analgesia and sedation. There should always be good communication between the radiologist and nurse administering sedation and analgesia so that painful procedures are avoided or minimized whenever possible. The amount and type of analgesia and sedation are highly dependent on patient and procedure factors (Surgical Pharmacology). Each patient's perception and response to pain is different, based on their physiologic response, cultural response, and history of previous radiology procedures. A visual analogue scale can be used to evaluate the patient's level of pain before, during, and after the procedure. The experienced nurse will know when additional sedation and analgesia are typically required and proceed accordingly so valuable time is not lost during the procedure.

In circumstances where the services of an anesthesia provider are needed, the perioperative nurse should assist the provider as needed because the anesthesia provider is often working in an unfamiliar setting. Providing anesthesia in imaging settings is not easily accomplished. Cases involving anesthesia services are typically scheduled in advance per hospital policy, and the availability of an anesthesia provider on short notice may be a limiting factor. A recent study showed how difficult it was to estimate anesthesia times for interventional radiology (IR), computed tomography (CT), and magnetic resonance (MR) imaging procedures and also developed useful guides for scheduled or elective procedures for all three areas (Research Highlight).

Providers find the anesthesia experience less satisfying than that accomplished in the OR where turnover times are more controlled (Arnold and Roberts, 2008). Dedicated anesthesia services for radiology departments are present in some locations. Working around multiple pieces of imaging equipment may interfere with patient contact. The possibility of hypothermia should be considered because of the usual room temperatures in the imaging areas. Anesthesia assistance may be needed for deepening sedation beyond the control of the imaging team. In cases where a general anesthetic is given the nurse should alert the postanesthesia care unit of the estimated time of arrival and ensure that all equipment needed for transport is available.

CONTRAST MEDIA. Since the beginning of radiographic imaging, contrast media have been used to enhance visualization of anatomic structures. Contrast agents can be positive or negative in effect. A negative contrast agent (e.g., carbon dioxide or air) attenuates (absorbs) the x-ray beam less than surrounding tissue. A positive contrast agent (e.g., the water-soluble intravascular agents discussed in this chapter and the various preparations of barium) attenuates the beam more than surrounding tissue. Contrast media are very useful in detecting diseased or abnormal tissues/organs because these appear different than normal tissues/organs after contrast injection. Contrast media can also be used to visualize a specific structure, such as a blood vessel, part of the urinary tract, or a cavity (Box 28-5). Visualization caused by contrast injection is affected by several issues. Iodine concentration is directly related to the radiopacity produced by the contrast medium. Other factors affecting visualization are the amount and speed of delivery of the contrast agent, blood flow and hemodilution of the area, and the size of the vessel being imaged. Thus iodine concentration, volume of contrast medium, and timing of the injection are critical to imaging.

In 1923 practitioners at the Mayo Clinic observed bladder opacification on abdominal x-rays from patients who had been given oral and intravenous sodium iodide for the treatment of syphilis. This accidental discovery lead to the quest for development of safe iodinated intravenous contrast media. The toxicity of sodium iodide prevented it from being a suitable contrast agent. The early efforts were focused on creating a contrast agent suitable for diagnostic intravenous urograms. Uroselectan was first used in 1929 and then refined as Uroselectan B.

In the mid-1950s sodium diatrizoate (distributed as Urografin, Renografin, and Hypaque) was introduced and used as the primary contrast medium for urologic and intravascular procedures. Sodium diatrizoate, a high-osmolality ionic contrast medium (HOCM), was far from ideal. This HOCM dissociated in solution, yielding an anion and cation that produced undesirable side effects, including vascular pain, nausea and vomiting, cardiovascular changes (e.g., bradycardia), and disturbances in the blood-brain barrier. Iothalamate (Conray), a high-osmolality contrast medium similar in composition to diatrizoate, was better tolerated, especially neurologically, but not as well tolerated by the cardiovascular system. The osmolality of diatrizoate and iothalamate is high (1500 to 2100 mOsm/kg of water). The osmolality of blood is 296 mOsm/kg of water. Many of the harsh side effects, such as pain on injection and nausea and vomiting, were attributed to this difference in osmolality. Metrizamide, a low-osmolality contrast medium (LOCM), was released in 1969. Metrizamide was unstable in solution and needed to be produced as a freeze-dried powder with a special diluent. In the late 1970s metrizamide replaced

SURGICAL PHARMACOLOGY

Medications Used for Sedation and Analgesia (and Antagonists)

The recommendations included here are generally acceptable guidelines and may require modification for individual patients at the discretion of the physician. Dosages provided are generally acceptable but may need to be reduced in a given patient to avoid serious cardiorespiratory depression or other undesired side effects. Furthermore, many of these medications have synergistic respiratory depressant effects; when administered in combination, lower dosages may be required.

Drug	Dose	Total	Onset	Duration	Nursing Considerations
BENZODIAZEPINES (SEDATIVES)					
Diazepam (Valium)	2-10 mg into rapidly infusing IV line; may repeat at 5-min intervals	0.1-0.2 mg/kg	1-5 min	15-60 min; may be greatly increased in pts >60 y/o	Patient should remain supine until effects of medication are absent and risk of hypotension has passed. Hepatic or renal insufficiency increases duration of effect.
Midazolam (Versed)	<60 y/o: 1.0-2.5 mg over 5 min (wait 2 min to evaluate) Titrate in small increments at 2-min intervals	Total maximum dose 2.5-5 mg	1-5 min	20-30 min	Too much or too little may cause cerebral hypoxia, agitation, combativeness. Hepatic insufficiency increases duration of effect; 30% dose reduction with concomitant use of opiate agonists or CNS depressants.
	>60 y/o, debilitated, or chronically ill: 0.5 mg (wait 3 min to evaluate) Titrate 0.5-mg increments at 2-3 min intervals	Total maximum dose 3.5 mg			Implement 50% dose reduction with concomitant use of opiate agonists or CNS depressants.
Lorazepam (Ativan)	44 mcg/kg 15-20 min before procedure	Total maximum dose 2 mg 15-20 min before procedure	5-15 min, peak unknown	24-48 hr	Use with caution in geriatric patients, debilitated, renal/hepatic disease. Dizziness, drowsiness, orthostatic hypotension can occur. Prepare immediately before use; has short-term stability. Monitor respirations q 5-15 min if given IV (rapid injections may cause cardiac arrest) and CNS changes. Check Y-site compatibilities. Give IV after diluting; give at 2 mg or less over 1 min.
OPIATE AGONISTS (NARCOTICS)					
Morphine	1-2 mg at 3-5 min intervals	Up to 0.1-0.15 mg/kg	1-5 min	3-5 hr	If respirations are 12/min or less, hold next dose. Hepatic or renal insufficiency increases duration of effect.
Fentanyl (Sublimaze)	Bolus of 1-2 mcg/kg, then 1 mcg/kg every hour.	1.5-2 mcg/kg	1-5 min	0.5-1 hr	Hepatic insufficiency increases duration of effect.
Hydromorphone (Dilaudid)	0.5-1 mg (titrate to effect)	Maximum 2 mg IV every 4-6 hr	15-30 min (peak 0.5-1 hr)	4-5 hr	Increased effects caused by alcohol, opiates, sedatives/hypnotics, antipsychotics, skeletal muscle relaxants. Check IV compatibilities. If direct IV route used, dilute.

Continued

SURGICAL PHARMACOLOGY

Medications Used for Sedation and Analgesia (and Antagonists)—cont'd

Drug	Dose	Total	Onset	Duration	Nursing Considerations
OPIATE ANTAGONIST*					
Naloxone (Narcan)	0.4-2 mg IV prn at 2-3 min intervals until respiratory function is restored		1-2 min	20-60 min	Narcotic effects may last longer than Versed. Must monitor at least 2 hr after giving Narcan.
BENZODIAZEPINE ANTAGONIST					
Flumazenil (Romazicon)	0.2 mg over 15 sec into rapidly infusing IV line	Maximum dose 1 mg	1-2 min	60 min	Use in patients taking chronic benzodiazepines or with acute head injury.

CNS, Central nervous system; *prn,* as needed; *y/o,* years old.
*Patients who receive reversal agents should be observed closely for an additional 2 hours.
Modified from Skidmore-Roth L: *Mosby's drug guide for nurses with 2010 update,* ed 8, St Louis, 2010, Mosby.

RESEARCH HIGHLIGHT

Predicting Anesthesia Times

Although the majority of IR procedures are accomplished with sedation, some procedures may require the presence of an anesthesia provider. Because anesthesia providers do not routinely practice in the IR setting, calculations related to anesthesia time may be incorrect. In this study, researchers evaluated anesthesia billing data and logbooks from diagnostic radiology and interventional radiology departments and current procedural terminology (CPT) codes from computerized tomography (CT) and magnetic resonance imaging (MRI) procedures in an effort to predict anesthesia time for imaging procedures. This information was found not particularly useful in predicting anesthesia time. Anesthesia time was more accurately assessed by expert judgment. The authors noted that radiology suites are not as interchangeable as ORs and suggested that completion times should be estimated and used to assist with scheduling interventional radiology procedures.

Modified from Dexter F et al: Predicting anesthesia times for diagnostic and interventional radiological procedures, *Anesth Analg* 102:1491-1500, 2006.

oil-based contrast media (e.g., Pantopaque) for use in myelography. Ioxaglate (Hexabrix), an ionic dimer contrast medium, was developed and is still in limited use today. Ioxaglate is contraindicated for myelography and radiculography because of its ionicity.

By the late 1970s a second generation of low-osmolality nonionic contrast media was introduced. Iohexol (Omnipaque), iopamidol (Isovue), ioversol (Optiray), iopromide (Ultravist), and ioxilan (Oxilan) were nonionic monomers. All of the second-generation LOCM were lower in osmolality and were better tolerated then metrizamide (Amipaque). Efforts to further reduce osmolality created the newest contrast media, the nonionic dimers iotrolan and iodixanol. Iotrolan has been removed from the market because of concerns about delayed cutaneous reactions. Iodixanol (Visipaque), the newest agent, is a nonionic dimer and carries six atoms of iodine on each molecule of contrast agent. The osmolality of iodixanol is 290 mOsm/kg of water, which is better tolerated by the body. The nonionic dimer iodixanol causes the least discomfort when injected into the body. The viscosity (11 centipoise [cps] at 37° C) of iodixanol is higher than that of the other contrast media. Viscosity is affected by both the iodine concentration and the temperature of the contrast medium. Warming reduces the viscosity of contrast media. The delivery of contrast media through catheters is therefore facilitated by warming it to body temperature.

Once injected, contrast medium moves throughout the extracellular space of the body. No metabolism of the contrast medium occurs. Contrast medium is cleared primarily by passive glomerular filtration. The renal tubules do not reabsorb any contrast agent. The half-life of contrast media is believed to be about 1 hour in patients with normal renal function. Another important pharmacokinetic property of contrast agents is that protein binding is minimal. No immunoglobulin E (IgE) antibodies are associated with contrast injection. The injection of contrast agents can cause organ-specific or system-specific changes (Box 28-6).

Physiologic Response to Contrast Media.. The physiologic response to intravenous injection of contrast media is multifold. Contrast media have an osmotic diuretic effect. Following contrast injection there is movement of contrast agent from the intravascular space to the interstitial fluid followed by elimination through renal clearance. Cardiac, pulmonary, and peripheral vascular changes have been noted. Heart rate may be affected. Disturbances in electrical conduction (e.g., bradycardia) may occur during cardiac angiography. Peripheral vascular resistance may decrease and peripheral vasodilation may occur. Contrast media cause the release of histamine from the mast cells within the lung. Pulmonary edema resulting from contrast agent administration is rare. Because contrast media have an irritant effect on the vascular endothelium of blood vessels, the patient may notice a sensation of heat following injection of contrast medium. This effect is less pronounced with LOCM and iso-osmolality contrast medium (IOCM) than with HOCM.

Medical problems that affect or disrupt the blood-brain barrier may place the patient at risk for seizure following contrast media injection. Contrast media inhibit the clotting mechanisms of the body by inhibiting platelet aggregation and limiting the clotting cascade. HOCM affect these processes more than LOCM or IOCM. This fact influences catheter technique

BOX 28-5

Indications for the Use of Iodinated Contrast Media

- **I.** Intravascular
  - **A.** Intravenous
    - **1.** Computed tomography
    - **2.** Digital subtraction angiography
    - **3.** Venography (phlebography)
      - **a.** Inferior vena cava and its tributaries
      - **b.** Superior vena cava and its tributaries
      - **c.** Extremities
      - **d.** Other venous sites
        - **(1)** Epidural venography
  - **B.** Intraarterial
    - **1.** Angiocardiography
    - **2.** Computed tomography
    - **3.** Coronary angioplasty
    - **4.** Pulmonary angiography
    - **5.** Aortography
    - **6.** Visceral and peripheral arteriography
    - **7.** Digital subtraction angiography
    - **8.** Central nervous system
      - **a.** Cerebral, vertebral, and spinal angiography
- **II.** Intrathecal (use U.S. Food and Drug Administration approved contrast media only)
  - **A.** Myelography (myelographic nonionic only)
  - **B.** Cysternography (myelographic nonionic only)
- **III.** Other (oral, rectal, or ostomy-gastrointestinal tract)
  - **1.** Conventional fluoroscopy
  - **2.** Computed tomography
  - **3.** Therapeutic uses
  - **A.** Body cavity use
    - **1.** Herniography
    - **2.** Peritoneography
    - **3.** Vaginography
  - **B.** Hysterosalpingography
  - **C.** Arthrography
  - **D.** Endoscopic retrograde cholangiopancreatography
  - **E.** Cholangiography
  - **F.** Nephrostography
  - **G.** Pyelography—antegrade, retrograde
  - **H.** Urethrography—voiding, retrograde
  - **I.** Cystography
  - **J.** Sialography
  - **K.** Ductography (breast)
  - **L.** Miscellaneous
    - **1.** Sinus tract injection
    - **2.** Cavity delineation (including urinary diversions, such as loop and pouch)

Modified from American College of Radiology: *Manual on contrast media, version 6,* 2008, available at www.acr.org/SecondaryMainMenuCategories/quality_safety/contrast_manual.aspx. Accessed September 6, 2009.

BOX 28-6

Organ-Specific or System-Specific Adverse Effects from Contrast Media

Adrenal Glands
- Hypertension (in patients with pheochromocytoma after intra-arterial injection)

Brain
- Headache, confusion, dizziness, seizure, rigors, lost or diminished consciousness or vision

Gastrointestinal Tract
- Nausea, vomiting, diarrhea, cramping

Heart
- Hypotension
- Dysrhythmia (asystole, ventricular fibrillation, ventricular tachycardia)
- Pulseless electrical activity (PEA)
- Acute congestive heart failure

Kidney
- Oliguria
- Hypertension
- Contrast-induced nephrotoxicity (CIN)

Pancreas
- Swelling/pancreatitis

Respiratory System
- Laryngeal edema, bronchospasm
- Pulmonary edema

Salivary Glands
- Swelling/parotitis

Skin and Soft Tissue
- Pain, swelling, flushing, erythema, urticaria, pruritus
- Compartment syndrome (from extravasation)

Thyroid
- Exacerbation of thyrotoxicosis

Vascular System
- Hemorrhage
- Thrombophlebitis

Modified from American College of Radiology: *Manual on contrast media, version 6,* 2008, available at www.acr.org/SecondaryMainMenuCategories/quality_safety/contrast_manual.aspx. Accessed September 6, 2009.

during angiography. Meticulous flushing is imperative. Complement activation is believed to be a consideration in contrast reactions.

Biphasic renal flow has been described following contrast administration. This involves a transient increase in blood flow and then a longer period of decreased blood flow to the kidneys. Contrast media–induced nephrotoxicity (CIN) can occur as a result of this physiologic change. CIN is diagnosed when no other specific cause of renal decline can be noted after the administration of contrast medium. The ACR

BOX 28-7

Formulas to Estimate GFR

COCKCROFT-GAULT FORMULA:

$$\text{Creatinine clearance, male (ml/min)} = \frac{140 - \text{age} \times \text{lean body mass (kg)}}{\text{Serum creatinine (SCr) (mg/dl)} \times 72}$$

Creatinine clearance, female = CrCl (male) × 0.85

MODIFICATION OF DIET IN RENAL DISEASE (MDRD) FORMULA:

GFR (ml/min per 1.73 m^2) = 175 × SCr (mg/dl) (exp[-1.154])
× age (exp[-0.203]) × 0.742 (if female) × 1.21 (if African American)

Modified from Al-Ghonaim M, Pannu N: Prevention and treatment of contrast-induced nephropathy, *Tech Vasc Interv Radiol* 9:42-49, 2006.

(2007b) states that there is no standard definition for CIN, but others define CIN either as an acute drop in glomerular filtration rate (GFR) estimated from a rise in serum creatinine level occurring within 72 hours of contrast exposure in the absence of another renal insult (Solomon et al, 2007) or as an absolute increase in serum creatinine level (0.5 or 1.0 mg/dl), a change in serum creatinine level that is a 25% to 50% increase over the baseline level, or a decrease in the estimated GFR (Bettman, 2008).

The patient's state of hydration and the existence of any preexisting renal insufficiency affect the likelihood of CIN. Patients with normal renal function tolerate contrast administration well given certain guidelines are observed. Because serum creatinine level is affected by many factors including age, gender, muscle mass, race, nutritional status, and diet, it is not the best indicator of renal function or GFR. This is a special concern among the elderly (Detrenis et al, 2007). Serum creatinine level has been used in the past to assess renal function because of the ease of obtaining a simple blood specimen and the rapid turnaround time to obtain results. Creatinine clearance has become the best current option to assess GFR before contrast agent administration. The GFR is estimated from the serum creatinine level by use of the Cockcroft-Gault formula or the Modification of Diet in Renal Disease (MDRD) formula (Box 28-7).

The development of CIN may be influenced by the type of injection—intravenous or arterial. The list of risk factors that have been studied includes emergency procedures, preexisting renal insufficiency, dehydration, diabetes mellitus (especially those patients with preexisting renal insufficiency), cardiovascular disease (hypertension, congestive heart failure), intraprocedural hypotension, diuretic use, advanced age, hyperuricemia, concurrent use of nephrotoxic drugs (e.g., cisplatin, gentamicin, tobramycin, vancomycin, amikacin), surgery, cholesterol emboli syndrome, use of nonsteroidal anti-inflammatory drugs (NSAIDs), and administration of large volumes of contrast media. Drugs that decrease renal perfusion (e.g., angiotensin-converting enzyme inhibitors, diuretics, and NSAIDs) may contribute to the development of CIN. The most notable predictor of CIN is believed to be underlying renal insufficiency. Careful patient selection is advised before contrast medium is given. It is important to note that risk factors are additive and interactive.

The pathophysiology of CIN is not fully known. Tumlin and colleagues (2006) cite three contributing factors: vasoconstriction, oxidative stress, and direct tubular toxicity. CIN presents clinically as acute renal failure and is usually nonoliguric, but oliguria can occur. Serum creatinine level may increase from day 1 to day 7 after contrast medium is used and then return to baseline in 1 to 2 weeks. Renal dialysis is needed in rare cases only. CIN is considered a "marker" for those with overall poor outcomes (Mauro et al, 2008).

It is important to identify the at-risk patient and determine the level of risk. Alternatives to a contrast study should be considered. An unenhanced (no contrast) examination or alternative modality may be used to obtain the necessary information. Carbon dioxide may be used as an alternative to water-soluble contrast media for certain angiographic studies.

CIN preventive measures have been developed. Hydration with normal saline alone or in combination with sodium bicarbonate has been used. The antioxidant *N*-acetylcysteine (NAC) has been used. Administration of oral NAC has been recommended on the day before and on the day of the contrast media study (ACR, 2007b). Other medications (including mannitol, furosemide, theophylline, fenoldopam) have been tried in the past without conclusive results. The ACR recommends hydration as the best preventive measure against CIN. Oral hydration is recommended if appropriate for the patient; intravenous hydration is recommended before and after the procedure if oral hydration is not possible. The use of LOCM or IOCM is recommended for patients with renal insufficiency (ACR, 2007b). McCullough and Soman (2005) advocate the use of iodixanol as the preferred contrast medium for high-risk patients. Preventive dialysis is not recommended for prevention of CIN; if hypotension occurs, preventive dialysis may be detrimental (Meschi et al, 2006). Hemofiltration is only recommended for patients with chronic renal disease who need cardiovascular procedures (Marenzi et al, 2006).

Contrast Media Reactions. Reactions to contrast media can occur and the risk varies according to several patient- and contrast-related factors. A prior reaction to contrast media is the single best predictor of a subsequent reaction but this may not always be the case (Mauro et al, 2008). Reactions are categorized as mild, moderate, or severe (Box 28-8). These categories are not necessarily distinct. A significant reaction can have the appearance of a minor reaction at the onset.

BOX 28-8

Categories of Contrast Media Reactions

MILD

Signs and symptoms appear self-limited without evidence of progression, including:

- Nausea, vomiting
- Cough
- Warmth
- Headache
- Dizziness
- Shaking
- Altered taste
- Itching
- Pallor
- Flushing
- Chills
- Diaphoresis
- Rash, hives
- Nasal stuffiness
- Edema of the eyes and face
- Anxiety

Treatment: Requires observation to confirm resolution and/or lack of progression, but usually no treatment is indicated. Patient reassurance is helpful.

MODERATE

Signs and symptoms are more pronounced. Moderate degree of clinically evident focal or systemic signs or symptoms, including:

- Tachycardia/bradycardia
- Hypertension
- Generalized or diffuse erythema
- Dyspnea
- Bronchospasm, wheezing
- Laryngeal edema
- Mild hypotension

Treatment: Clinical findings in moderate reactions frequently require prompt treatment. These situations require close, careful observation for possible progression to a life-threatening event.

SEVERE

Signs and symptoms are often life-threatening, including:

- Laryngeal edema (severe or rapidly progressing)
- Unresponsiveness
- Cardiac arrest
- Convulsions
- Profound hypotension
- Clinically manifested dysrhythmias

Treatment: Requires *prompt* recognition and aggressive treatment; manifestations and treatment frequently require hospitalization.

Modified from American College of Radiology: *Manual on contrast media,* version 6, 2008, available at www.acr.org/SecondaryMainMenuCategories/quality_safety/contrast_manual.aspx. Accessed September 6, 2009.

Careful observation of the patient and early recognition and treatment intervention are imperative. The overall rate of reaction to nonionic contrast media is small. The ACR (2008) estimates the rate for serious reactions is 1 to 2 per 1000 patients. Severe reactions to contrast media are not IgE-mediated or immunologic in nature. Because of this they are described as anaphylactoid reactions. These are also referred to as idiosyncratic reactions because they are unpredictable. The clinical manifestations of an anaphylactoid reaction are the same, however, as those of an anaphylactic reaction in which there is an allergen-IgE response and release of mast cell mediators. The majority of serious reactions occur "immediately or within 20 minutes" after the contrast injection (ACR, 2008). Increased capillary permeability and constriction of bronchial smooth muscle cells are present. Facial and laryngeal edema, urticaria, bronchospasm, and hypotension may lead to a life-threatening situation if not recognized and treated promptly.

Nonidiosyncratic (sometimes referred to as chemotoxic reactions) are predictable. Reassurance may be all that is needed for the patient experiencing a vasomotor reaction. Nausea and vomiting are usually transient. If a vasovagal reaction (with symptomatic bradycardia and hypotension) occurs, simply raising the patient's legs to increase intravascular volume can be of value. The vasovagal response may be reversed with fluids and atropine if bradycardia persists.

Delayed reactions are extremely uncommon but can occur from 1 hour to several days after injection of contrast media (Brockow, 2009). Past treatment with interleukin-2 may be associated with a delayed cutaneous reaction. Iodine "mumps" and syndrome of acute polyarthropathy may be other examples of delayed reactions (ACR, 2008). Most patients recover from contrast reactions without long-term sequelae (Wang et al, 2008). All contrast reactions should be well documented and patients should be advised to inform their primary care providers and referring physicians of any problems with procedures involving contrast media (Patient and Family Education).

Careful observation and preparation to respond to an emergency situation are necessary at all times. All patients should be observed for the possibility of a contrast reaction after injection and intravenous access should remain until there is reasonable assurance that a reaction will not occur. Patients with known or suspected past reactions to contrast media may be pretreated (Box 28-9). Premedication does not guarantee that a reaction will not occur. The injection of contrast media should be discontinued at the first sign of a reaction and a quick assessment performed. Intravenous fluids to secure intravenous access should be given via tubing that does not contain residual contrast media. All personnel in the area should be knowledgeable about reactions and know their role in the treatment of reactions (Rapid Response Team box).

Contrast Media Extravasation. Extravasation occurs when contrast medium is injected into or leaks into soft tissue. It can cause tissue damage as a result of the toxicity of the agent or through pressure (e.g., compartment syndrome). The risk for

PATIENT AND FAMILY EDUCATION

Discharge Instructions for Contrast Media Injection

Always provide the patient and the caregiver *verbal* and *written* instructions. Provide them with the name and telephone number of the physician or nurse to call if questions arise.
Review the physician's explanation of postdischarge care and evaluate the patient's response to the instructions provided.

GENERAL INSTRUCTIONS AFTER INJECTION OF CONTRAST MEDIA

- Increase your fluid intake over the next 24 hours to help your kidneys pass the contrast media (x-ray dye).
- Call your physician if any of the following occur:
  - You have any worsening of the pain or symptoms you were having before the procedure.
  - The place where the contrast media was injected, or the catheter was put into your skin, begins to bleed or swell, or it becomes more painful.
  - Your arm, leg, or foot becomes cool or cold.
  - You have slurred speech, balance problems, or trouble using your arm or leg.
  - You develop a rash, itching, sweating, or trouble breathing.

INSTRUCTIONS FOR CONTRAST MEDIA REACTIONS

- Call the radiology nursing station if your symptoms do not resolve, or you develop new symptoms such as hives or a rash, itching, prolonged or frequent vomiting, chest tightness, shortness of breath, dizziness, or swelling.
- Take the medications prescribed to treat your reaction. Oral antihistamines, such as diphenhydramine (Benadryl), may make you too drowsy to drive or operate machinery safely. They can affect concentration and interfere with children's learning in school. These medications should be taken only as long as directed.
- If you do not respond to the treatment prescribed for your reaction, it is important that you see a medical professional for re-evaluation.
- Do not attempt to treat or "wait out" severe reactions at home. Go immediately to a hospital emergency department.
- If no one is available to drive you right away, call an ambulance for emergency medical transport.
- Obtain and wear a MedicAlert bracelet and carry an identification card describing your allergy.
- Inform healthcare providers about your allergy before any procedures are performed.
- Follow up with your healthcare provider to let him or her know about your reaction. At this follow-up appointment, he or she can evaluate your recovery from the reaction and adjust any medications.

INSTRUCTIONS FOR CONTRAST MEDIA EXTRAVASATION

- Keep the area elevated higher than your heart.
- Use a cold pack or warm compresses, as instructed, on the area for the next 4 hours.
- Avoid any tight-fitting clothing/jewelry near the affected site.
- Call your physician if the pain gets worse, or the swelling does not improve after 24 hours.

Modified from Canobbio MM: *Mosby's handbook on patient teaching,* ed 3, St Louis, 2006, Mosby; *Medical treatment for drug allergy,* available at www.emedicinehealth.com/drug_allergy/page8_em.htm. Accessed September 6, 2009; *Mosby's nursing consult: patient education instructions; cardiac catherization, CT scanning, intravenous pyelogram,* 2008, St Louis, Mosby.

BOX 28-9

Premedication Options for Contrast Allergy

1. Prednisone 50 mg by mouth at 13 hours, 7 hours, and 1 hour before contrast media injection, *plus* diphenhydramine (Benadryl) 50 mg intravenously, intramuscularly, or orally 1 hour before contrast medium injection.
2. Methylprednisolone (Medrol) 32 mg by mouth 12 hours and 2 hours before contrast media injection. An antihistamine (as in option 1) can also be added to this regimen.

Modified from American College of Radiology: *Manual on contrast media,* version 6, 2008, available at www.acr.org/SecondaryMainMenuCategories/quality_safety/contrast_manual.aspx. Accessed September 6, 2009.

extravasation is increased when a power injector is used or the patient has certain medical conditions (e.g., circulatory problems of an extremity, history of radiation or surgery).

Extravasation of contrast medium should be prevented by establishing a reliable peripheral injection site and assessing the site before injection of the contrast agent. Commercial extravasation detector devices are available but they should not be a substitute for patient site assessment, observation, and communication. The nurse should instruct the patient to report any burning, stinging, or tight feeling that occurs with the injection of the contrast agent, and if complaints occur they should be investigated. The patient may not be aware of the occurrence of an extravasation or may not be able to report symptoms; examples of such patient populations include infants or young pediatric patients, patients with limited mental ability, or patients with a decreased level of consciousness (e.g., from sedation or medical condition) or inability to communicate. Extravasation may appear as "blush" when intraarterial images are taken, as in the example of a diagnostic study for gastrointestinal bleeding.

An extravasation should be brought to the attention of the radiologist immediately after it occurs. Treatment is based on the nature of the extravasation. Close follow-up is indicated for any extravasation because the initial evaluation may not reveal the extent of the problem (ACR, 2008). Treatment options are per the radiologist's preference, with limb elevation and warm or cold compress application being the most frequently used therapies. Surgical consultation is advised for significant

RAPID RESPONSE TEAM

Contrast media reactions represent an area where quick recognition of the problem and rapid intervention can prevent escalation of a serious condition. Perioperative nurses working in the IR setting must be familiar with the signs and symptoms of a contrast media reaction so they can respond rapidly to the situation. The information below outlines the steps to take in managing contrast media reactions in adults and children.

Symptom	Adult Management	Pediatric Management
Urticaria	1. Discontinue injection if not completed. 2. No treatment needed in most cases. 3. Give H_1-receptor blocker: diphenhydramine PO/IM/IV 25-50 mg. *If severe, or widely disseminated, give alpha agonist: epinephrine SubQ (1:1000) 0.1-0.3 ml (=0.1-0.3 mg) if no cardiac contraindications.*	1. No treatment needed in most cases. 2. Give H_1-receptor blocker: diphenhydramine PO/IM/IV 1-2 mg/kg up to 50 mg. *If severe, or widely disseminated, give alpha agonist: epinephrine SubQ (1:1000) 0.01 ml/kg.*
Facial or laryngeal edema	1. Give O_2 6-10 L/min (via mask). 2. Give alpha agonist: epinephrine SubQ (1:1000) 0.1-0.3 ml (=0.1-0.3 mg) or, especially if hypotension evident, epinephrine (1:10,000) slowly IV 1-3 ml (=0.1-0.3 mg). Repeat as needed up to a maximum of 1 mg. *If not responsive to therapy or if there is obvious acute laryngeal edema, seek appropriate assistance (e.g., rapid response or code team).*	1. Give O_2 6-10 L/min (via mask, face tent, or blow-by stream). Monitor ECG, O_2 saturation, and blood pressure. 2. Give alpha agonist: epinephrine SubQ or IM (1:1000) 0.01 ml/kg, up to 0.3 ml/dose. Repeat in 3-5 min as needed. 3. Give H_1-receptor blocker: diphenhydramine IM/IV 1-2 mg/kg, up to 50 mg. 4. Give beta-agonist inhalers (metaproterenol, terbutaline, albuterol) 2-3 puffs; repeat as necessary.
Bronchospasm	1. Give O_2 6-10 L/min (via mask). Monitor ECG, O_2 saturation, and blood pressure. 2. Give beta-agonist inhalers (metaproterenol, terbutaline, albuterol) 2-3 puffs; repeat as necessary. If unresponsive to inhalers, use SubQ, IM, or IV epinephrine. 3. Give epinephrine SubQ or IM (1:1000) 0.1-0.3 ml (=0.1-0.3 mg); or especially if hypotension evident, epinephrine (1:10,000) slowly IV 1-3 ml (=0.1-0.3 mg). Repeat as needed up to maximum of 1 mg. *Seek appropriate assistance (e.g., rapid response or code team) for severe bronchospasm, or if O_2 saturation <88% persists.*	Same as treatment for laryngeal edema.
Hypotension with tachycardia	1. Elevate legs 60 degrees or more (preferred) or place in Trendelenburg's position. 2. Monitor ECG, O_2 saturation, and blood pressure. 3. Give O_2 6-10 L/min (via mask). 4. Rapidly infuse large volumes of Ringer's lactate or normal saline. *If poorly responsive, give epinephrine (1:10,000) slowly IV 1 ml (=0.1 mg). Repeat as needed up to maximum of 1 mg. If still poorly responsive, seek appropriate assistance (e.g., rapid response or code team).*	1. Give O_2 6-10 L/min via mask. Monitor ECG, O_2 saturation, and blood pressure. 2. Elevate legs 60 degrees or more (preferred) or place in Trendelenburg's position. 3. Keep patient warm. 4. Give IV or IO normal saline or Ringer's lactate 20 ml/kg over 5-10 min. Bolus infusion over 10-20 min in patients with myocardial dysfunction. *Seek appropriate assistance (e.g., rapid response or code team).*
Hypotension with bradycardia (vagal reaction)	1. Elevate legs 60 degrees or more (preferred) or place in Trendelenburg's position. 2. Give O_2 6-10 L via mask. Monitor ECG, O_2 saturation and blood pressure. 3. Rapid IV administration of large volumes of Ringer's lactate or normal saline. 4. If patient does not respond, give atropine 0.6-1 mg IV slowly. Repeat up to a total dose of 0.04 mg/kg. 5. Seek appropriate assistance (e.g., rapid response team or code team)	1. Give O_2 6-10 L/min via mask. Monitor ECG, O_2 saturation, and blood pressure. 2. Elevate legs 60 degrees or more (preferred) or place in Trendelenburg's position. 3. Keep patient warm. 4. Give IV or IO normal saline or Ringer's lactate 20 ml/kg over 5-10 min. Bolus infusion over 10-20 min in patients with myocardial dysfunction. 5. Give atropine IV 0.02 mg/kg if patient does not respond quickly to steps 2-4. Minimum initial dose of 0.1 mg. Maximum initial dose of 0.5 mg (infant/child) or 1.0 mg (adolescent). 6. Atropine dose may be doubled for second administration. *Seek appropriate assistance (e.g., rapid response or code team).*

IM, Intramuscular; *IO,* intraosseous; *IV,* intravenous; *PO,* orally; *SubQ,* subcutaneous.

Modified from American College of Radiology: *Manual on contrast media,* version 6, 2008, available at www.acr.org/SecondaryMainMenuCategories/quality_safety/contrast_manual.aspx. Accessed September 6, 2009.

extravasations. Compartment syndrome can develop following severe reactions and requires immediate management.

UNIVERSAL PROTOCOL AND STANDARD PRECAUTIONS. The nurse is often the person responsible for ensuring that the *Universal Protocol for Preventing Wrong Site, Wrong Procedure, Wrong Person Surgery* is observed in the procedure areas. The "Time Out" must involve the whole team and be done just before the procedure is initiated. Special positioning for the radiology procedure and multiple procedures involving position changes may become sources of confusion so vigilance is advised.

Personal protective equipment should be worn according to facility policy and procedure. All standard Universal Precautions and infection control measures should be observed in the procedure area. If the patient has recently undergone a nuclear medicine scan, the half-life of the isotope tracer should be known. It may be necessary to dispose of contaminated drapes and supplies per nuclear medicine disposal policies.

POSITIONING. The patient's position on the procedure table will be determined by the type of procedure to be performed. It is important that the patient is transferred safely onto the procedure bed and that a reasonably comfortable position is arranged. The nurse pads all bony prominences and places pillows to relieve pressure points. For procedures such as nephrostomy tube placement or kyphoplasty, the patient will be positioned prone. The prone position may be difficult for elderly or acutely ill patients to achieve without assistance. Care should be taken to assist the patient and not to rush because injuries to skin or joints or intravenous displacement can occur. Care should also be taken so that tension is not placed on any existing drainage tubes. Ostomy bags may need to be emptied before placing the patient in a prone position. All sponges, wedge pillows, or other devices that are used for positioning should be kept out of the field of view for imaging. It is important to ask the patient if the position will be comfortable to maintain for the length of the procedure. Assure the patient that sedation and analgesia will be given, if that is the case, after appropriate positioning and placement of monitors. The nurse carefully plans the placement of the monitoring equipment and connecting cables so they will not interfere with the imaging area of interest. For example, when lateral abdominal filming is anticipated the right leg electrocardiogram lead and cable will need to be out of view. Placement of monitoring equipment should not interfere with the best possible access to the patient for monitoring or emergency reasons. If the electrosurgical unit is to be used, the nurse places the grounding pad in an area that will not be in the field of view. Equipment used for physiologic monitoring and resuscitation of the patient in the magnetic resonance imaging setting must be MRI compatible.

PROCEDURES. Interventional procedures fall into several categories (Box 28-10), but most are initiated with the Seldinger technique. This technique, developed in 1953 by the Swedish radiologist Dr. Sven-Ivar Seldinger, involves a guidewire (leader) fed through a puncture needle (Figure 28-5). The Seldinger technique changed interventional radiology because it provided a less invasive and safer means of access to vessels. After sterile preparation and draping, a local anesthetic is administered over the intended entry site, usually the groin for an angiogram that uses the retrograde femoral artery approach. A small dermatomy is made just before the puncture. A needle (Seldinger 18-gauge, 2¾-inch or other) with stylet is used to gain vascular access and then the stylet is removed. A pulsatile backflow of blood will be noted with arterial access. A guidewire is advanced, after which the needle is removed while the vessel is compressed. A sheath can then be placed over the guidewire and a catheter can be advanced. The guidewire is then removed.

A puncture can be either a single-wall puncture or a double-wall vessel puncture. For vascular access the location of the puncture is crucial. In the case of groin access, the femoral artery puncture is made over the middle third of the femoral head well below the inguinal ligament. The femoral head helps with compression of the artery after access is removed. Punctures that are too high (above the inguinal ligament) can result in bleeding after access is discontinued. Low arterial punctures have been associated with pseudoaneurysm formation. Fluoroscopy over the femoral head helps to confirm the location of access. Obesity may make identification of anatomic landmarks difficult; in these patients a portable Doppler may be useful. Doppler is also helpful when the patient's pulse is not easily palpable. A high brachial artery puncture or axillary artery puncture may be done if femoral artery puncture is not possible or desired. The presence of radial and ulnar pulses and their quality should be documented before the procedure, similarly to documentation for distal extremity pulses for a femoral artery puncture. A translumbar puncture is rarely used. Hemorrhage, distal embolization, and pseudoaneurysm development are potential complications of an arterial puncture.

The Seldinger technique may also be used during other interventional procedures such as a percutaneous abscess drainage procedure, percutaneous nephrostomy, or chest tube placement.

Biopsy specimens obtained during procedures should be labeled per institutional policy and protocols. Specimen preparation, requirements for fixative additives, and handling should be done in accordance with established policy and procedures. A cytology technologist may be requested to be present during the procedure to determine if adequate tissue has been obtained.

Evaluation. During the evaluation phase of care the nurse determines if the outcomes established for the patient were met and revises outcomes and interventions as necessary. The evaluation period provides opportunities to improve nursing interventions through careful reflection and analysis of outcomes. The following are possible evaluation statements relating to the Sample Plan of Care (see p. 1221):

- The patient verbalized an acceptable level of pain as defined with a 1 to 10 pain scale.
- The patient demonstrated a decreased level of anxiety, verbalized less apprehension, maintained eye contact, and was able to comply with requests even though anxiety persisted.
- The patient verbalized understanding of the procedure and described the actions to take after discharge.
- The patient's airway was maintained and oxygen saturation was within preprocedure baseline limits.
- The patient's vital signs were within acceptable limits, peripheral pulses returned to baseline, and there was no evidence of excessive bleeding.
- The patient's skin was intact with no reddened areas or lesions.

BOX 28-10

Types of Interventional Procedures

ARTERIAL DIAGNOSTIC AND THERAPEUTIC PROCEDURES
- Arteriography for diagnostic or therapeutic purpose
- Aortoiliac interventions (stent placements), angioplasty
- Carotid interventions
- Endovascular repair (peripheral to abdominal aortic aneurysm (AAA) repair, arterial)
- Embolotherapy (for perioperative planning, trauma, other)
- Thrombolytic therapy for arterial disease
- Stroke intervention
- Peripheral interventions
- Renovascular disease interventions
- Neurointerventional disease management (cerebral aneurysm, arteriovenous malformations)

VENOUS DIAGNOSTIC AND THERAPEUTIC PROCEDURES
- Venous access placement (portacath, triple-lumen catheters, midline catheters, peripherally inserted central catheters)
- Venous reflux and varicose vein management
- Hemodialysis access and catheter maintenance
- Portal hypertension management (TIPS)
- Inferior vena caval filter placement (permanent and temporary) and removal
- Thrombolytic therapy
- Venous sampling (e.g., parathyroid, adrenal, renal vein)
- Retrieval of foreign body

NONVASCULAR DIAGNOSTIC AND THERAPEUTIC PROCEDURES
- Abscess drainage or seroma tube placement
- Chest tube placement
- Percutaneous gastrostomy tube (G-tube) or gastrojejunostomy tube (GJ-tube) placement
- Percutaneous jejunostomy feeding tube (J-tube) placement
- Cecostomy tube placement
- Gastrointestinal stent placement
- Percutaneous biliary tube placement
- Percutaneous nephrostomy tube placement
- Ureteral stent placement
- Percutaneous nephrolithotomy
- Varicocele interventions
- Lacrimal procedures (balloon dilation, stent placement, stone removal)
- Biopsies of solid organs (e.g., liver, kidney, prostate, bone, lung, or breast)

BONE AND SPINAL DIAGNOSTIC AND THERAPEUTIC PROCEDURES
- Myelograms
- Diskograms
- Lumbar punctures (for pressure measurement, spinal fluid collection, or isotope injection)
- Vertebral augmentation procedures (vertebroplasty, kyphoplasty)
- Selective nerve blocks
- Facet injections
- Stellate ganglion blocks
- Epidural steroid injection
- Periradicular therapy

GYNECOLOGIC PROCEDURES
- Uterine artery embolization
- Uterine fibroid embolization
- Fallopian tube cannulation
- Pelvic congestion intervention

ONCOLOGY PROCEDURES

Embolotherapy
- Chemoembolization of the liver
- Transarterial placement of yttrium-90 microspheres (90Y)
- Tumor ablation with radiofrequency (RFA)/thermal, cryotherapy, other
- Brachytherapy delivery

MISCELLANEOUS OTHER PROCEDURES
- Botox® therapeutic use (for psoas spasm or piriformis syndrome), or for cosmetic reasons
- Trauma interventions
- Pleurodesis
- Paracentesis
- Thoracentesis

At the conclusion of an angiographic procedure the nurse may be involved in ensuring hemostasis of the puncture site and applying dressings. Hemostasis is obtained by manual pressure, compression devices, vascular closure suture, or collagen plug. Additional medication for analgesia, administered either locally or intravenously, may be needed before manual or compression device hemostasis. The time the catheter and/or sheath are removed should be noted. Compression should be firm but should not obliterate the distal pulses. In addition to vital signs, distal pulses should be assessed during this period. A loss of pulse could indicate distal embolism or vascular spasm, and the radiologist should be notified immediately. The color and temperature and neurosensory status of the extremity should be observed. The nurse should also monitor the patient for signs of hematoma formation at the puncture site or retroperitoneal hemorrhage. Manual pressure should be applied if hemorrhage and hematoma formation are suspected. After hemostasis is achieved, the affected extremity should be kept still for a length of time, as determined by the type of closure performed. Any signs or symptoms of stroke should be reported immediately. Pseudoaneurysm formation, nerve damage, and infection, although rare, can occur after arterial puncture.

The patient will be transported to a recovery area and monitored according to the amount of sedation and analgesia received, pain level, vital signs, and other discharge assessment criteria per the specific procedure and postanesthesia recovery room criteria. The type of interventional procedure performed will determine other variables that will be monitored, including distal pulses for angiography; neurologic, motor, and sensory signs for the lower extremities after vertebroplasty; or urine output following nephrostomy. Patients who have undergone biopsies should be monitored for signs of bleeding. After lung biopsy blood-tinged sputum may be present. Hemoptysis or signs of pneumothorax should be reported immediately. Patients who have undergone liver biopsy may complain of pain radiating to the shoulder.

The inpatient can be transferred according to facility policy, usually when vital signs are stable and pain has been managed. Neurointerventional procedure patients may be transferred to an intensive care setting after the procedure.

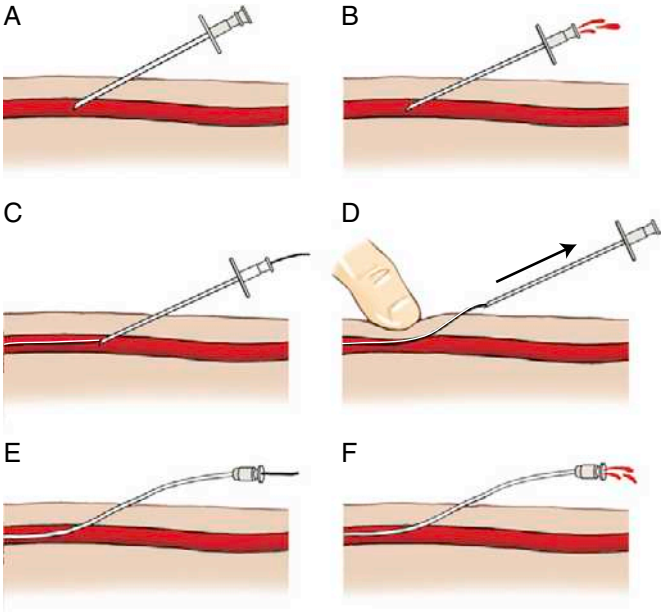


FIGURE 28-5 Seldinger technique. **A**, Insertion of needle. **B**, Placement of needle in lumen of vessel (inner cannula removed). **C**, Insertion of guidewire. **D**, Removal of needle (guidewire remains in place). **E**, Threading of catheter over guidewire. **F**, Removal of guidewire.

Outpatients will need to meet criteria similar to those for other surgical procedures per facility policy (Ambulatory Surgery Considerations). Discharge instruction forms should be procedure specific. Items to be included in the discharge instructions are activity restrictions, possible complications and when/who to call for help, diet, medications, specific care related to procedure, driving restrictions, signs of infection, and follow-up care plan/appointment. Patients who have had arterial punctures should be given precise instructions on actions to take in case of hemorrhage or other puncture site complication. Patient and family teaching with return demonstrations for procedures such as tube care should be done. Instructions regarding care of drainage bags and required flushing of tubes are essential. Sterile technique demonstration is critical in many instances, including PICC line care. Teaching videos, patient information booklets developed by a device's manufacturer, and facility-developed handouts will be useful in patient teaching. A uniform postprocedure phone call form will prompt the nurse to ask the appropriate questions. Postprocedure phone calls for outpatients are made the day after the procedure when possible or as soon thereafter per policy and procedure. These calls generate information not only about outcomes and possible complications but also about the patient's perceived satisfaction with the procedure and nursing care provided. This information will be useful for performance improvement data collection for outpatient nursing care.

Some outpatient procedures may require a 23-hour observation stay as a result of pain, unforeseen procedure events, or changes in the patient's condition. A planned 23-hour stay may be arranged in advance. For example, the patient may be hospitalized for symptoms of postembolization syndrome, which occurs after the blood supply is interrupted to an organ, as expected in the case of uterine fibroid embolization. Pain, nausea (and possible vomiting), fever, and an increased white cell count are expected signs and symptoms. The nursing report should include information about the procedure, all procedure-specific instructions, and information about possible equipment needed, such as wall suction after chest tube placement. Documentation of the entire procedure and reports should be completed per facility policy.

AMBULATORY SURGERY CONSIDERATIONS

Discharge Assessment/Summary

- Physician order to discharge patient has been provided.
- Patient has stable vital signs (resembling baseline vital signs), including Spo_2 level.
- Patient shows no evidence of respiratory depression.
- Patient is oriented per baseline to person, place, and time.
- Patient can take fluids, if appropriate, without nausea.
- Patient can void, if a procedure-specific criterion.
- Patient can ambulate with/without assistance as appropriate, and has no dizziness.
- Pain has been addressed/managed.
- Bleeding is not present; drainage is per procedure expectation.
- Written discharge instructions including medication reconciliation with phone number to call have been given to patient. (Patients are informed how to obtain necessary supplies, if applicable.)
- A responsible person is available to escort patient to home/stay with patient.

REFERENCES

American College of Radiology (ACR) et al: Practice guideline for interventional clinical practice, *J Vasc Interv Radiol* 16:149–155, 2005.

American College of Radiology (ACR): *Practice guideline on informed consent for image-guided procedures*, 2007a, available at www.acr.org. Accessed November 3, 2008.

American College of Radiology (ACR): *Practice guideline on the use of intravascular contrast media*, 2007b, available at www.acr.org. Accessed November 3, 2008.

American College of Radiology: *Manual on contrast media*, version 6, 2008, available at www.acr.org/SecondaryMainMenuCategories/quality_safety/contrast_manual.aspx. Accessed September 6, 2009.

Arnold J, Roberts A: No longer 'conscious sedation,' *Interventional News* 32:8, 2008.

Beaty AD et al: Seafood allergy and radiocontrast media: are physicians propagating a myth? *Am J Med* 121:158e1–158e4, 2008.

Bettman M: Contrast agents. In Mauro M et al: *Image-guided interventions*, Philadelphia, 2008, Saunders.

Brockow K: Immediate and delayed reactions to radiocontrast media: is there an allergic mechanism? *Immunol Allergy Clin North Am* 29:453–468, 2009.

Dendy PP: Radiation risks in interventional radiology, *Br J Radiol* 81:1–7, 2008.

Detrenis S et al: Contrast medium administration in the elderly patient: is advancing age an independent risk factor for contrast nephropathy after angiographic procedures, *J Vasc Interv Radiol* 18:177–185, 2007.

Health Physics Society: *Ionizing radiation-safety standards for the general public*, available at http://hps.org/documents/publicdos_ps005-3.pdf. Accessed May 21, 2009.

Klein LW et al: Joint Inter-Society Task Force on Occupational Hazards in the Interventional Laboratory, *J Vasc Interv Radiol* 20:147–153, 2009.

Marenzi G et al: Comparison of two hemofiltration protocols for prevention of contrast-induced nephropathy in high-risk patients, *Am J Med* 119:155–162, 2006.

Marx MV: Radiation safety and protection in the interventional environment. In Mauro M et al: *Image-guided interventions*, ed 2, Philadelphia, 2008, Saunders.

Mauro M et al: *Image-guided interventions*, ed 2, Philadelphia, 2008, Saunders.

McCullough PA, Soman SS: Contrast-induced nephropathy, *Crit Care Clin* 21:261–280, 2005.

Meschi M et al: Facts and fallacies concerning the prevention of contrast medium-induced nephropathy, *Crit Care Med* 34:2060–2068, 2006.

Po J: *Nurse legend radiology nursing,* American Radiological Nurses Association Spring Educational Meeting, New Orleans, 2005.

Shabanie A: Conscious sedation for interventional procedures: a practical guide, *Tech Vasc Interv Radiol* 9:84–88, 2006.

Society of Interventional Radiology (SIR): *What is interventional radiology?* Patient Brochure, 2005, available at www.sirweb.org/medical-professionals/PIB_PDFs/SIR_What_is_IR_PIB.pdf. Accessed August 31, 2009.

Solomon R et al: *CIN strategies: anticipate, manage, prevent, imaging economics*, 2007, available at www.imagingeconomics.com/assets/pdf/tyco.pdf. Accessed September 6, 2009.

Tumlin J et al: CIN Consensus Working Panel: Pathophysiology of contrast-induced nephropathy, *Am J Cardiol* 98 [suppl]:14K-20K, 2006.

Uppot RN: Impact of obesity on radiology, *Radiol Clin North Am* 45:231–246, 2007.

Wang CL et al: Frequency, outcome, and appropriateness of treatment of nonionic iodinated contrast media reactions, *AJR* 191:409–415, 2008.

CHAPTER 29

Integrated Health Practices: Complementary and Alternative Therapies

SUSAN M. CRAIG

HISTORY AND BACKGROUND

Any accurate presentation of the history of medicine in the United States needs to include influences from the botanic cultural traditions of Asia, India, Europe, and the First Nations. Our current medical system, called *biomedicine,* began to dominate sometime in the mid-1800s with the discovery that microorganisms were responsible for disease and pathologic damage and that antitoxins and vaccines could improve the body's ability to oppose the effects of pathogens. Armed with this knowledge, scientists and clinicians began to refine surgical procedures and treat previously serious and fatal infections.

As biomedicine dominated the healthcare system, it became the mainstream or "conventional" approach, establishing the standards for diagnosis and treatment of illness. By the 1990s, however, consumer faith and trust in this conventional system began to falter and many Americans sought complementary or alternative treatments for their healthcare. Complementary and alternative medicine (CAM) has grown to constitute a significant percentage of American healthcare dollars and visits. This growth is sustained by the trend for patients to be more empowered healthcare consumers and the availability of media information about the many alternatives to the mainstream, traditional Western biomedical approach to medicine.

Myths and misconceptions initially prevented the investigation and development of promising therapies outside the biomedical regimen. In response to growing consumer pressure, anecdotal evidence, and a small body of published scientific results, the U.S. Congress established the Office of Alternative Medicine (OAM) within the office of the Director, National Institutes of Health (NIH), in 1992. This office was given responsibility for (1) facilitating fair, scientific evaluation of alternative therapies that showed promise in health promotion and (2) reducing barriers to the acceptance and utilization of those alternative therapies that showed promise.

In 1998 the OAM became the National Center for Complementary and Alternative Medicine (NCCAM, 2009a). This expansion into a center allowed more substantial funding for and initiation of research projects, providing more sound information about CAM therapies and systems. The annual budget for NCCAM has grown significantly, as has the sophistication of research designs of studies being funded by the center. The NCCAM adheres to guidelines set forth in public policy as noted in Box 29-1.

Many CAM therapies and interventions stem from a philosophy of wholeness, with intent to treat the entire person (body-mind-spirit) (Evidence for Practice). This is in contrast to the current "gold standard" of randomized, control-led clinical trials, which may not be the best, or indeed appropriate, way to measure the effectiveness of many CAM therapies. Conventional scientists and physicians and the proponents of CAM often debate about the appropriate forms of research to determine efficacy and safety of alternate therapies. A reason for this disparity stems from divergent theoretic models. The *comprehensive approach* takes into account multidimensional factors that may not easily or appropriately be studied independently. The comprehensive approach is more congruent with the philosophic underpinnings of most CAM. The *biomedical approach,* on the other hand, is concerned with a disease orientation, suggesting that a specific agent or variable is responsible for a specific disorder or illness.

The NCCAM has categorized the many CAM modalities into five major domains: alternative medical systems, mind-body interventions, biologically based therapies, manipulative and body-based methods, and energy therapies. Numerous treatments and systems are within each category. The remainder of this chapter discusses the major domains and provides examples of each.

MAJOR CATEGORIES OF COMPLEMENTARY AND ALTERNATIVE MEDICINE

Alternative Medical Systems

An estimated 10% to 30% of human healthcare is delivered by practitioners such as surgeons and nurses who have been trained in the mainstream, traditional Western biomedical model. The remaining 70% to 90% involves care given in a healthcare system that is based on alternative traditions—self-care based in folk practice or many practices that range somewhere between alternative and traditional healthcare. Many of these therapies are culturally, ethnically, spiritually, or religiously derived (Figure 29-1). Among the diverse values, beliefs, and practices found in the many cultural groups in the

EVIDENCE FOR PRACTICE

Evaluating Complementary and Alternative Medicine Therapies

In a recent survey of 31,000 Americans, the Centers for Disease Control and Prevention (CDC) estimated that 36% use some form of complementary and alternative medicine (CAM). In discussing the use of CAM with perioperative patients, nurses have a unique opportunity to advise patients on best practices to adopt when considering the use of CAM therapies. Nurses should include the following advice when counseling patients about choosing CAM therapies:

- Take charge of your health by being an informed consumer. Investigate the therapy to determine what studies have been done on its safety and effectiveness.
- The internet is a good source to find information about CAM. In evaluating information on the internet you should always ask the following questions:
  - Who runs the web site? Is it a government, university, or reputable medical or health-related association? Is it sponsored by a manufacturer of products, drugs, and so on? It should be easy to clearly identify the sponsor.
  - What is the purpose of the site? Is it to educate the public or sell a product? The purpose should be clearly stated.
  - What is the basis of the information? Is it based on scientific evidence with clear references?
  - How current is the information? Is it reviewed and updated frequently?
- If you do not have access to the internet, contact the NCCAM Clearinghouse at 1-888-644-6226 for assistance.
- Visit your local library or medical library to search for scientific information about CAM.
- Discuss CAM with your healthcare provider before making any decision about care. Ask questions about any possible interactions with medications you currently take or therapy you are undergoing. If your physician cannot answer your questions, he or she may be able to refer you to someone who can.
- Before taking herbal supplements:
  - Talk to your physician before starting to take herbal supplements.
  - Talk to a licensed pharmacist if you have questions about the supplement, and discuss any potential reactions with any prescription or nonprescription medications (over-the-counter [OTC] medications) you currently take.
  - Read labels carefully. Buy only supplements that are approved by the American Botanicals Council's Commission E.
  - Buy products from a reputable herbal company. Be cautious about products for sale through magazines, TV, radio, or the internet.

Modified from *Are you considering using complementary and alternative medicine (CAM),* available at http://nccam.nih.gov/health/decisions/consideringcam.htm. Accessed June 9, 2009.

United States are those relating to health, illness, professional healthcare, and folk healthcare (Box 29-2). They include well-known and respected Asian systems of medicine. Many Asian medicine techniques or systems are widely known here in the United States. The most well-known and popular of these include herbal medicines, massage, energy therapy, acupressure, acupuncture, and qi gong. This alternative medicine system has a wide range of applications from health promotion to the treatment of illness. A significant aspect of Asian medicine is an emphasis on diagnosing and treating disturbances of *qi* (pronounced "chee"), or vital energy, and restoring its proper balance (Micozzi, 2006).

Ayurveda is a traditional system from India that strives to restore the innate harmony of the individual while placing equal emphasis on body, mind, and spirit. Ayurvedic practitioners use many products and techniques to cleanse the body and restore balance. Key foundations are universal connectedness (e.g., that all living and nonliving things are joined together; health will be good if one's mind and body are in harmony; disease arises when a person is out of harmony with the universe); the body's constitution or *prakriti (e.g., the person's unique physical and psychologic characteristics and how the person functions to maintain health); and life forces or doshas.* Each person has a combination of three doshas; each dosha has a particular relationship with a bodily function and can be upset for a variety of reasons. Treatment is tailored to each person's constitution and predominant dosha. Practitioners expect patients to be active participants because many ayurvedic treatments require changes in diet, lifestyle, and habits (NCCAM, 2009b).

Native American, Middle Eastern, Tibetan, Central and South American, and African cultures have developed other traditional medical systems (Micozzi, 2006). Other examples of complete alternative medicine systems are naturopathic and homeopathic medicine systems. Homeopathic medicine is based on the principle that "like cures like" (i.e., a substance that in large doses produces the symptoms of a disease will in a very diluted dose cure the patient). Small doses of plant extracts and minerals specially prepared are given to stimulate the body's defense mechanisms and encourage healing processes. A careful evaluation of symptoms enables the practitioner to determine a patient's specific sensitivity and to select the appropriate remedy.

Naturopathic medicine emphasizes health restoration as well as disease treatment based on the belief that disease is a manifestation of alterations in the body's natural healing processes. Naturopathic physicians use multiple modalities, including clinical nutrition and diet; acupuncture; herbal medicine; homeopathy; spinal and soft tissue manipulation; physical therapies involving ultrasound, light, and electric currents; therapeutic counseling; and pharmacology (Pizzorno and Snider, 2006).

Mind-Body Interventions

A growing scientific movement has explored the mind's ability to affect the body. The clinical application of this relationship is categorized as *mind-body medicine.* Some mind-body interventions (e.g., behavioral-cognitive therapy), formerly categorized as CAM therapies, have been assimilated into conventional mainstream medicine. Progressive relaxation techniques, biofeedback, meditation, and cognitive-behavioral approaches have a well-documented theoretic basis with supporting scientific evidence. Other mind-body interventions still considered CAM include hypnosis, music, dance, art therapy, prayer, and mental healing.

Biologically Based Therapies

The CAM category of biologically based therapies includes biologically based and natural-based practices, products, and interventions, some of which overlap with mainstream

BOX 29-1

Ten Guiding Principles for Legislative and Administrative Recommendations

Following are 10 guiding principles from the White House Commission on Complementary and Alternative Medicine Policy (WHCCAMP) for legislative and administrative recommendations that will ensure public policy maximizes the potential benefits of complementary and alternative medicine (CAM) to all citizens.

EXECUTIVE SUMMARY

The WHCCAMP was established by Executive Order No. 13147 in March 2000. The order states that the commission is to provide the President, through the Secretary of Health and Human Services, with a report containing legislative and administrative recommendations that will ensure public policy maximizes the potential benefits of CAM to all citizens. The report of the commission is to address the following:

- The coordination of research to increase knowledge about CAM products
- The education and training of healthcare practitioners in CAM
- The provision of reliable and useful information about CAM practices and products to healthcare professionals
- Guidance regarding appropriate access to and delivery of CAM

The commission's 20 presidentially appointed members represented an array of healthcare interests, professional backgrounds, and knowledge. Healthcare expertise was provided by both conventional and CAM practitioners.

Based on its mission and responsibilities, the commission endorsed the following 10 guiding principles to shape the process of making recommendations and to focus the recommendations themselves:

1. *A wholeness orientation in healthcare delivery.* Health involves all aspects of life—mind, body, spirit, and environment—and high-quality healthcare must support care of the whole person.
2. *Evidence of safety and efficacy.* The commission is committed to promoting the use of science and appropriate scientific methods to help identify safe and effective CAM services and products and to generate evidence that will protect and promote the public health.
3. *The healing capacity of the person.* People have a remarkable capacity for recovery and self-healing, and a major focus of healthcare is to support and promote this capacity.
4. *Respect for individuality.* Each person is unique and has the right to healthcare that is appropriately responsive to him or her, respecting preferences and preserving dignity.
5. *The right to choose treatment.* Each person has the right to choose freely among safe and effective care or approaches, as well as among qualified practitioners who are accountable for their claims and actions and responsive to the person's needs.
6. *An emphasis on health promotion and self-care.* Good healthcare emphasizes self-care and early intervention for maintaining and promoting health.
7. *Partnerships as essential to integrated healthcare.* Good healthcare requires teamwork among patients, healthcare practitioners (conventional and CAM), and researchers committed to creating optimal healing environments and to respecting the diversity of all healthcare traditions.
8. *Education as a fundamental healthcare service.* Education about prevention, healthy life-styles, and the power of self-healing should be made an integral part of the curricula of all healthcare professionals and should be made available to the public of all ages.
9. *Dissemination of comprehensive and timely information.* The quality of healthcare can be enhanced by promoting efforts that thoroughly and thoughtfully examine the evidence on which CAM systems, practices, and products are based and make this evidence widely, rapidly, and easily available.
10. *Integral public involvement.* The input of informed consumers and other members of the public must be incorporated in setting priorities for healthcare and healthcare research and in reaching policy decisions, including those related to CAM, within the public and private sectors.

CAM is a heterogeneous group of medical, healthcare, and healing systems other than those intrinsic to mainstream healthcare in the United States. Although "complementary and alternative medicine" is the term used in this report, the commission recognizes that the term does not fully capture all the diversity with which these systems, practices, and products are being used by consumers, CAM practitioners, and mainstream healthcare institutions.

From the White House Commission on Complementary and Alternative Medicine Policy: *Executive summary,* available at www.whccamp.hhs.gov/es.html. Accessed June 6, 2009.

medicine's use of dietary supplements. Herbal, orthomolecular, individual biologic therapies and special dietary treatments are encompassed in biologically based therapies.

Herbs are plants or parts of plants that contain and produce chemical substances that act on the body (Figure 29-2). Some diet therapies are believed to promote health and prevent and/or control health. Proponents of diet therapies include religious factions such as Seventh Day Adventist, or Jewish Kosher. Veganism, vegetarianism, raw food diets, and diets promoted by Drs. Atkins, Pritikin, and Weil are other examples of therapeutic nutrition. Orthomolecular therapies use differing concentrations of chemicals or megadoses of vitamins aimed at treating disease. Many biologic therapies are available that are not currently accepted by mainstream medicine, such as the use of cartilage products from cattle, sheep, or sharks for treatment of cancer and arthritis or the use of bee pollen to treat autoimmune and inflammatory diseases.

Manipulative and Body-Based Methods

Methods that are based on the movement or manipulation of the body include chiropractic, osteopathy, and massage. Touch and manipulations with the hands have been used in healing and medical practice since the beginning of the history of medicine. At one time, the physician's hands were considered the most important diagnostic and therapeutic tool. This remains true today, despite sophisticated diagnostic equipment and modalities (Box 29-3). Manual healing methods are based on the principle that dysfunction of a part of the body often affects secondarily the function of other discrete, possibly indirectly connected body parts. Theories have developed for correction of these secondary dysfunctions by realigning body parts or manipulating soft tissues. Chiropractic science is concerned primarily with the relationship between structure (spine primarily) and function (nervous system primarily) of

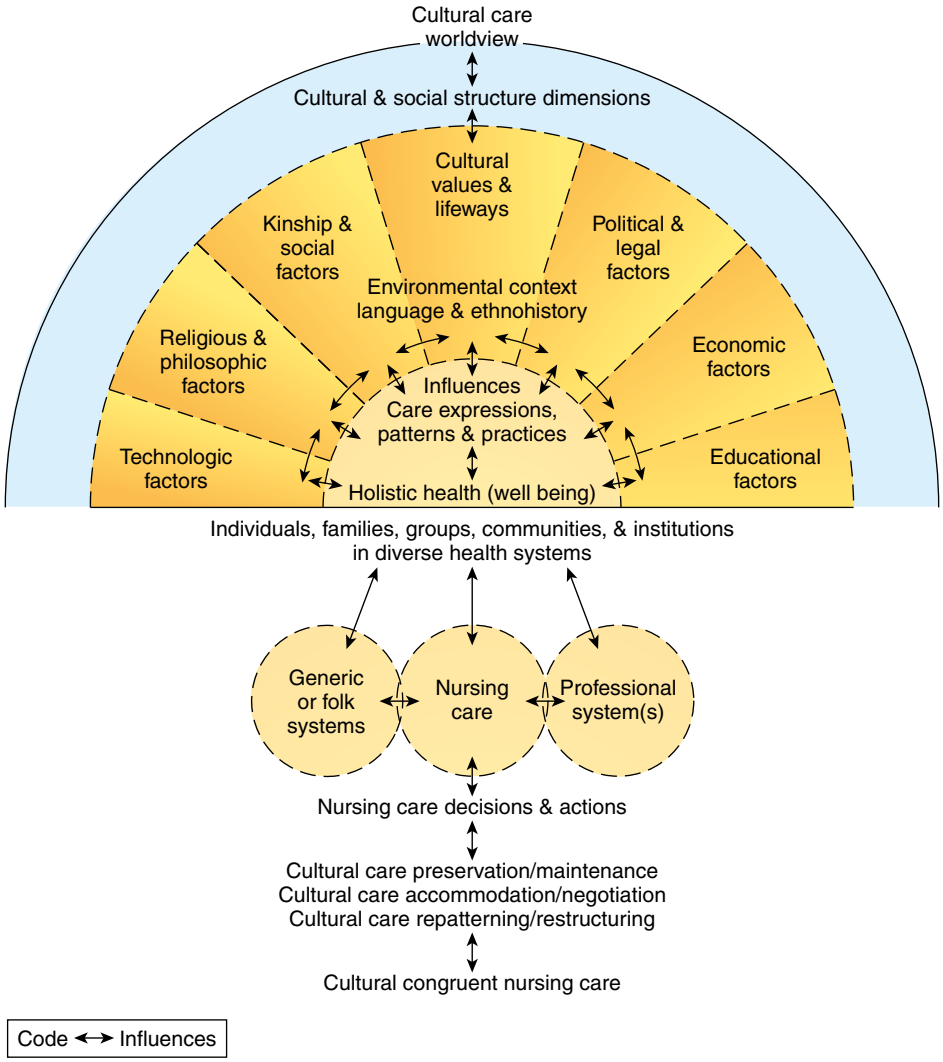


FIGURE 29-1 The Leininger Sunrise Model. From a holistic, worldview stance, the Sunrise Model serves as a map depicting the cultural, social, and environmental dimensions affecting individuals, families, communities, and institutions.

the human body to preserve and restore health. Osteopathic medicine incorporates an extensive body of work that supports the use of osteopathic techniques for both musculoskeletal and nonmusculoskeletal problems. Massage therapy is one of the oldest methods known in the practice of healthcare. Many different massage techniques are aimed at helping the body heal itself through the use of manipulation of the soft body tissues.

Energy Therapies

Energy therapies have been categorized into two groups: biofield therapies (those that focus on fields believed to originate within the body) and electromagnetic fields (those that originate from other sources). The existence of energy fields that originate within and around the body has not yet been definitively proven. However, many studies have examined the experiences of recipient or practitioner and the outcomes of this type of energy therapy. Examples of therapies with a biofield basis include acupuncture, reiki, qi gong, therapeutic touch (TT), and healing touch. Therapies that involve electromagnetic fields use unconventional pulsed fields, magnetic fields, alternating current fields, or direct current fields. These therapies have been clinically applied with patients who have arthritis, cancer, and pain (Kolthan, 2009).

COMPLEMENTARY AND ALTERNATIVE MEDICINE USE AND SURGERY

Energy Therapies

Patients have choices in how to manage their healthcare. However, surgery is the most invasive of all options (History box). As healthcare consumers become more knowledgeable about their health they may seek complementary modalities to augment traditional Western medical therapies. To use the term *alternative* is actually misleading. Many progressive medical facilities embrace a holistic patient focus, exploring and integrating nontraditional healing modalities to support an individualized surgical experience. Biofield therapies represent a nonpharmacologic anxiolytic for surgical patients that may be integrated with an allopathic treatment plan.

HISTORY

The Historical Basis for Complementary Therapies in Nursing

The philosophical basis for complementary therapies has been present since the inception of nursing as a profession. Florence Nightingale emphasized the need to create a supportive environment to foster healing and advocated the use of music in the healing process. The medical condition of a patient has always been just as important as the "rest" of the patient as nurses strive to address emotional needs and individual patient concerns. In this excerpt from a 1918 textbook, the following recommendations are provided for preparing the surgical patient:

> The general preparation of the patient begins from the time that the surgical condition is recognized. Patients should be treated in such a manner as to maintain, and indeed increase, their confidence in a successful solution of their trouble. Anything tending toward discouragement should be obviated. As a rule, the nearer the individual's normal manner of living is imitated, the more satisfactory the result. If the patient is not ill enough to be confined to bed it is well for him to walk about, read, go to the toilet, take his own bath, and at the time set for the operation walk to the OR. By so doing not only is the patient's mind kept active but especially in hospital work a not inconsiderable amount of nurse's time saved. Nervous patients should be insured a good rest the night prior to the operation by the administration of a sedative, preferably a combination of the bromids. Any concomitant disease should receive appropriate treatment.

Modified from Fowler RS: *The operating room and the patient—a manual of pre- and post-operative treatment,* Philadelphia, 1918, Saunders; Snyder M, Lindquist R: An overview of complimentary/alternative therapies. In Snyder M, Lindquist R, editors: *Complimentary and alternative therapies in nursing,* ed 5, New York, 2006, Springer.

Many ancient cultures refer to a human biofield (Table 29-1) or "life force." Sometimes referred to as "energy work," biofield therapeutics are a range of interventions sharing common beliefs. First is the existence of a "universal force" or "healing energy" arising from God (as the person understands this being), the cosmos, the earth, or another supernatural source. Second, the human biofield, as part of the "universal field," is dynamic, open, complex, and pandimensional. Human biofields are constantly changing, interacting with each other, the environment, and the universal force field. Third, the ability to use one's biofield for healing is considered to be universal, although few people are aware of it without specific training. Last, practitioners intend to positively affect the patient's biofield, either by direct contact or by using the hands in proximity, similar to the ancient practice of "laying on of hands" (Keegan and Shames, 2005) (Table 29-2).

Therapeutic Touch (TT). TT is the contemporary interpretation of several ancient healing modalities. Dolores Krieger and Dora Kunz developed TT in the early 1970s. The practice, like others that form part of the body of CAM, consists of learned skills for the conscious manipulation of human energies. In practice it is not necessary for the practitioner (healer) to actually touch the recipient (healee), because the energy field can be "felt" several inches away from the physical body. TT describes a process of healing with clear definitions of the required skills and knowledge for successful practice. Explanations of the assumptions, the concepts, and the background of the practice, based on Keegan and Shames (2005), follow.

ASSUMPTIONS

- *A human being is an open energy system.* This assumption implies that the transfer of energy is natural and continuous. When a practitioner transfers energy to a healee using TT, it is without effort and guided by conscious, mindful action. The practitioner adds intentionality within a compassionate context.

BOX 29-2

Cultural Characteristics Related to the Balance of "Hot" and "Cold"

A naturalistic or holistic approach often assumes that there are external factors (some good, some bad) that must be kept in balance if we are to remain well. The balance of "hot" and "cold" is a part of the belief system in many cultural groups, such as the Arab, Chinese, Filipino, and Hispanic cultures. To restore a disturbed balance (i.e., to treat) requires the use of opposites (e.g., a "hot" remedy for a "cold" problem). Different cultures may define "hot" and "cold" differently. It is not a matter of temperature, and the words used might vary; for example, the Chinese have named the forces yin (cold) and yang (hot). Western medicine cannot ignore the naturalistic view if many of its patients are to have appropriate treatment for illness as well as disease.

HOT CONDITIONS AND THEIR CORRESPONDING TREATMENTS

Hot Conditions	Cold Foods	Cold Medicines and Herbs
Fever	Fresh vegetables	Orange flower water
Infection	Tropical fruits	Linden
Diarrhea	Dairy products	Sage
Kidney problem	Meats such as goat, fish, chicken	Milk of magnesia
Rash	Honey	Bicarbonate of soda
Skin ailment	Cod	
Sore throat	Raisins	
Liver problem	Bottle milk	
Ulcer	Barley water	
Constipation		

COLD CONDITIONS AND THEIR CORRESPONDING TREATMENTS

Cold Conditions	Hot Foods	Hot Medicines and Herbs
Cancer	Chocolate	Penicillin
Pneumonia	Cheese	Tobacco
Malaria	Temperate-zone fruits	Ginger root
Joint pain	Eggs	Garlic
Menstrual period	Peas	Cinnamon
Teething	Onions	Anise
Earache	Aromatic beverages	Vitamins
Rheumatism	Hard liquor	Iron preparations
Tuberculosis	Oils	Cod liver oil
Cold	Meats such as beef, water fowl, mutton	Castor oil
Headache	Goat's milk	Aspirin
Paralysis	Cereal grains	
Stomach cramps	Chili peppers	

Modified from Seidel HM et al: *Mosby's guide to physical examination,* ed 6, St Louis, 2006, Mosby.

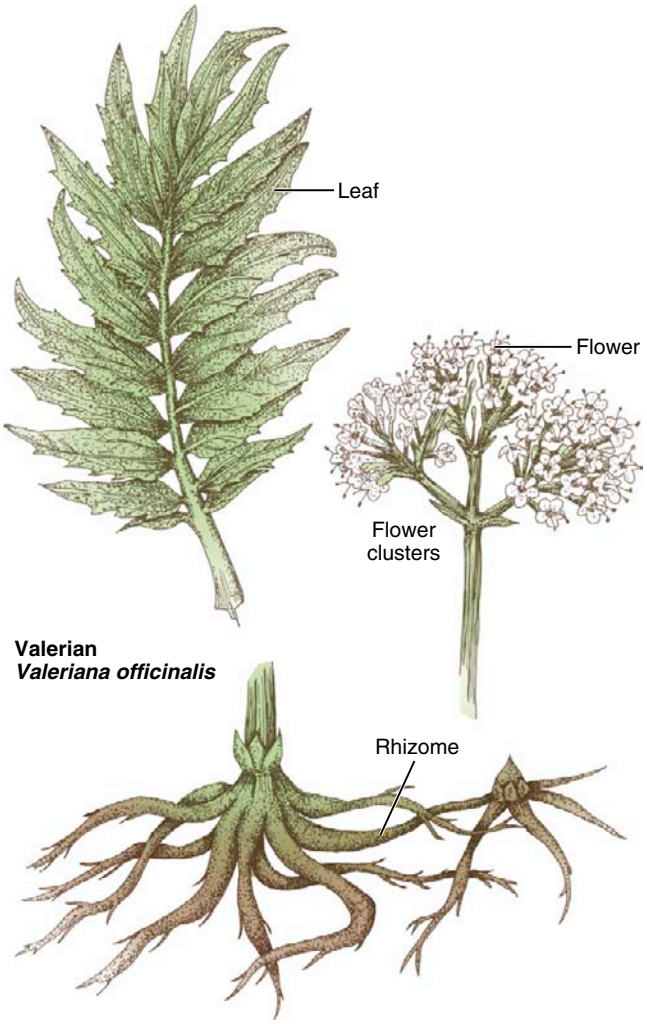


FIGURE 29-2 Valerian is a perennial plant cultivated throughout the world. Its reported uses include treatment of nervous disorders such as anxiety, restlessness, and insomnia. The plant rhizomes and roots are used to produce valerian in the forms of capsules, crude tea, extracts, and tinctures and in combination with products containing other herbs.

- *A human being is bilaterally anatomically symmetric.* Symmetry is apparent in several anatomic systems, most clearly seen in the skeleton. This symmetry is the rational basis for the inference that there is also a pattern in the underlying human energy field. This provides the background for the TT practitioner's assessment of the healee's energy state.
- *Illness is an imbalance in an individual's energy field.* With TT, the practitioner manipulates the energy field by directing or modulating using the sense of touch much like the other four major senses of the body. All these senses are able to act from a distance without direct connection. The human energy field extends a few inches away from the body surface, and the practitioner senses fine energetic cues such as changes in pattern.
- *Humans have natural abilities to transform and transcend their conditions of living.* These functions are, in a sense, prerequisites for healing to occur.

BOX 29-3

The Use of Palpation in Physical Examination

Palpation involves the use of your hands and fingers to gather information through the sense of touch. Certain parts of your hands and fingers are better than others for specific types of palpation. The palmar surface of the fingers and finger pads is more sensitive than the fingertips and is used whenever discriminatory touch is needed for determining position, texture, size, consistency, masses, fluid, and crepitus. The ulnar surface of the hand and fingers is the most sensitive area for distinguishing vibration. The dorsal surface of the hands is best for estimating temperature; of course, this estimate provides only a crude measure and is best used to detect temperature differences in comparing parts of the body.

Touch is in many ways therapeutic, and palpation is the actuality of the "laying on of hands." It is the moment at which we begin our physical invasion of the patient's body. Our much-repeated advice that your approach be gentle and your hands be warm is not only practical but also symbolic of your respect for the patient and for the privilege the patient gives you.

Modified from Seidel HM et al: *Mosby's guide to physical examination,* ed 6, St Louis, 2006, Mosby.

TABLE 29-1

Biofield Terms and Source Culture

Term	Source Culture
Ankh	Ancient Egyptian
Bioenergy	American, European
Ki	Japanese
Life force	General use
Oki, Orenda, Ton, Wakan	American Indian: Huron, Iroquois, Dakota, Lakota
Pneuma	Ancient Greek
Prana	Sanskrit, Ancient Hindu Indian
Qi	Chinese
Subtle energy	American, European
Sila	Inuit
Tane	Hawaiian

Modified from Cassidy CM: Social and cultural factors. In Micozzi MS, editor: *Fundamentals of complementary and integrative medicine,* ed 3, St Louis, 2006, Saunders.

CONCEPTS AND CONSTRUCTS

- *Laying on of hands.* This is a healing practice found in multiple ancient cultures as well as contemporary religious groups.
- *Vital energy fields.* All persons share a unity with nature and all living things, which includes universal energies. Most Eastern and ancient cultures have words and concepts for this phenomenon; the Western culture does not. This concept was derived from Chinese, Indian, and Native American cultures and other ancient religions; it supports or demonstrates some of the theories of quantum physics and of nurse theorist Martha Rogers, but it is not derived from these sources.
- *Energy transfer.* This is described as a method by which one individual can transfer or send energy to another.

TABLE 29-2

Comparisons of Selected Biofield Therapies

Therapy	Practice Initiated	Developers	Hand Placement	Theoretic Basis and Intent
Healing Touch	1981	American Holistic Nurses Association	Both on and off the body	Uses elements of Healing Science and Therapeutic Touch in conjunction with crystal and dowsing to treat whole person and specific disorders.
Qi gong	Traditional	Chinese	At meridian points or short distance from the body	Qi follows meridians and body patterns to heal biologic disorders.
Reiki	Traditional 1800s 1936	Buddhist Japan—Hawayo Takata United States—Mikao Usui	A few standardized hand placements on the physical body	Spiritual energy from universe is channeled by "masters" to heal spiritual body, which in turn heals physical body.
Therapeutic Touch	1972	Dolores Krieger and Dora Kunz	Primarily off the body 2-4 inches	Aligning Kunz's Human Energy Field Model with Martha Rogers' Science of Unitary Human Beings, the centered practitioner assesses, directs, and modulates biofield energy to achieve relaxation response for healing of whole person.
Reflexology	Traditional	Ancient method of treatment for ailments dating back to Egyptians and beyond	Application of pressure to sites on foot, hands, ears, and so on that correspond with organs and nerves to cause a reflex arc of stimulation to area in need	Promotes balance and wellness through nerve stimulation.

Modified from Engebretson J, Wardell D: Energy-based modalities, *Nurs Clin North Am* 42:243-259, 2007; National Center for Complementary and Alternative Medicine: *Energy medicine: an overview,* available at http://nccam.nih.gov/health/whatiscam/energy/energymed.htm. Accessed June 12, 2009.

- *Energy congestion.* When energy is not flowing from head to toe but seems to be localized, or *stuck* at a certain level of the body, it is considered congested. Although energy flow is not only head to toe, this is considered the major flow pattern.
- *Energy imbalance.* When the energy field does not appear to be symmetric, there seems to be some disturbance or difference in the field on one side and not the other.
- *Inner practitioner.* With TT, persons in the role of practitioner have to be more than masters of techniques—they must become masters of themselves. This concept, like the laying on of hands, was derived from multiple sources including cultural and religious and the martial arts, as well as personal observation and experience.
- *Intentionality.* This concept addresses the focused and inner intent to help another achieve the maximum level of wholeness or well-being that he or she is capable and desirous of attaining.
- *Centered consciousness.* This concept describes the act of self-searching—going within to explore the deeper levels of oneself. Centered consciousness is a concept derived from ancient cultures and religions.

BACKGROUND. To work within biofields, the practitioner uses a model or map to focus the healing energy. Chakras, or energy centers, described by the Upanishads in the Vedas, the oldest literature of the East Indian people, are often used as a reference point. Although the most detailed descriptions are in the Upanishads, the attributes are found in the teachings of other cultures as widely geographic as the Sufis of the Middle East to the First Nations, particularly from the North American Southwest (Figure 29-3).

TT practice lends itself well to the fast-paced surgical environment. The skills learned through study of TT provide a trained practitioner with the ability to center quickly and use intention to calm both himself/herself and others nearby in stressful situations. Research design, methods, techniques, and sample sizes are considerations for future studies into how biofield therapeutics may benefit surgical patients. Replicating past studies, as well as new research based on physiologic data and quantitative studies, is necessary (Research Highlight). It has become evident that the concepts involved in energy therapies need consistent definitions. If the concepts do not have preestablished definitions, they cannot be quantified or measured in meaningful ways. However, interest is high and research continues in an effort to better understand a phenomenon that seems to provide meaningful relief to the patient as well as to often-stressed nurse (or other healthcare) colleagues.

Perioperative Medical Hypnotherapy

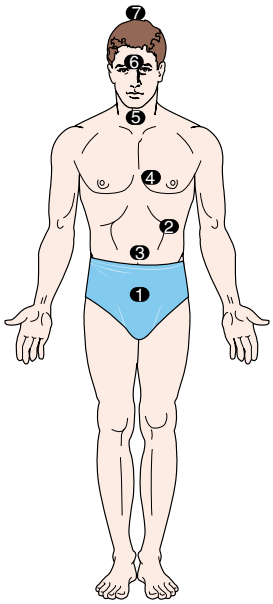
Use of medical hypnotherapy in hospitals and clinics for perioperative care is becoming more common. Patients are seeking an active role in their treatment and are better informed regarding surgical options. Participating in perioperative medical hypnotherapy allows patients to take shared responsibility for their healing process, giving them a measure of control, because all hypnosis is self-hypnosis. Meaningful and active

RESEARCH HIGHLIGHT

Therapeutic Touch (TT) and Human Cell Growth

As part of 2-year in vitro study at the University of Connecticut Health Center, researchers determined that TT stimulates the growth of human cells in culture. This research examined culture growth of fibroblasts, osteoblasts, and tenocytes discarded from podiatry procedures of healthy patients. The study compared the effects of TT provided by three experienced TT practitioners and sham TT (provided by a "sham healer," an individual who had no knowledge of TT) against untreated control cultures. Researchers measured the cell growth and determined that TT produced a statistically significant difference in the fibroblast cell proliferation. In measuring osteoblast growth they determined that TT did produce significant cell proliferation compared to the control, but not to the sham treatment. In the tenocytes' grouping, TT produced significant cell proliferation in comparison to both the control and the cells treated by the sham practitioner. Although this study was limited in scope, it does provide the basis for further exploration into practices involving the human biofield and the mechanisms by which organisms respond.

Modified from Groncowicz GA et al: Therapeutic touch stimulates the proliferation of human cells in culture, *J Altern Complement Med* 14(3): 233-239, 2008.



	English Name	Situation
1	Root or basic chakra	At the base of the spine
2	Spleen or splenic chakra	Over the spleen
3	Navel or umbilical chakra	At the navel, over the solar plexus
4	Heart or cardiac chakra	Over the heart
5	Throat or laryngeal chakra	At the front of the throat
6	Brow or frontal chakra	In the space between the eyebrows
7	Crown or coronal chakra	On the top of the head

FIGURE 29-3 Chakras.

participation empowers a patient to enter into anesthesia and surgery with confidence.

Surgery is a life-changing event, and each perioperative medical hypnotherapy patient is unique. The initial assessment serves to determine goals and explore questions relative to emotional as well as physical concerns. The hypnotherapist, working within the patient's belief system, helps acknowledge areas of the patient's concern as a multidisciplinary partnership of healing is forged in a patient-centered manner.

As the hypnotherapist guides the patient into relaxation and induces hypnosis, both therapist and patient journey into the body, together addressing predetermined issues. Fear of the unknown, preprocedure anxiety, changes in body image, anticipated pain or nausea, loss of organs, and transplantation of new organs are some examples of issues that may be addressed in the perioperative setting (Gurgevich, 2007).

Hypnosis compassionately allows a patient to explore emotions without judgment or expectation of those feelings. The practice of emotional awareness, of being present with feelings, and of holding those feelings sacred can bring a sense of peace and healing insights during a time of profound stress, such as that experienced by many surgical patients. Predetermined suggestions or affirmations may increase confidence in the healthcare team, increase compliance with the treatment plan, decrease blood loss, maintain intraoperative homeostasis, reduce the need for sedation or pain medication, decrease postoperative nausea or vomiting, and increase patient satisfaction (Valente, 2006).

Postoperative hypnotherapy sessions reinforce continued participation of patients in their healing process. This may take the form of establishing metabolic gauges in the "control room" or a symbolic shield of protection, holding or sending color, light, or a certain feeling of safety to a specific part of the body. It may be expressing gratitude to and confidence in the medical and nursing community. Follow-up sessions allow both patient and hypnotherapist to evaluate attainment of preoperative goals, consider postoperative outcomes, and explore issues relevant to the ongoing healing process.

Guided Imagery

Another therapy closely related to hypnosis is guided imagery. Imagery, or thinking in pictures, is the natural language of the unconscious mind and is used by the autonomic nervous system as a primary mode of communication. The autonomic nervous system controls unconscious body functions such as heart rate, immune function, digestion, blood flow, smooth muscle tension, and pain perception (Figure 29-4). Guided imagery for surgical patients may be in the form of pre-scripted tapes that lead the patient through relaxation exercises and provide healing suggestions. In other instances, the perioperative nurse may assist the patient with guided imagery through the use of a calming, monotone voice; a smooth speaking delivery; and the use of relaxing images, such as a place in nature. The perioperative nurse coaches the patient to see, feel, smell, sense, and hear the imagined scene. Benefits of guided imagery with surgery patients may include the following (Ignatavicius, 2010):

- Decreased anxiety
- Decreased pain perception
- Faster recovery
- Increased sense of control

Aromatherapy in Perioperative Services

Aromatherapy involves the therapeutic use of fragrance (e.g., aromatic plant extracts and essential oils) applied to the patient's body through inhalation or topical methods, or rarely

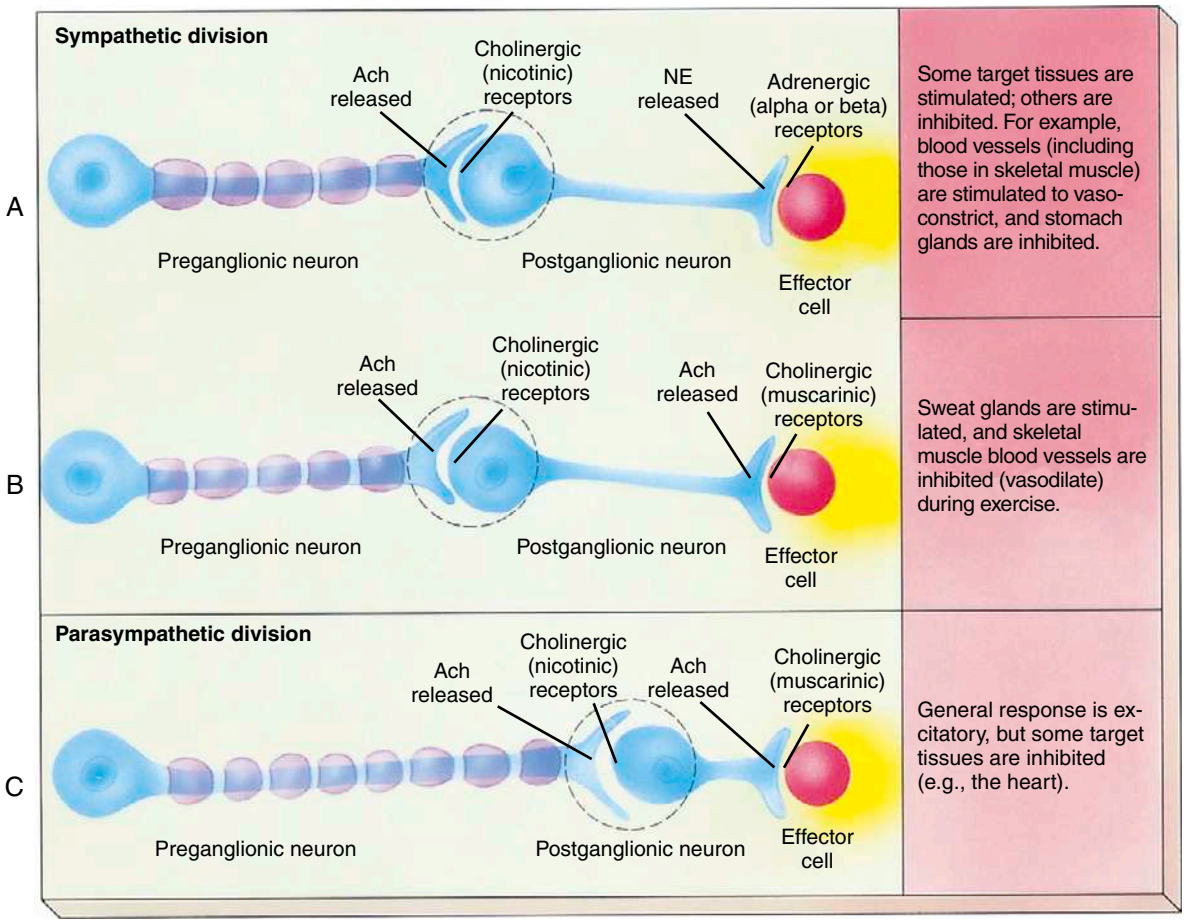


FIGURE 29-4 Locations of neurotransmitters and receptors in the autonomic nervous system. In all pathways, preganglionic fibers are cholinergic, secreting acetylcholine *(Ach)*, which stimulates nicotinic receptors in the postganglionic neuron. Most sympathetic fibers are adrenergic (**A**), secreting norepinephrine *(NE)*, thus stimulating alpha- or beta-adrenergic receptors. A few sympathetic postganglionic fibers are cholinergic, stimulating muscarinic receptors in effector cells (**B**). All parasympathetic postganglionic fibers are cholinergic (**C**), stimulating muscarinic receptors in effector cells.

ingestion. Long before Western medicine, use of aromatherapy and herbs was part of physicians' practice and prescriptive use and was taught in all of the original Nightingale schools (Radzyminski, 2007). Clinical aromatherapy is gaining acceptance with consent and participation of patients. It is practiced by certified clinical aromatherapy practitioners (CCAPs), knowledgeable about the specific properties of essential oils and how they interact with patients and the therapeutic environment. CCAPs use clinical-grade essential oils in a controlled way for specific, measurable outcomes. These may affect the patient on a psychologic, physiologic, or cellular level. The choice of essential oil is based on the chemistry of that essential oil and its proven effects (Table 29-3).

As pharmacology combines medications to potentiate effect, aromatherapy may act synergistically with traditional treatment; or it may be offered in concert with other complementary modalities to relieve discomfort, thereby reducing dosages of analgesics or sedatives. Potential uses for perioperative services include reducing anxiety for patients and their families in the waiting area and ameliorating nausea and vomiting during the immediate postoperative phase (Steflitsch and Steflitsch, 2008).

The nursing process of aromatherapy begins with obtaining consent for use of aromatics and collecting pertinent information. Assessment of the patient, the physical environment, and the team of caregivers defines the healing environment. Along with review of the medical and nursing histories, allergies, vital signs, and laboratory values, subjective data are relevant, such as how to offer treatment. The plan of therapy may include direct inhalation (on a cotton ball or through a diffuser), compresses, topical application, or massage. As with all nursing interventions, postprocedure follow-up with the patient is imperative to assess efficacy of this intervention.

Additional well-designed research is required to provide data substantiating the value of clinical aromatherapy as another component of holistic perioperative nursing practice.

Music and Surgery

The therapeutic and healing properties of music have been recognized throughout history. Music is recognized as a way to decrease the physiologic and behavioral anxiety found in most individuals awaiting surgical procedures, and has been validated through many research and evidence-based studies and reviews (Sendelbach et al, 2006; Klassen et al, 2008).

TABLE 29-3

Essential Oils and Their Properties

Property	Essential Oils
Antiemetic	Chamomile, lavender, lemon, peppermint, ginger
Antiseptic	Bergamot, clove, eucalyptus, lavender, juniper, thyme, tea tree
Anxiolytic	Benzoin, bergamot, chamomile, jasmine, lavender, neroli, rose, sandalwood, verbena, ylang-ylang
Analgesic	Lavender, West Indian lemongrass, peppermint, Turkish oregano, Brazilian mint
Sedating	Bergamot, chamomile, jasmine, lavender, neroli, rose, ylang-ylang
Stimulating	Basil, black pepper, eucalyptus, peppermint, rosemary
Antiinflammatory	German chamomile, rosemary, black pepper, helichrysum

From Mantle F, Tiran D: *A-Z of complementary and alternative medicine,* London, 2009, Churchill Livingstone; Steflitsch W, Steflitsch M: Clinical aromatherapy, *J Men Health* 5(1):74-85, 2008.

Music has been shown to increase metabolism; increase or decrease muscular energy, breathing rate, blood volume, pulse rate, and blood pressure; and lower sensory stimuli thresholds. Music can touch patients deeply and thus transform their anxiety and discomfort into relaxation and healing.

Anxiety and pain are common perioperative nursing diagnoses identified in the sample plans of care in Unit II (Surgical Interventions) in this book. Because anxiety and pain lead to increased stress and stress may cause detrimental physiologic reactions, many nursing interventions are undertaken to reduce patients' anxiety. Music is a nursing intervention that is easy to administer, relatively inexpensive, and noninvasive.

Music is therapeutic if used in a manner that enables its elements and their influences to aid in integration of the body, mind, and spirit of the patient during the treatment of an illness or disability. When selecting music to invoke physiologic and psychologic changes, it is important to note the attributes of music. Factors that need to be considered are the various elements of music (e.g., tempo, mode, pitch, rhythm, harmony, melody); listener characteristics (e.g., age, language, culture, education, musical preferences); and the mode of delivery (e.g., headphones, speakers). Slow, quiet music without lyrics tends to lower the physiologic responses associated with stress and anxiety. Fast tempos tend to increase tension, while slow tempos can cause suspense. A tempo of 60 to 72 beats/min appears to promote relaxation and decrease anxiety, as theorized by matching the normal heart rate of humans. Research also demonstrates the importance of patient-selected music that is familiar, desirable, and meaningful, which often leads to positive responses from patients. The use of headphones blocks unpleasant environmental sounds, a common occurrence in busy preoperative holding areas and OR suites. Compact disks or MP3 players provide consistent, uninterrupted music, which is critical towards the success of the ongoing therapeutic reactions that music affords. Best of all, music therapy can be used preoperatively, intraoperatively, and postoperatively.

Anticipation of surgery commonly produces anxiety. The preoperative waiting period may be more stressful and anxiety-provoking for some patients than the anticipated surgical intervention. High levels of anxiety cause negative physiologic manifestations, such as elevated blood pressure, that can lead to postoperative complications, such as increased cardiac workload. High levels of preoperative anxiety may result in postoperative complications such as depression, fear, and anger, and the use of music during the preoperative phase can decrease anxiety and significantly lessen complications in the postoperative phase of recovery. Emotions are altered, apprehension and tension are reduced, and sympathetic stimulation and adrenocortical activation are more controlled. Therefore changes in vital signs, such as elevated blood pressure and increased heart rate, are minimal. Studies have verified that patients listening to music had a significant decrease in anxiety and pain when compared with patients in a control group who did not listen to music (Klassen et al, 2008).

Patients undergoing surgery in which local or regional anesthetics are administered have an acute awareness of the environment found within the OR. The OR may appear threatening, with unfamiliar machines, equipment, noises, and smells. Physical positioning and exposure of body parts intensify anxiety. Unfamiliar sounds, bright lights, and technical language add to the stressors of the surgical experience. During surgery, patient-selected music reduces anxiety by providing the patient some autonomy through self-selected musical choices, while distracting the patient from what is happening within the environment. The music not only blocks the various sounds in the room but also provides an escape through imaginative thought. Researchers support the idea that musical vibrations have an effect on the subconscious mind. Older patients have reported comfort and strength by listening to hymns and other music of spiritual or psychologic support. Daydreaming, imagery, escape, and fantasizing are common to listeners. This creates a release of tension and is a way of focusing attention away from threats. Intraoperative music may decrease the patient's anxiety and consequently minimize the need for patient-controlled conscious sedation and analgesia. Music can have a positive effect during general anesthesia when delivered through headphones or earpieces, as long as care is exerted to prevent pressure points and volume increases.

The subject of patient awareness during anesthesia and surgery continues to receive much attention (see Chapter 7). Auditory functioning may be largely intact, especially in patients undergoing cardiac, trauma, or cesarean section procedures. As many as 1% to 2% of all patients may experience awareness during general anesthesia and while most do not experience pain, up to 36% of patients who experience recall do report some pain (Orser et al, 2008). Much of the extensive literature regarding intraoperative recall is anecdotal. As a result, understanding the confluence of factors relevant to patient recall or wakefulness is limited. The use of intraoperative music delivered by way of a headset can facilitate a more pleasant surgical experience if recall or awareness becomes an issue.

Pain is a common problem in the postanesthesia care unit (PACU). Pain results in negative respiratory, cardiovascular, gastrointestinal, renal, neuroendocrine, and autonomic nervous system consequences for patients. The traditional means to providing pain relief in the PACU has been through medications. Because the effect of medications differs from person to

person, experts have suggested that a combination of pharmacologic and nonpharmacologic therapies has a greater potential for providing optimal pain relief (Tse et al, 2005).

Music has a long history as an adjunct to healing and pain control. Soothing music is a potential pain-management strategy. Reduced anxiety and the ability to relax are components of comfort. Soothing music can decrease anxiety, improve relaxation and comfort, and improve emotional status.

The noise levels of the OR and PACU contribute to the discomfort of patients (Nightingale, 1859). The level of noise typically encountered during the surgical experience is potentially harmful to patients because of the undesirable effects of a release of stress hormones on the cardiovascular system, including increased vasoconstriction, heart rate, and blood pressure. Noise also increases psychologic stress and discomfort, and patients' ability to cope is reduced. Soothing music delivered through a headset can block out external noises and can serve as a distraction from the noise of the PACU.

When using music as a nursing intervention to promote physiologic and psychologic well-being, the nurse prepares both the patient and the environment. The nurse should inform the patient of the purpose of the music experience and interview the patient about musical preferences, allowing the patient to listen to portions of selected music to ensure the music will afford the therapeutic purpose. The use of music therapy is documented in the medical record. A library of different types of music selections should be available. When compiling these collections, it is important that attention is given to the tempo, rhythm, melody, and harmony of the music (as noted earlier). In addition to implementing the music intervention, nurses must monitor patients' responses to ensure that intended outcomes are achieved, making adjustments as necessary.

Psychoneuroimmunology

A great deal of change has transpired in healthcare as sophisticated techniques have been developed to define intricate biologic systems and the underlying connections among these systems. Psychoneuroimmunology theory and research have insights for all complementary and alternative therapies (Micozzi and Amri, 2006) as well as perioperative nursing.

Psychoneuroimmunology studies the relationship between the brain and immune function. Thus perioperative nursing interventions that seek to reduce stress influences have the potential to improve immune system function. This involves how perioperative nurses communicate with patients as well as our behaviors, the attitudes we convey, the language we use, and our very presence (Table 29-4).

Early animal conditioning studies showed links on a molecular level (immune regulators: neurotransmitters and hormones) that act to stimulate nerves or trigger physiologic changes. Further, the perception of stress is known to lead to a reduced ability to fight infection. Because measurement of immune function is a complicated process, much remains to be learned about the precise mechanism of how psychosocial or emotional factors affect susceptibility to disease.

Herbs and Surgery

The use of herbal and botanic products is common today. Surveys estimate that 22% to 32% of patients having surgery use herbal medicines or supplements (Ang-Lee et al, 2005). However, many patients do not communicate this information to their conventional medical physicians or nurse caregivers, because they are unsure of the reaction of conventional caregivers to their use of alternative substances.

TABLE 29-4

Languaging for Nurses

Positive, Therapeutic Language	Negative, Toxic Language
We're giving you the medication that will let you gently go to sleep.	We're going to put you to sleep now.
We are well trained in how to take care of you.	Don't be afraid.
I'll be with you the entire time to make sure you stay asleep and comfortable.	Don't worry; you won't wake up during surgery.
Focus your energy on healing.	Don't give up.
You might feel pressure; some people don't feel anything.	This isn't going to hurt. Just a little bee sting.

Modified from Eslinger MR: The power of suggestion, languaging for nurses, AHNA beginnings, *Am Holist Nurs Assoc* 29(2):22-23, 2009.

Botanicals are marketed as food supplements in the United States. Manufacturers are not allowed to make claims about health benefits for these products because they are not FDA-approved. Since 1994, when the Dietary Supplement Health and Education Act (DSHEA) was passed, the definition of dietary supplements has broadened. A product that contains a vitamin, mineral, herb, amino acid, or other botanic or dietary substance used to supplement the diet is considered a dietary supplement; this includes concentrates, metabolites, constituents, extracts, and combinations of listed ingredients. These supplements are no longer subject to premarket safety evaluations by the FDA. Once a supplement is marketed, under the DSHEA, the FDA can restrict its use only if it can be shown that the product is unsafe.

There are no regulations establishing criteria for purity, manufacturing procedures, or identification of ingredients for these supplements. Therefore the potential exists for high variability in the potency of different batches of the same botanic product. In addition, impurities and unknown substances may also be present in these products. Because herbal products are so readily available and have such widespread media attention, many people think that they can safely self-medicate (Patient and Family Education). Another mistaken assumption is that dietary supplements are safer than prescribed or over-the-counter drugs.

Botanicals may initiate a pharmacologic response within the body and therefore should be considered as medications from a medical or nursing perspective (Risk Reduction Strategies). Many herbal products have actions that could be dangerous during surgery. Some herbal supplements may accentuate the toxicity of anesthetics or interfere with drug metabolism or clearance (Surgical Pharmacology). Herbal supplements may also have a role in the perioperative setting and are an important consideration for nurses (Research Highlight).

Coagulation Interactions. Anesthesia providers are concerned about the potential increased risk of instability intraoperatively resulting from inhibition of coagulation with the use

PATIENT AND FAMILY EDUCATION

Advising Patients about CAM

Nurses have traditionally acted as guides for patients as they navigate through the healthcare system, providing counseling and advice. When providing education to patients about CAM, the nurse should consider the overwhelming amount of information available via the internet and popular media. The internet is a popular source of information regarding the use of herbal and dietary supplements and other CAM therapies, but caution must be used in evaluating the validity of the information that is accessed. Nurses can use the following tips from the National Institutes of Health (NIH) to educate their patients on accessing reliable information from the internet. These tips are also useful for nurses to use when evaluating consumer information from the internet.

CONSIDER THE SOURCE—USE RECOGNIZED AUTHORITIES

- Know who is responsible for the content.
- Look for an "about us" page. Check to see who runs the site: Is it a branch of the federal government, a nonprofit institution, a professional organization, a health system, a commercial organization, or an individual?
- There is a big difference between a site that says, "I developed this site after my heart attack" and one that says, "This page on heart attack was developed by health professionals at the American Heart Association."
- Web sites should have a way to contact the organization or webmaster. If the site provides no contact information, or if you cannot easily determine who runs the site, use caution.

FOCUS ON QUALITY—ALL WEBSITES ARE NOT CREATED EQUAL

- Does the site have an editorial board? Is the information reviewed before it is posted?
- This information is often on the "about us" page, or it may be under the organization's mission statement or be part of the annual report.
- Determine if the board members are experts in the subject of the site. For example, a site on osteoporosis whose medical advisory board is composed of attorneys and accountants is not medically authoritative.
- Look for a description of the process of selecting or approving information on the site. It is usually in the "about us" section and may be called "editorial policy," "selection policy," or "review policy."
- Sometimes the site will have information "about our writers" or "about our authors" instead of an editorial policy. Review this section to find out who has written the information.

BE A CYBERSKEPTIC—QUACKERY ABOUNDS ON THE WEB

- Does the site make health claims that seem too good to be true? Does the information use deliberately obscure, "scientific" sounding language? Does it promise quick, dramatic, miraculous results? Is this the only site making these claims?
- Beware of claims that one remedy will cure a variety of illnesses, that it is a "breakthrough," or that it relies on a "secret ingredient."
- Use caution if the site uses a sensational writing style (lots of exclamation points, for example).
- A health web site for consumers should use simple language, not technical jargon.
- Get a second opinion! Check more than one site.

LOOK FOR THE EVIDENCE—RELY ON MEDICAL RESEARCH, NOT OPINION

- Does the site identify the author? Does it rely on testimonials?
- Look for the author of the information, either an individual or an organization. Good examples are "Written by Jane Smith, R.N.," or "Copyright 2003, American Cancer Society."
- If there are case histories or testimonials on the web site, look for contact information such as an email address or telephone number. If the testimonials are anonymous or hard to locate (e.g., "Jane from California"), use caution.

CHECK FOR CURRENCY—LOOK FOR THE LATEST INFORMATION

- Is the information current?
- Look for dates on documents. A document on coping with the loss of a loved one does not need to be current, but a document about the latest treatment of AIDS needs to be current.
- Click on a few links on the site. If there are a lot of broken links, the site may not be kept up-to-date.
- Beware of bias—What is the purpose? Who is providing the funding?

ASK WHO PAYS FOR THE SITE

- Check to see if the site is supported by public funds, by donations, or by commercial advertising.
- Advertisements should be labeled. They should say "Advertisement" or "From our Sponsor."
- Look at a page on the site, and see if it is clear when content is derived from a noncommercial source and when an advertiser provides it. For example, if a page about treatment of depression recommends one drug by name, see if you can tell if the company that manufactures the drug provides that information. If it does, you should consult other sources to see what they say about the same drug.

Modified from *MedlinePlus guide to healthy web surfing,* available at www.nlm.nih.gov/medlineplus/healthywebsurfing.html. Accessed June 13, 2009.

of ginger, ginseng, feverfew, ginkgo, and garlic (Skidmore-Roth, 2010). One difficulty with analyzing case reports is the lack of laboratory analysis of the purported botanicals. In some reported cases in which prolonged or excessive bleeding occurred, the patient had been taking multiple herb supplements and drugs. Many plants contain anticoagulant components, including ginger, ginseng, feverfew, and others; however, it is unknown if the danger posed is clinically significant.

Sedative Interactions. Some botanicals have significant sedative actions. Anesthesia providers are concerned about the potential for valerian and St. John's wort to prolong or

RISK REDUCTION STRATEGIES

Potential Herb-Pharmaceutical Interactions

Although many complementary therapies are relatively safe and pose little risk to the patient, certain herbal medications have the potential for causing harm through unfavorable interactions with medications used in and out of the perioperative setting. The nurse plays a vital role in performing a thorough medication history to identify potential herbal-pharmaceutical interactions and providing education to the patient about the possible consequences of combining herbs with prescribed and over-the-counter medications.

Herb	Pharmaceutical	Unfavorable Herbal Interaction
Garlic, feverfew, ginger	Warfarin	May increase anticoagulant effect
Astragalus and licorice	Corticosteroids, cyclosporine	Immunosuppressive effects may be inhibited
Echinacea	Corticosteroids	Immunosuppressive effects may be inhibited
	Anabolic steroids, methotrexate, or other hepatotoxic drugs	Hepatotoxicity
Hawthorne	Digoxin	May potentiate effect
Siberian ginseng	Warfarin	May inhibit anticoagulation
	Digoxin	May interfere with assays
All ginsengs, yohimbe	MAOIs Phenelzine and others	May cause headaches, tremors, and insomnia
Licorice	MAOIs Phenelzine and others	May act as inhibitors and potentiate effects
	Digoxin	May cause hypokalemia
Chromium	Hypoglycemics	May decrease insulin requirements and potentiate effects
Chamomile, feverfew, and St. John's wort	Iron	May inhibit iron absorption
Borage, evening primrose oil	Phenobarbital Phenytoin	May lower seizure thresholds
Ephedra (banned by U.S. FDA)	Cardiac glucosides or halothane	Cardiac dysrhythmias
	MAOIs, guanethidine	Enhanced sympathomimetic effects
	Oxytocin	Hypertension, potentiates contractile effects
Gingko	ASA, NSAIDs, warfarin, or heparin	Increased bleeding risk
Valerian	Sedative/hypnotic or anesthetic agents	Potentiated or prolonged effects
St. John's wort	Cyclosporine	Posttransplant complications
	MAOIs, steroids, warfarin, sympathomimetics, antidepressants	Alters drug metabolism for unpredictable results
Goldenseal	Oxytocin	Potentiates contractile effect

ASA, Aspirin; *FDA,* Food and Drug Administration; *MAOIs,* monoamine oxidase inhibitors; *NSAIDs,* nonsteroidal antiinflammatory drugs.
Modified from Skidmore-Roth L: *Mosby's handbook of herbs & natural supplements,* ed 4, St Louis, 2010, Mosby; Mills S, Bone, K: *The essential guide to herbal safety,* Philadelphia, 2005, Churchill Livingstone.

potentiate the sedative effect of anesthetic agents. Valerian has been associated with central nervous system (CNS) depression and muscle relaxant effects in animals; large doses of valerian may contribute to delirium and high-output cardiac failure on emergence from general anesthesia. Although St. John's wort has been found to inhibit the binding of naloxone, to date no cases have been reported of excessive sedation when combined with narcotics. In addition, there is concern about the monoamine oxidase inhibitor (MAOI) activity of St. John's wort, although no cases of MAOI effects in humans have been reported (Skidmore-Roth, 2010).

Cardiovascular Interactions. Hypertension and cardiac dysrhythmias are potential adverse events that may result from the sympathetic stimulation that occurs during intubation and surgery. Ephedra has been associated with cardiovascular effects, including hypertension, palpitations, tachycardia, stroke, and seizures. The long-term use of licorice may cause hypertension, dysrhythmias, or hypokalemia, which can potentiate muscle relaxants and cause adverse cardiovascular effects (Skidmore-Roth, 2010).

Because the use of botanic supplements may increase the risk of adverse herb-drug interactions, patients should be counseled to discontinue herbs preoperatively. Generally surgeons recommend that patients stop taking any herbal supplement at least 2 weeks preoperatively (Ang-Lee et al, 2005). Most patients, however, do not see an anesthesia provider until the day of surgery or a few days before surgery; so the implementation of this recommendation is challenging. Clinical research is insufficient to quantify the actual dangers of these herbal supplements. However, because individuals vary in their absorption, distribution, and clearance of the drugs administered during anesthesia, adding unknown chemicals into an already complex and fast-acting mix of drugs is likely an unnecessary risk.

Integrative Health Therapies and Perioperative Nursing

A variety of factors influence the perioperative patient's experience. Well-informed healthcare consumers increasingly choose a blend of traditional and nontraditional healing modalities with sensitivity to cultural, spiritual, and health education needs. Public involvement and legislative policy decisions are just beginning to equalize emphasis between the traditional biomedical model of care and a holistic comprehensive focus. Integrating health and wholeness incorporates elements

SURGICAL PHARMACOLOGY

Herbs: Effects and Precautions/Recommendations

The use of herbal supplements has become increasingly popular as people become more educated consumers and take a more active interest in their health. Because herbal supplements and other nutriceuticals are available without prescription, patients may not reveal their use of these therapies unless specifically questioned. The perioperative nurse must always consider the possibility that the patient is taking supplements and assess for their use. As with other medications the patient may be taking, the nurse is responsible to know the potential for interaction with medications used in the perioperative period. The information that follows offers a source for broadening the perioperative nurse's knowledge of commonly used herbal supplements.

Herb (Scientific Name) and Other Names	Uses and Desired Effects	Potential Side Effects	Precautions and Recommendations
Garlic *(Allium sativum)* Clove garlic Ajo Poor man's penicillin	Antioxidant; antibiotic; lowers low-density lipids (LDLs) to prevent atherosclerosis; has antihypertensive, antiplatelet, and antithrombolytic properties	May prolong bleeding or clotting time, potentiate effects of antihypertensive or anticoagulant drugs	Large doses (>5 cloves) may cause gastrointestinal (GI) upset, garlic breath/flatus. Discontinue use at least 7 days preoperatively.
Ginkgo *(Ginkgo biloba)* Duck foot Kew tree Maidenhair tree Silver apricot Fossil tree	Antioxidant; anticlotting; enhances blood flow (especially to brain); reduces cellular lesions, retinal edema; treats symptoms of peripheral vascular disease and dementia; inhibits platelet-activating factors; used to enhance brain function and memory; treats headaches, depression, vertigo, and tinnitus	Headache, GI upset, palpitations, dizziness, or skin reactions	Causes increased bleeding risk by inhibiting platelet activity, lowering fibrinogen levels, and decreasing plasma viscosity. May potentiate anticoagulant therapy. Discontinue use at least 36 hr preoperatively.
Ginseng American ginseng *(Panax quinquefolius)* Chinese ginseng or Korean ginseng *(Panax ginseng)* Siberian ginseng *(Eleutherococcus ginseng)*	Antioxidant; enhances memory and immune function; increases stamina; decreases fatigue; reduces stress response; lowers blood glucose level; inhibits clotting	Usually mild and dose-related: nervousness, dizziness, mastalgia "Ginseng abuse syndrome" (>15 g/day) = insomnia, hypotonia, and edema Siberian ginseng may falsely elevate digoxin levels; potentiate monoamine oxidase inhibitors (MAOIs)	Contraindicated for patients with hypoglycemia, hypertension, and cardiac disorders. Avoid with other stimulants; may lead to tachycardia or hypertension. May decrease effectiveness of warfarin (decreased international normalized ratio [INR]). May cause postmenopausal bleeding. Discontinue use at least 7 days preoperatively.
Ephedra *(Ephedra sinica)* Ma huang Mexican or Mormon tea Dessert tea Natural ecstasy Natural fen-phen Ephedrine Chinese joint fir	Stimulant; bacteriostatic; antitussive; decongestant; bronchodilator; used for weight loss	Hypertension (HTN), tachycardia, dysrhythmias, cardiac arrest, myocardial infarct, nausea, vomiting, decreased GI motility, mydriasis, diuresis, anxiety, constipation, dizziness, headache, insomnia, psychosis, urine retention, seizure, stroke, uterine contractions	Do not use with cardiac glycosides, guanethidine, MAOI medications. Do not use for patients with anxiety, HTN, glaucoma, enlarged prostate, or heart disease. Discontinue use at least 24 hr preoperatively. Limit use to 7 days.
Echinacea *(Echinacea purpurea, E. pallida, E. angustifolia)* Purple coneflower	Antiinfective; antiinflammatory; enhances immune function; may prevent or minimize symptoms and duration of common cold, upper respiratory infection (URI); enhances wound- and burn-healing process	May activate T-cells Cross-allergic reaction Immune suppression if taken long term	Discontinue as far in advance preoperatively as possible. Should not be used by patients with autoimmune diseases. Should not be used by patients with allergy to sunflower. Avoid use for transplant patients or those with liver dysfunction.

Continued

SURGICAL PHARMACOLOGY

Herbs: Effects and Precautions/Recommendations—cont'd

Herb (Scientific Name) and Other Names	Uses and Desired Effects	Potential Side Effects	Precautions and Recommendations
St. John's wort *(Hypericum perforatum)* Amber touch-and-heal Goatweed Klamath weed	Anxiolytic; antidepressant (mild to moderate symptoms), may take 4-6 wk for effect; relieves dyspepsia and insomnia; mechanism: inhibits uptake of neurotransmitters	Photosensitization, skin irritation, restlessness, fatigue May prolong effects of anesthesia and potentiate meperidine or other narcotics Possible peripheral neuropathy, serotonergic crisis	May alter metabolism of other drugs: cyclosporine, warfarin, steroids, protease inhibitors. Do not combine with ephedra. Discontinue use at least 5 days preoperatively.
Cayenne *(Capsicum annuum)* Hot chili pepper Paprika	External use: muscle spasm or soreness Internal use: GI disorders	External: skin irritation, especially if used longer than 2 days Internal: lower GI discomfort; overdose may cause hypothermia	Avoid use preoperatively.
Feverfew *(Tanacetum parthenium)* Featherfew Midsummer daisy	Antipyretic; relieves arthritis, fever, headache, and migraine pain; increases fluidity of respiratory mucus; promotes menses and uterine contractions	Oral lesions, GI tract irritation Rebound headache with sudden cessation Hypersensitive reaction in those allergic to ragweed, asters, chrysanthemums, or daisies May increase clotting time	Causes increased bleeding risk. Avoid use preoperatively.
Goldenseal *(Hydrastis canadensis)* Orange or yellow root Ground raspberry Tumeric root Eye root	Antibacterial, antiinflammatory properties; diuretic (no sodium excreted); laxative; improves immune function; aids digestion; regulates menses	Hypotension, nausea, vomiting, abdominal cramping May exacerbate edema or hypertension May potentiate effects of insulin	May cause electrolyte imbalance, seizures, respiratory paralysis. Avoid use preoperatively.
Valerian *(Valerian officinalis)* All heal Setwell Vandal root	Mild anxiolytic, muscle relaxant, hypnotic and sedative; may ease symptoms of benzodiazepine withdrawal	Headache, excitability, nausea, visual disturbance Potentiates sedative/hypnotics Long-term use may increase anesthesia tolerance Sudden cessation may cause withdrawal symptoms	Potentially prolongs anesthesia recovery time. Treat withdrawal symptoms with benzodiazepines. If possible, taper dose over 1-2 wk preoperatively. If not, continue use until surgery.
Ginger *(Zingiber officinale)* African ginger Black ginger	Prevents nausea caused by motion sickness, pregnancy, chemotherapy, and anesthesia; antispasmodic	Heartburn Inhibition of platelet aggregation	Causes increased bleeding risk. Avoid use preoperatively.
Kava kava *(Piper methysticum)* Awa, kawa Intoxicating pepper Tonga	Anxiolytic; mild sedative; muscle relaxant; sleep aid	Adverse effect on motor reflexes and judgment	Potentiates sedative/hypnotics. Discontinue use at least 24 hr preoperatively.
Licorice *(Glycyrrhiza glabra)* Sweet root	Antipyretic; antiviral; demulcent; expectorant; beneficial for chronic fatigue, allergies, asthma, bronchitis, depression, emphysema, herpes, and hypoglycemia; treats gastritis and gastric and duodenal ulcers	May cause headache, muscle flaccidity, lethargy, edema, HTN, hypokalemia, or other electrolyte imbalance, and electrocardiogram (ECG) changes (prolonged QT interval) Pseudoprimary aldosteronism a possible complication	Contraindicated for chronic liver conditions, renal insufficiency, hypertonia, or existing hypokalemia. Avoid use for more than 7 consecutive days.

SURGICAL PHARMACOLOGY

Herbs: Effects and Precautions/Recommendations—cont'd

Herb (Scientific Name) and Other Names	Uses and Desired Effects	Potential Side Effects	Precautions and Recommendations
Saw palmetto *(Serenoa repens)* Sabal cabbage palm	Relieves benign prostatic hypertrophy; has antiandrogenic and antiexudative properties	Headache, increased appetite	Causes additive effects with other hormone therapies.
Dong quai *(Angelica polymorpha)*	Relieves menstrual disorders; increases effects of ovarian and testicular hormones	Dizziness, headache, nausea, miscarriage, dermatitis, GI upset, photosensitivity	Avoid use in pregnancy.
Huang qi *(Astragalus membranaceous)*	Antibacterial; increases production of white blood cells (WBCs); immunostimulant; cardiotonic; energy tonic (strengthens *wei qi*); regulates water metabolism	Inhibits platelet aggregation and fibrinolysis	Causes increased bleeding risk.
Black cohosh *(Cimicifuga racemosa)* Rattle root Squaw root	Antihypertensive; lowers cholesterol; reduces mucus production; induces labor to aid in childbirth; relieves menopausal symptoms (hot flashes)	May lead to premature labor if used in pregnancy	Avoid use in pregnancy.
Senna *(Cassia senna)*	Stimulating laxative	Abdominal cramping; affects absorption in GI system	Causes potential electrolyte imbalance.
Vitamin E (D-α-tocopherol)	Antioxidant used for cardiovascular disease	Reduced platelet adhesion and aggregation	Causes increased bleeding risk.
Yohimbe *(Pausinystalia yohimbe)*	Increases blood flow (particularly to genitalia) and libido	Anxiety, hallucinations, HTN, elevated heart rate, headache, dizziness, flushing	Avoid use by patients with psychologic or renal disorders.
Hawthorn *(Crataegus oxyacantha)* May bush May blossom Whitethorn	Antihypertensive; dilates coronary blood vessels; improves cardiovascular function (inotropic and beta-blocking effect); lowers cholesterol	Nausea, fatigue, sweating, headache, hypotension, mild central nervous system (CNS) depression	Use caution with cardiac glycosides, CNS depressants, antihypertensives, and nitrates.

Modified from Skidmore-Roth L: *Mosby's handbook of herbs & natural supplements,* ed 4, St Louis, 2010, Mosby; Mills S, Bone K: *The essential guide to herbal safety,* Philadelphia, 2005, Churchill Livingstone.

RESEARCH HIGHLIGHT

The Use of Ginger to Prevent Postoperative Nausea and Vomiting

Postoperative nausea and vomiting (PONV) are significant problems for many patients administered general anesthetics. This complication not only is distressing for the patient but also, if uncontrolled, can result in additional complications such as wound dehiscence, fatigue, dehydration, and electrolyte imbalances. The PONV phenomenon has been widely studied, yet the development of a universally effective and consistent solution has not been achieved. Complementary therapies may offer an additional option for patients with PONV.

Researchers in Thailand conducted a review and meta-analysis of 5 randomized trials with a total of 363 patients from existing literature to determine the effectiveness of a fixed dose of ginger compared to a placebo in the treatment of PONV. Ginger has long been used in China as a treatment for nausea and vomiting. Researchers postulate that the antiemetic properties are due to its antiserotonin-3 effects on the central nervous system and the gastrointestinal system.

Patient ages ranged from 31 to 46 years and the surgery types were primarily endoscopic in nature. In the studies, the treatment group received 1 g of ginger and the control group received a placebo 1 hour before anesthesia was induced. Analysis of the results showed that ginger was significantly better than placebo for the prevention of PONV. The incidence of PONV was 35% lower in the patients treated with ginger when compared to the control group.

Researchers concluded that ginger is an effective therapeutic option in the prevention of PONV, but the exact role of ginger as an antiemetic warrants additional study.

Modified from Chaiyakunapruk N et al: The efficacy of ginger for the prevention of postoperative nausea and vomiting: a meta-analysis, *Am J Obstet Gynecol* 194:95-99, 2006.

PATIENT SAFETY

Encouraging the Patient/Physician Relationship

Perioperative nurses can encourage safety in patients who use CAM by promoting the National Center for Complementary and Alternative Medicine (NCCAM) *Time to Talk* education campaign. The goal of the campaign is to ensure safe and coordinated care for patients while helping to minimize the risks of interaction with any conventional therapy in which the patient may be engaged. The campaign also seeks to inform and educate patients so they are empowered to make better healthcare decisions and more effectively manage their health. Nurses can provide the following tips from NCCAM to patients as a starting point for discussing CAM with their providers:

- When completing patient history forms, be sure to include all therapies and treatments you use. Make a list in advance. Also note any medical specialists or CAM practitioners you see. Take the list with you whenever you visit a healthcare provider.
- Tell your healthcare providers about all therapies or treatments—including over-the-counter and prescription medicines as well as herbal and dietary supplements.
- Take control. Do not wait for your providers to ask about your CAM use.
- If you are considering a new CAM therapy, ask your healthcare providers about its safety, effectiveness, and possible interactions with medications (both prescription and over-the-counter).

Modified from National Center for Complementary and Alternative Medicine: *Time to talk,* available at http://nccam.nih.gov/timetotalk/backgrounder.htm. Accessed June 13, 2009.

AMBULATORY SURGERY CONSIDERATIONS

Supporting CAM in the Ambulatory Surgical Setting

As advocates using the holistic approach, perioperative nurses play an important role in supporting the patient who desires to use CAM in the perioperative setting. It is important to balance the use of conventional and nonconventional interventions in respecting the patient's wishes and providing safe care. Many CAM interventions are well suited to the ambulatory setting, including music therapy, aromatherapy, and energy interventions. The nurse must ensure that any healthcare personnel who wish to treat the patient in the perioperative setting do so under the institution's policies and procedures. The nurse should document any use of CAM in the perioperative nursing record along with the patient's response.

In the educator role, the nurse may be able to partner with patients to empower them to research the safety and efficacy of the techniques they are using. The preoperative assessment offers a prime opportunity for the nurse to identify possible safety risks for the perioperative patient. Whenever possible the preoperative assessment should be conducted a few days before the planned surgical procedure to allow ample time to gather data and begin patient teaching in a controlled, unhurried setting versus the typical fast pace that occurs on the patient's day of admission to the ambulatory surgery setting. The nurse can use this time to educate patients about the impact of CAM therapies in the perioperative period and beyond. By obtaining information in advance about the patient's use of these medications, the nurse can impact safe care by advising the patient to consult with the surgeon and modify the treatment regimen to avoid anesthetic complications.

The preoperative assessment also allows a forum to educate patients about the need to obtain reliable information about CAM. In discussing the patient's use of CAM, the nurse should remind the patient that results should be supported by clinical trials and that information on the internet may be commercial in nature rather than scientific (see Patient Education box on p. 1251). Patients who use CAM should also be encouraged to notify their physician if any side effects occur.

Modified from Dossey BM, Guzzetta CE: Holistic nursing practice. In Dossey BM et al, editors: *Holistic nursing, a handbook for practice,* ed 4, Boston, 2005, Jones and Bartlett; Plauntz LM: Preoperative assessment of the surgical patient, *Nurs Clin North Am* 42:361-377, 2007; Caspi O: Evidence-based medicine and clinical decision making. In Rakel D, editor: *Integrative medicine,* ed 2, Philadelphia, 2007, Saunders.

of self-responsibility for wellness and self-awareness to inner changes on the part of the patient.

A collaborative partnership of professionals involved in an individual's care optimizes resources that promote comprehensive, effective, less-invasive/nonpharmacologic adjuncts to allopathic medical treatment (Patient Safety). Perioperative nurses using available resources on interactions among prescriptions, dietary supplements, and herbals ensure preoperative medication safety. Seeking out and participating in appropriate research methodologies are essential for grounding the diverse components of our practice in evidence-based knowledge.

Documenting integrated care may involve noting herbals or the dietary supplement regimen the patient followed preoperatively. The nurse should also note whether these were discontinued and, if so, when. Nurse energy work practitioners who comply to a patient's request for energy treatment may refer to the North American Nursing Diagnosis Association (NANDA International) diagnosis "Potential Energy Field Disturbance" when comfort measures such as TT, healing touch, or reiki are provided by the perioperative nurse.

Integrative health therapies have a place in each perioperative nurse's practice (Ambulatory Surgery Considerations). Nursing history demonstrates a philosophic attitude of altruism and compassion, founded in creating an environment of healing. Awareness of how vital self-care practices are to sustaining a caregiver role may ultimately benefit our practice. Self-care learning and meditative experiences may come full circle by enhancing the caregiver's therapeutic use of self through presence, compassion, and holistic assessment skills.

REFERENCES

Ang-Lee M et al: Complimentary and alternative therapies. In Miller RD, editor: *Miller's anesthesia*, ed 6, Philadelphia, 2005, Churchill Livingstone.

Gurgevich S: Self-hypnosis techniques. In Rakel D, editor: *Integrative medicine*, ed 2, Philadelphia, 2007, Saunders.

Ignatavicius DD: Introduction to complementary and alternative therapies in nursing. In Ignatavicius DD, Workman ML, editors: *Medical-surgical nursing: patient-centered collaborative care*, ed 6, St Louis, 2010, Saunders.

Keegan L, Shames KH: Touch: connecting with the healing power. In Dossey BM et al: *Holistic nursing, a handbook for practice*, ed 4, Boston, 2005, Jones and Bartlett.

Klassen JA et al: Music for pain and anxiety in children undergoing medical procedures: a systematic review of randomized controlled trials, *Ambul Pediatr* 8(2):117–128, 2008.

Kolthan D: Introducing complementary and alternative therapies, *J Nurs Pract* 5(1):18–20, 2009.

Micozzi MS: Translation from conventional medicine. In Micozzi MS, editor: *Fundamentals of complementary and integrative medicine*, ed 3, St Louis, 2006, Saunders.

Micozzi MS, Amri H: Neurohumoral physiology and psychoneuroimmunology. In Micozzi MS, editor: *Fundamentals of complementary and integrative medicine*, ed 3, St Louis, 2006, Saunders.

National Center for Complementary and Alternative Medicine (NCCAM): *Important events in NCCAM history*, available at www.nih.gov/about/almanac/organization/NCCAM.htm. Accessed June 6, 2009a.

National Center for Complementary and Alternative Medicine (NCCAM): *Ayurvedic medicine: an introduction*, available at http://nccam.nih.gov/health/ayurveda/introduction.htm. Accessed June 6, 2009b.

Nightingale F: *Notes on nursing*, London, 1859, JB Lippincott.

Orser BA et al: Awareness during anesthesia, *Can Med Assoc J* 178(2): 185–188, 2008.

Pizzorno JE, Snider P: Naturopathic medicine. In Micozzi MS, editor: *Fundamentals of complementary and integrative medicine*, ed 3, St Louis, 2006, Saunders.

Radzyminski S: Legal parameters of alternative-complementary modalities in nursing practice, *Nurs Clin North Am* 42:189–212, 2007.

Sendelbach SE et al: Effect of music therapy on physiologic and psychological outcomes for patients undergoing cardiac surgery, *J Cardiovasc Nurs* 21(3):194–200, 2006.

Skidmore-Roth L: *Mosby's handbook of herbs & natural supplements*, ed 4, St Louis, 2010, Mosby.

Steflitsch W, Steflitsch M: Clinical aromatherapy, *J Ment Health* 5(1):74–85, 2008.

Tse MMY et al: The effect of music therapy on postoperative pain, heart rate, systolic blood pressure and analgesic use following nasal surgery, *J Pain Palliat Care Pharmacother* 19(3):21–29, 2005.

Valente SM: Hypnosis for pain management, *J Psychosoc Nurs Ment Health Serv* 44(2):22–30, 2006.

CHAPTER 30

Workplace Issues and Staff Safety

REBECCA M. PATTON

The goals of healthcare are to reduce the burden of illness, injury, and disability and to improve the health and functioning of patients. Unsafe working environments jeopardize those twin goals, through unintended consequences for patients, care providers, and organizations (Nelson, 2006). Perioperative nurses play a critical role in making the workplace environment safer. They strive daily to keep the OR safe for patients, other members of the perioperative staff, and themselves.

Employers create a climate of safety for their employees and patients by providing a framework of institutional support. Factors that affect the safety climate include management commitment to safety, healthcare worker involvement in safety decisions, implementation of measures to reduce safety hazards in the work environment, opportunity for feedback on safety improvements, and individual accountability.

Yet, even with strong institutional support, OR nurses and surgical technologists face daily challenges to their well-being and the effectiveness with which they can do their jobs. Routine occupational activities, such as lifting patients and equipment, can cause back injuries and musculoskeletal disorders, while unsafe working environments can lead to occupational injuries from slips, trips, and falls. In addition, nurses and surgical technologists regularly face low-level but repeated exposures to numerous hazardous materials, including residues from medications, anesthetic gases, sterilization chemicals, radiation, latex, cleaning chemicals, and disinfection agents. Nurses and surgical technologists also risk injuries from sharps and exposure to bloodborne pathogens, hazardous chemicals, and workplace violence.

ERGONOMICS

Perioperative nurses and surgical technologists routinely face a wide array of occupational hazards that place them at risk for work-related musculoskeletal injuries, a frequent and costly occupational issue in nursing (Association of periOperative Registered Nurses [AORN], 2007). More than any other work-related injury or illness, musculoskeletal disorders (MSDs) are responsible for lost work time, the need for protracted medical care, and permanent disability among healthcare workers (American Nurses Association [ANA], 2008b). The extent of musculoskeletal injuries among nurses should be no surprise, given that nurses lift an estimated 1.8 tons per shift (Edlich et al, 2005).

Studies of back-related workers' compensation claims reveal that nursing personnel have the highest claim rates of any occupation or industry (ANA, 2003). Back injuries affect approximately 38% of all nurses (ANA, 2008b), and an estimated 12% of nurses who leave the profession each year do so because of back injuries (ANA, 2009).

The high incidence of MSDs among nurses is the cumulative effect of repeated patient handling events, often involving unsafe loads. Nurses and surgical technologists often lift, transfer, or reposition patients on OR beds and transport vehicles, and assist with prepping with their arms outstretched or their bodies bent forward in awkward postures and positions, increasing the risk for injury (de Castro, 2004). Several factors influence the level of risk, including the patient's weight, the transfer distance, the extent of the workspace, instrument temperature, unpredictable patient behavior, and awkward positions such as stooping, bending, and reaching (Nelson, 2006; Nelson et al, 2009).

Work in the perioperative environment particularly requires an unavoidable constant—moving and lifting large quantities of patient equipment and instrumentation daily. Nurses and surgical technologists also face risk of injury by standing on floor lifts and platforms while holding instruments and equipment. An ergonomically healthy workplace can decrease or prevent injury to its workforce.

SAFE PATIENT HANDLING AND MOVEMENT

Concentrated efforts to address workplace safety for nurses have been under way for some time. In 2005 the American Nurses Association (ANA) partnered with the Association of periOperative Registered Nurses (AORN), the National Institute for Occupational Safety and Health (NIOSH), and the James A. Haley Veterans Administration Medical Center (VAMC) in Tampa, Florida, to form the Workplace Safety Task Force. Its aim was to prepare a safe patient handling algorithm guidance document to support ergonomically healthy workplaces. The task force began by identifying high-risk tasks specific to perioperative nurses that could be addressed with specific ergonomic tools. These tasks included transferring patients on and off OR beds, repositioning patients on the OR bed, lifting and holding patients' extremities, standing for long periods of time, holding retractors for long periods of time, lifting and moving equipment, and sustaining awkward positions. The task force developed seven ergonomic tools, or *algorithms,* to guide workplace safety in the perioperative setting. These clinical tools incorporate current ergonomic safety concepts, scientific evidence, and the use of technology, such as safe patient handling equipment (AORN, 2007).

What is an algorithm? An algorithm is a set of rules for solving a problem in a finite number of discrete steps. In this

case, the algorithm is an ergonomic tool designed to help make decisions in performing various healthcare tasks. The tool directs the caregiver through a series of questions (see the diamond boxes in Figure 30-1) and provides optimal responses for action—specifically, whether assistive equipment should be used, what type of equipment would best support the task, and how many caregivers are needed to perform the task safely. The purpose of the set of algorithms is to standardize practice based on research and task analysis, rather than to allow each caregiver to rely solely on his or her own training and experience to make decisions (Nelson, 2006).

The ergonomic tools should be used in the context of an assessment and plan of care for each patient. The plan of care is designed to communicate decisions about the patient's safe handling practices among all staff likely to participate in these tasks.

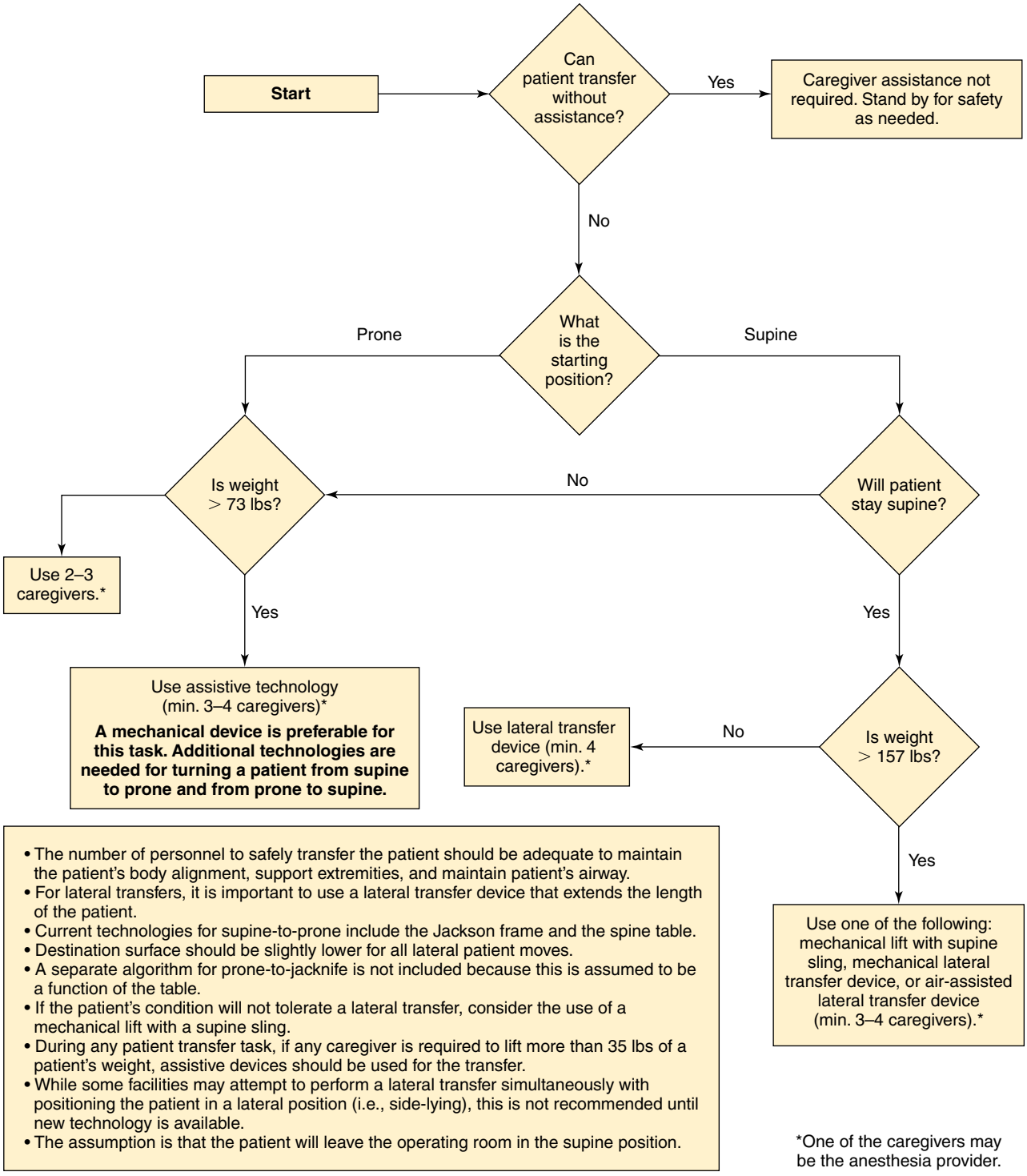


FIGURE 30-1 Lateral transfer from stretcher to and from the OR bed.

Seven Ergonomic Tools for Safe Patient Handling and Movement

This section explains the seven ergonomic tools for safe patient movement and handling.

1. *Ergonomic tool #1: Lateral transfer from stretcher to and from the OR bed* is shown in Figure 30-1. Lifting and moving patients occurs frequently in perioperative settings, with patients being transferred to and from transport carts and the OR bed. Many patients are completely or partially dependent on assistance with moving because of anesthesia (AORN, 2007). Lifting and moving patients is a hazardous patient care activity. Fully 38% of nurses have suffered injuries related to moving, lifting, or repositioning patients, and about one half of nurses have experienced chronic pain that they associate with these activities (Peter D. Hart Research Associates, 2006).
2. *Ergonomic tool #2: Positioning and repositioning the patient on the OR bed into and from the supine position.* Healthcare providers must often reposition patients, once they are on the OR bed, to provide appropriate exposure of the surgical site. They frequently lift and maneuver the patient while simultaneously placing a positioning device. Ergonomic Tool #2 provides guidelines for repositioning the patient in a safe manner.
3. *Ergonomic tool #3: Lifting and holding legs, arms, and head for prepping in a perioperative setting.* OR nurses often must lift or hold patients' limbs during skin preparation. Ergonomic Tool #3 is a table that provides calculations to determine whether it is safe for only one caregiver to lift the weight of various limbs and the safe length of time the limbs can be lifted.
4. *Ergonomic tool #4: Prolonged standing.* This tool provides relief to OR nurses and surgical technologists, often required to stand in one place for long periods of time during surgery. Prolonged standing can cause acute and chronic back, leg, and foot pain, as well as fatigue.
5. *Ergonomic tool #5: Retraction.* OR team members must sometimes hold retractors for long periods of time to expose the surgical site. This tool considers whether a self-retaining retractor can safely be used and, if not, how to determine an optimal working height and posture for the retracting team member (assistant in surgery, such as a physician's assistant [PA] or registered nurse first assistant [RNFA]).
6. *Ergonomic tool #6: Lifting and carrying supplies and equipment.* Members of the OR team lift and carry many types of supplies, instrument trays, and equipment. This tool uses the NIOSH lifting index (described below) to predict the risk of back pain from lifting specific objects in the OR.
7. *Ergonomic tool #7: Pushing, pulling, and moving equipment on wheels.* This tool makes recommendation on the number of people required to safely push or pull equipment on wheels; it is especially useful for prescribing safe movement of hospital and OR beds.

The use of assistive devices is recommended for situations where manual lifting puts the caregiver at substantial risk of injury. According to ANA's *Handle with Care* Campaign, the development of patient care ergonomics programs that include the use of assistive patient handling equipment and devices has essentially rendered "manual" patient handling unnecessary. A growing selection of equipment and devices makes available technology suitable for the variety of patient handling tasks performed by nurses (de Castro, 2004). Box 30-1 lists a number of such patient handling devices currently available. Figure 30-2 illustrates the ceiling lift device in use in the OR.

Evidence of the efficacy of safe patient handling techniques is now widespread. In one study conducted by the NIOSH on resident handling in nursing homes, a safe handling and movement program reduced resident-handling workers' compensation injury rates by 61%, lost workday injury rates by 66%, and restricted workdays by 38% (Nelson, 2006).

NIOSH Lifting Equation

The recommendation to use lifting devices for moving patients arises from a body of research that demonstrates that mechanical lifting equipment, as part of a program to promote safe patient handling, can significantly reduce musculoskeletal injuries among healthcare workers. In 1981 NIOSH developed

BOX 30-1

Categories and Descriptions of Safe Patient Handling Equipment and Devices

Inflatable lateral-assist devices	Flexible mattress inflated with air to create a cushioned layer for patient transfer
Friction-reducing lateral-assist devices	Boards made with smooth, low-friction material used for patient transfer
Mechanical lateral-assist devices	Height-adjustable stretchers used for patient transfer
Transfer chairs	Chairs that convert into stretcher, eliminating the transfer from a horizontal plane (bed or stretcher) to a seated position
Powered full-body sling lifts	Portable or ceiling-mounted lift devices to lift and transfer highly dependent patients
Powered stand-assist and repositioning lifts	Lift with arm and/or back slings to assist patients with some weight-bearing ability
Bed improvements to support transfer or repositioning	Beds that convert directly into chairs or equipped with shearless pivot that minimizes slipping toward foot of bed when head is raised
Sliding boards	Boards made of smooth, rigid, low-friction material for seated bed-to-chair or chair-to-toilet transfers that act as a supporting bridge
Stand-assist and repositioning aids	Secure devices, either free-standing or attached to beds, to help support patients to lift themselves

From de Castro AB: Handle with Care®: the American Nurses Association's campaign to address work-related musculoskeletal disorders, *Online J Issues Nurs* 9(3 Sept), 2004, available at www.nursingworld.org/MainMenuCategories/ANAMarketplace/ANAPeriodicals/OJIN/TableofContents? Volume92004/No3Sept04/HandlewithCare.aspx. Accessed March 9, 2009. Reprinted with permission.

FIGURE 30-2 Ceiling lift.

a lifting equation to calculate recommended weight limits for specified two-handed, manual lifting tasks (Waters, 2007). Although the equation was not originally recommended for the lifting of humans, the equation has been revised and is now recommended for many patient lifting activities under certain conditions (e.g., the patient can follow directions, the amount of weight the caregiver handles can be estimated). The Revised NIOSH Lifting Equation (RNLE), promulgated in 1991, provides a mathematical equation to determine the recommended weight limit (RWL) and lifting index (LI) for selected two-handed manual lifting tasks. The RWL is defined for a specific set of task conditions and represents the weight of the load that nearly all healthy workers could perform over a substantial period of time (e.g., up to 8 hours) without an increased risk of developing lifting-related low-back pain (AORN, 2007).

The concept behind the Lifting Equation is to start with a recommended weight that is considered safe for an ideal lift and then to reduce the weight as the task becomes more stressful (e.g., the distance of the load from the worker increases, the duration of the task increases, type of handhold varies) (AORN, 2007). In general, the revised equation yields a recommended 35-lb maximum weight limit for use in patient handling tasks. When the weight to be lifted exceeds this limit, assistive devices should be used (Waters, 2007).

The formula produces a recommended weight limit that can be used to determine the lifting index. This lifting index may then be used to identify potentially hazardous lifting jobs or to compare the relative severity of two jobs for the purpose of selecting the better option. The equation has also been used to provide recommendations for lifting objects such as lead aprons, sterile packs, body positioning devices, and instrument pans or trays (AORN, 2007).

SLIPS, TRIPS, AND FALLS

Although slips, trips, and falls (STFs) may occur in many places throughout a hospital or ambulatory surgery center, the OR is of special interest because it is the site where critical patient care occurs. An STF that disables a worker is expensive in terms of both direct and indirect costs, but a disabling fall of an OR team member may adversely affect a patient as well. A fall in the OR can cause direct patient injury, disrupt the surgical procedure, contribute to surgical errors, and delay the current surgery as well as other scheduled surgeries while other staff attend to or replace the injured staff member (Brogmus et al, 2007).

STFs remain the second leading cause of serious injury among hospital workers (Hughes, 2009), accounting for the largest proportion of injuries to healthcare workers who lost time from work (Collins et al, 2008). Hospitals are responsible for slip, trip, and fall incidence rates 67% higher than those in other U.S. private industries (Collins et al, 2008). STFs account for nearly 14% of all workers' compensation costs (Brogmus et al, 2007). The average cost to an employer when a worker experiences a fall is $12,470 (Hughes, 2009).

STF Causes and Prevention

STFs are caused by many factors, including wet floors, uneven floor surfaces, low-profile equipment and cords, cluttered or poorly lit walkways, and improper footwear. Historically, STF incidents have been considered largely nonpreventable, and blame has been laid more often than not on carelessness of the fall victim (Collins and Bell, 2009). Research has shown, however, that a comprehensive STF-prevention program can significantly reduce workers' compensation claims. To a large degree, STFs are preventable (Bell et al, 2008).

Wet Floors. In one 10-year study, STFs resulting from liquids (e.g., water; fluid; and slippery, greasy, and slick spots) were the most common cause (24%) of STF workers' compensation claims (Bell et al, 2008). Anticipatory planning to avoid wet spots, however, can reduce the rate of falls. Providing lids for all cups or other open containers being transported helps to avoid spills. Installing paper-towel holders in high-spill areas, such as near scrub sinks, nursing stations, and elevators, helps employees to clean up spills promptly (Hughes, 2009).

Wet floors should be signaled by placing highly visible "Caution: Wet Floor" signs, preferably 4 feet tall and with flashing lights, in areas that have been recently mopped (Hughes, 2009). Housekeeping staff should be equipped with beepers so that they can be quickly alerted to spill areas. In a NIOSH study, employees were able to call a housekeeping hotline to report a spill and were encouraged to use pop-up caution signs placed throughout the hospital to cover spills until housekeeping arrived. The hospital also purchased highly visible yellow absorption towels that employees could toss onto a spill until it was cleaned (Bell et al, 2008).

In the OR, liquids on the floor can make an otherwise slip-resistant surface hazardous (Brogmus et al, 2007). Using a

dripless, brush-free gel solution for surgical hand scrubs minimizes water splashes. In addition, when used at the surgical site, gel-based skin preps are less likely to run than liquid prep solutions. They are also less likely to pool under patients or to drip and pool on the floor or OR bed (Brogmus et al, 2007).

Pads can be used to temporarily cover a spill that occurs in an OR because fluids spilled during surgery are hazardous (Hughes, 2009). Fluid solidifiers usually are composed of a granulated substance that can be sprinkled onto a spill or poured into a container with fluid. Fluid solidifiers absorb liquid and solidify the fluid into gel. Adding a fluid solidifier in a liquid medical-waste container or on a fluid spill on the floor serves to control fluid and to reduce the risk of slips and falls (Brogmus et al, 2007). Effective containment also includes adequate waste containers for the planned procedure and readily available waste-control supplies, including absorptive products.

Uneven Floor Surfaces. One NIOSH study found that, while 36% of same-level incidents occurred because of floor contaminants such as wet floors, the remainder (64%) of the falls on the same level occurred at transition areas, such as from dry to wet, on uneven surfaces, or from one type of floor surface to another (Collins et al, 2006). Hospitals should ensure that there are no uneven surfaces, including thresholds, on floors. In stairwells with potentially low visibility, the nosing on the top and bottom steps can be painted to provide visual cues.

Unobstructed Pathways. Pathways must be kept clear, particularly of low-profile equipment and cords that can be easily overlooked in patients' rooms, hallways, ORs, or other care areas (Hughes, 2009). If possible, cords should not cross walkways; if this is impossible, cords should be covered or taped. Extension cords are also often found under desks and at nursing stations; where feasible, cord organizers, cord clamps, or retractable cord holders should be used to minimize these tripping hazards.

Keeping pathways clear is especially difficult in the OR, where multiple cables and cords are used in surgical procedures. Newer ORs are equipped with articulated ceiling-mounted booms that help keep cords off the floor and systems that integrate cables into the OR bed. Cords and cables in older ORs should be routed so that they do not stretch across walking paths, and they should be secured by bundling, taping, or braiding. Routing and securing cords makes it easier to check that all necessary cords are properly connected, and doing so makes it less likely that a patient will be injured or the procedure prolonged because someone trips on a cord (Brogmus et al, 2007).

Low-standing equipment and supplies are potential tripping hazards. These include buckets, rolling stools or step stools, support structures for equipment, and supply containers. OR staff often have to navigate around IV tubing and poles. The Occupational Safety and Health Administration (OSHA) suggests marking mobile equipment such as stools with a bright color or a taped X to make them more visible and distinguishable from the floor (OSHA, 2008c). Also, even though protective and absorptive mats play a safety role, they too can pose a tripping hazard. Slip-resistant absorptive mats should be used, and soiled absorptive mats should be removed. A mat that is oversaturated can swell and become a slipping and tripping hazard (Brogmus et al, 2007).

Failures in teamwork and communication can lead to surgical errors. One study found that when preoperative briefings occurred such errors decreased by more than 50%. In a recent study (Berenholtz et al, 2009), a majority of surgical team members who participated in a study of 37,133 briefings and debriefings using a standard 1-page tool said the process improved communication and teamwork. On average, the briefing took 2.9 minutes, and the debriefing took 2.5 minutes. Planning reduces critical events and errors, as well as risks to patients and OR personnel. After considering the layout of equipment, tubes, and cords and the team's response to trips and spills (Brogmus et al, 2007), any concerns held by the perioperative nurse or surgical technologist can be addressed during the preoperative briefing.

Lighting. Lighting throughout the healthcare facility must be adequate to visualize pathways, particularly stairways, when supplies or other items are being carried (Hughes, 2009). Adequate lighting is of specific and critical importance in the OR. Advancements in surgical technology, such as minimally invasive surgery (MIS) procedures, have increased the use of LED monitors in the OR. This increasingly requires dimming general room lighting while leaving the surgical site highly illuminated. Not only does this leave the rest of the OR dimly lit, but also the high illumination on the surgical site makes adapting one's vision to the dimmer room lighting more difficult (Brogmus et al, 2007). Dimmer lighting, of course, tends to heighten the risks of not seeing tripping hazards or fluids on the floor.

Proper Footwear. Proper footwear minimizes the risk of STFs. Lessons can be learned from industries, such as food service and commercial fishing, in which antislip footwear is standard (Hughes, 2009). Slip-resistant shoes are perhaps most effective at eliminating falls from slips. Specialized footwear is estimated to reduce the risk of slips and falls by 50% (Staal et al, 2004). In addition to being slip resistant, shoes should fully surround the foot and provide support (Hughes, 2009). Further, shoes should meet, and preferably exceed, the wet and dry test minimums of the U.S. footwear industry, should be comfortable, should be appropriate for both on- and off-the-job use, and should be affordable (Staal et al, 2004). Other research has suggested that the use of slip-resistant shoes by employees is encouraged when employers provide shoes or a payroll deduction for approved shoe purchases (Collins and Bell, 2009).

Programmatic STF Prevention and Reduction

Given the diverse age, job duties, and experience of healthcare workers, an STF program is critical to create a safe work environment. During program development, each healthcare facility should conduct a hazard vulnerability analysis to study the facility's unique set of hazards so they can be appropriately addressed in a workplace safety program that includes targeted STFs (Hughes, 2009).

A comprehensive prevention program can significantly reduce injuries. NIOSH researchers, in one study, compared injury rates and workers' compensation costs for a 10-year period before, during, and after the implementation of interventions. They found a 58% reduction in workers' compensation claims for slips, trips, and falls in the postintervention period (Bell et al, 2008). One key component of a successful STF prevention

program is to educate workers about the importance of STF prevention and to encourage every employee to take personal responsibility for eliminating STF hazards. Whether this involves personally cleaning spills or cordoning off an area to alert fellow employees while waiting for housekeeping staff to arrive, a successful STF program requires that all hospital staff share responsibility for prevention (Collins and Bell, 2009).

SHARPS SAFETY AND BLOODBORNE PATHOGENS

Scope and Significance of Problem

In the high-risk perioperative environment, healthcare workers routinely face exposure to bloodborne pathogens (BBPs) and percutaneous injuries (PIs). According to the Centers for Disease Control and Prevention (CDC), hospital-based personnel sustain 385,000 needlesticks and other sharps-related injuries each year—an average of more than 1000 sharps injuries daily (CDC, 2008b). The OR, with 33% of injuries, has the highest proportion of PIs relative to those sustained in all other hospital settings (Research Highlight). When applied to the CDC's estimate for annual number of hospital PIs in the United States, this translates to 128,000 OR PIs each year (Davis, 2006). In an international study, needlestick injuries per 1000 full-time equivalents (FTEs) for medical-surgical unit nurses were 146 in the United States, 209 in Canada, 157 in the United Kingdom, and 488 in Germany. Nurses working in the OR and/or other perioperative settings had sharp device injury rates double those of nurses in other specialties in the United States and Canada—255 and 569 injuries per 1000 per year, respectively (Clarke et al, 2007).

RESEARCH HIGHLIGHT

Inoculation Volume Delivered by Suture Needles

Needlestick injury is a common occurrence in the OR. Most data about seroconversion from needlesticks are based on hollow-bore needles and inoculation volumes of pure blood delivered by suture needles. Data are lacking, however, on contaminant transmission in less viscous body fluids that are not prone to coagulation and the effect of layers of gloves on contaminant transmission.

For this study, an enzyme-colorimetry assay was used to quantify the volume of inoculation delivered by suture needles coated with a water-like contaminant through various types and layers of surgical gloves. They found that one glove layer removed 97% of the contaminant from tapered suture needles and 65% from cutting needles. Additional layers of gloves did not significantly improve contaminant removal from tapered needles.

For cutting needles, however, two layers of gloves removed 91% of the contaminant, which was significantly better than one glove. Three gloves did not afford significant additional protection. There were no statistically significant differences between glove types.

This research supports using double-gloves for maximum safety. A single layer of gloves removes contaminant from tapered needles as effectively as multiple layers, but for cutting needles, double-gloving offers superior protection.

Adapted from Lefebvre DR et al: An enzyme-mediated assay to quantify inoculation volume delivered by suture needlestick injury: two gloves are better than one, *J Am Coll Surg* 206:113-122, 2008.

Although the hepatitis B virus (HBV), the hepatitis C virus (HCV), and the human immunodeficiency virus (HIV) are the pathogens most commonly transmitted during patient care, injuries from needles and other sharp devices used in healthcare and laboratory settings are associated with the transmission of approximately 20 pathogens (CDC, 2008b). In one study of the prevalence of BBPs in an urban, university-based general surgical practice, testing revealed that 38% of all operations involved patients infected with a BBP: 26% were infected with HIV, 4% with HBV, 35% with HCV, and 17% with both HIV and HCV (Davis, 2006). The risk of transmission after a needlestick or sharps injury is estimated to be 6 to 30 out of every 100 people for HBV, 3 to 10 out of every 1000 people for HCV, and 1 out of every 300 people for HIV.

Exposure to bloodborne pathogens occurs during all phases of the perioperative process. The American College of Surgeons (ACS) estimates that cuts or needlestick injuries occur in 1% to 15% of all operations (ACS, 2005). Risk of a sharps injury increases during more invasive, longer procedures that result in higher blood loss. Fatigue resulting from working extended hours in combination with the fast pace of the perioperative environment may also contribute to increased risk of PIs (AORN, 2009a). Other factors that may contribute to surgical PIs include frequent handling of sharp instruments, prolonged contact of surgical personnel with open surgical sites, presence of relatively large quantities of blood (Jagger et al, 1998), unsafe needle handling techniques, assignment of incision closure to relatively inexperienced staff, and failure to use a neutral zone for passing sharps between personnel (Davis, 2006).

Although injuries from hollow-bore needles constitute the majority of percutaneous injuries in the healthcare field overall, the pattern of injuries inside the OR is somewhat different. Suture needle injuries (SNIs) are by far the predominant cause of PIs in the surgical setting, accounting for as many as 77% of these injuries (AORN, 2009a), and are also the leading cause of occupational exposure to bloodborne pathogens among OR professionals (Davis, 2006).

Box 30-2 provides information on bloodborne pathogens and legislation.

Preventing Injuries During Surgery

Surgery involves precise, regimented actions that require planning, communication, and teamwork. These same elements can be employed to mitigate inherent hazards associated with sharp devices in the perioperative setting (AORN, 2009a). AORN has developed a list of risk reduction strategies that OR nurses can use to protect themselves from exposure injuries in surgery. Care in setting up the surgical work area includes placement of sharp items, constant awareness of the location of sharps and other sterile team members during surgery, and careful disposal of sharps after surgery. Such care contributes to ensuring a surgical environment that is safe for all participants. These risk reduction strategies are presented in the following sections.

Safe Handling Practices for Surgical Sharps. Observing safety precautions during all phases of surgery, from setup to cleanup, reduces the number of injuries and exposures for all OR personnel.

BOX 30-2

Bloodborne Pathogen Legislation

Protecting healthcare workers from bloodborne pathogens was largely neglected until the global AIDS epidemic of the 1980s. The CDC, the first federal agency to respond, in 1987 issued guidelines for Universal Precautions to protect workers at risk of exposure to blood or body fluids of patients.

In 1991 OSHA issued a rule for Occupational Exposure to Bloodborne Pathogens, based on the concept of Universal Precautions. The Needlestick Safety and Prevention Act, enacted in 2000, directed OSHA to revise its Bloodborne Pathogens Standard. OSHA subsequently revised its final rule to include a special focus on needlestick and other percutaneous exposures to bloodborne pathogens. OSHA's Bloodborne Pathogens Standard now requires that engineering and work-practice controls be used to eliminate or minimize exposures to blood and other potentially infectious materials (OPIMs), including human body fluids, tissue, or organs; and HIV- or HBV-containing cell or tissue cultures.

In particular, the Standard requires that sharps injuries in the surgical area be eliminated or minimized through the use of such measures as safe needles and other sharps devices; blunt-tip suture needles; needleless IV connectors; proper containers for sharps; a "No Pass Zone" for surgical instruments; and a method to pass equipment safely between surgeon and assistants. The Standard also recommends the use of scalpel blades with safety features; the use of alternative cutting methods, when appropriate; and the use of mechanical (self-retaining) retraction devices. Other requirements include wearing appropriate personal protective equipment (PPE), such as gloves, gowns, face shields or masks, and shoe covers, if blood or OPIM exposure is anticipated and adhering to the following practices regarding contaminated needles and sharps: contaminated needles and other sharps should not be bent, recapped, sheared, or broken; and they should be discarded immediately.

One unique feature of the Needlestick Safety and Prevention Act was the required participation of healthcare workers in evaluating and selecting safety-engineered needles and sharps; further, employers were mandated to document evaluation and implementation of safety-engineered devices. Employers were also required to maintain a sharps injury log to document the types of devices causing injuries and an explanation of the circumstances of each incident.

There is convincing evidence that this legislation, particularly as it pertains to safety-engineered devices, has been successful. U.S. researchers identified reductions in injury rates that have been attributed to the passage of federal sharps legislation in 2000 and more vigorous enforcement of safety guidelines. In an international study, researchers concluded that sharps injury rates were lowest in the United States, where the use of safety-engineered devices is highest and where federal regulation has a positive impact on nurse safety. Within the United States, a study at Memorial Sloan-Kettering Cancer Center (MSK) in New York explored the effects of adopting safety-engineered devices. After adoption, there was an overall reduction in sharps injuries of 58%, with a 71% reduction in injuries from hollow-bore needles and a 75% reduction in injuries among nurses, the occupational group that typically sustains the highest proportion of injuries. The same study found, however, that surgical settings are least likely to adopt safety-engineered devices, such as blunt suture needles and shielded scalpel blades.

Modified from Jagger J et al: The impact of U.S. policies to protect healthcare workers from bloodborne pathogens: the critical role of safety-engineered devices, *J Infect Pub Health* 1:62-71, 2008; Occupational Safety and Health Administration: *Hospital eTool, surgical suite module, bloodborne pathogens (BBPs),* 2008, available at www.OSHA.gov/SLTC/etools/hospital/surgical/surgical.html#BloodbornePathogens. Accessed April 6, 2009; Clarke SP et al: Sharp-device injuries to hospital staff nurses in 4 countries, *Infect Control Hosp Epidemiol* 28:473-478, 2007.

During preparation for surgery:

- Organize the work area (Mayo stand, back table) so that sharps are always pointed away from the person setting up.
- Establish a separate area, a "neutral zone," to place a reusable sharp for safe handling during the procedure; include identification and agreement about this neutral zone in the preoperative briefing.
- Use standardized sterile field setups throughout the surgical services department.

During the procedure:

- Use neutral or hands-free techniques for passing sharp items, instead of passing hand to hand.
- Give verbal notification when passing a sharp device.
- Be aware of other sterile team members in and near the area when handling a sharp device.
- Keep track of, and account for, all sharp items throughout the procedure.
- Keep hands away from the surgical site when sharp items are in use (i.e., suturing, cutting).
- Use gloves and an instrument to pick up sharp items (e.g., suture needles, hypodermic needles, scalpel blades) that have fallen on the floor.

During postprocedure cleanup:

- Inspect the surgical setup used during the procedure for sharps.
- Transport reusable sharps in a closed, secure container to the designated cleanup area.
- Inspect the sharps container for overfilling before discarding disposable sharps in it.
- Do not place hands or fingers into a container to dispose of a device.
- Keep hands behind the sharp tip when disposing.

The Risk Reduction Strategies box provides information on requirements for the most effective sharps disposal containers.

The Neutral Zone. The "neutral zone" has been defined as a location on the surgical field where sharps are placed in a predesignated sterile basin or tray or on a magnetic pad, from which the surgeon or assistant can retrieve them. After use, the items are placed back in the neutral zone, and the scrub person retrieves them. This technique eliminates hand-to-hand passing of sharps between the surgeon and the scrub person, so that no two individuals touch the same sharp at the same time. In one study, when this hands-free technique (HFT) was

RISK REDUCTION STRATEGIES

Requirements for Sharps Disposal Containers

- Durable, closable, leakproof, and puncture resistant
- Appropriate size for user and type of sharps
- Container designed for "letter-drop" of sharps
- Lids allow sharps to enter by gravity without need for additional manipulation
- Within horizontal reach of healthcare team members (close to the point of use) who dispose of sharps
- Container, level of fullness (full line), proper warning labels (biohazard labels), and color coding (orange, orange-red) must remain visible to healthcare team members
- Self-closing lids to prevent overfill if container is not see-through to observe fill line
- Ease of assembly and operation, including one-handed disposal

used at least 75% of the time during the procedure, there was a 59% decrease in exposure incidents during procedures in which the blood loss was at least 100 ml (Stringer et al, 2002). As it reduces the chance of accidental needle punctures and cuts, use of the neutral zone to transfer sharps has been recommended by the ACS and AORN (Berguer and Heller, 2004), as well as by OSHA (Davis, 2006).

The following suggestions make the most valuable use of the neutral zone:

- A magnetic pad or basin may be used to create the neutral zone; if a basin is used, it should be placed on the field and not held by the scrub person.
- Dedicate the neutral zone to sharps only; these include suture and hypodermic needles, scalpels, and other sharp instruments.
- The scrub person and surgeon or assistants should confer on the best placement of sharps in the neutral zone.
- Place only one sharp at a time in the neutral zone.
- Announce the transfer of a sharp before placing it in the neutral zone (such as "knife down"); after announcement, orient the sharp in the correct position in the neutral zone (i.e., place it such that the person picking it up does not have to alter its position in his or her hand).
- Include identification of the neutral zone during hand-off communications to relief scrub persons.

PERSONAL PROTECTIVE EQUIPMENT

The use of personal protective equipment (PPE) has proven very effective against transmission of pathogens in the OR. For prevention of infection among OR nurses, two practices are particularly useful: double-gloving and the use of eye protection.

Double-Gloving

Glove barrier failure commonly occurs in the perioperative setting. The frequency of glove perforation during surgery has been studied extensively and found to range from 8% to 50% (Misteli et al, 2009). Glove failures can be caused by punctures, tears by sharp devices, or spontaneous failures; all these failures expose the wearer to bloodborne pathogens. Studies have demonstrated that glove perforations often occur after an average of 40 minutes of use during surgical procedures. When two pairs of gloves are worn, in most instances only the outer glove perforates when punctured by a sharp device. In addition, research demonstrates that when two pairs of gloves are worn and a puncture occurs, the volume of blood transferred from a solid sharp device (e.g., suture needle) is reduced by as much as 95%. AORN advises double-gloving during invasive procedures, noting that 18 clinical trials have demonstrated that double-gloving minimizes the risk of exposure to blood and that double-gloving reduces by as much as 87% the risk of exposure to blood and body fluids if the outer glove is punctured (AORN, 2009b).

Eye Protection

In one study of blood exposures in OR personnel, blood contact with the mucosa of the eyes was the most common type of exposure from splashing or spraying, accounting for 45% of incidents (compared with only 7% and 5% of cases occurring to the mucosa of the nose or mouth, respectively) (Jagger et al, 1998). This finding suggests that barrier protection for the nose and mouth is more consistently worn by OR personnel than eye protection. As it is now well documented that the conjunctivae serve as a transmission route for HIV and HCV, it is recommended that all OR members, regardless of proximity to the surgical site, wear protective eyewear as routinely as surgical masks (Jagger et al, 1998).

BLUNT SUTURE NEEDLES

Suture needle injuries (SNIs) are the predominant cause of PIs in the surgical setting. Straight suture needles pose the highest risk of injury per needle use, but the majority of SNIs occur during suturing of fascia or muscles with unprotected, curved sharp suture needles (Davis, 2006). According to the ACS, blunt suture needles permit suturing of fascia and other structures with minimal risk of injuring the surgeon, even when the surgeon's glove is punctured. All published studies to date have demonstrated that the use of blunt suture needles can substantially reduce or eliminate needlestick injuries from surgical needles. The ACS supports the universal adoption of blunt suture needles as the first choice for fascial suturing to minimize or eliminate needlestick injuries from surgical needles (ACS, 2005). The use of blunt suture needles has also been officially endorsed by AORN and the Council for Surgical and Perioperative Safety (Box 30-3).

Eliminating exposure to hazards cannot be accomplished in a "once and done" manner. Often, several diverse steps must be taken simultaneously. These might be as different as hazard-proofing a room, changing the type of equipment used, and changing staff behavior by asking each team member to wear a particular type of protective garment. The Evidence for Practice box explains this approach as the Hierarchy of Controls model.

RESPONDING TO EXPOSURE

OSHA regulations require healthcare organizations to protect their workers and to have a sharps injury and bloodborne pathogen exposure control plan (ECP). By law, the plan must be written, communicated to all workers in the perioperative setting, and uniformly supported and enforced by perioperative

BOX 30-3

Blunt Suture Needles

The blunt needle does not have a sharp point; it dissects tissue as it is used, causing less tissue trauma than a conventional sharp-pointed needle. The risk of needlestick injury is significantly reduced. The following organizations support the use of blunt needles in surgery:

- The American College of Surgeons: Issued a statement on blunt suture needles, noting that the College supported "the universal adoption of blunt suture needles as the first choice for fascial suturing to minimize or eliminate needle-stick injuries from surgical needles" and recommending that "blunt suture needles should be available in various sizes and with a range of suture adequate for different surgical applications."
- The Council on Surgical and Perioperative Safety (CSPS): Endorsed use of blunt suture needles as a recommended sharps safety measure.
- NIOSH: Strongly encouraged the use of blunt-tip suture needles to decrease percutaneous injuries to surgical personnel (NIOSH, 2008).
- AORN: In its recommended practice for prevention of transmissible infections, AORN notes that the use of blunt suture needles is a method for reducing injuries caused by needles.

Adapted from American College of Surgeons: Statement on sharps safety, *Bull Am Coll Surg* 92(10), 2007, also available at www.facs.org/fellows_info/statements/st-58.html; Association of periOperative Registered Nurses (AORN): Recommended practices for prevention of transmissible infections in the perioperative practice setting. In *Perioperative standards and recommended practices*, Denver, 2009, The Association; Council on Surgical and Perioperative Safety: *The CSPS endorses that all measures to prevent sharps injuries will be used, inclusive of: double-gloving, use of blunt suture needles, hands-free technique or neutral zone, and the universal adoption of all sharps safety measures in perioperative care is recommended,* adopted July 15, 2007, available at www.cspsteam.org/information/information1.html. Accessed February 5, 2009; NIOSH: Use of blunt-tip suture needles to decrease percutaneous injuries to surgical personnel, *Safety Health Inform Bull,* publication no. 2008-101, 2008, available at www.cdc.gov/niosh/docs/2008-101/default.html. Accessed February 5, 2009.

EVIDENCE FOR PRACTICE

Hierarchy of Controls

The Hierarchy of Controls model defines a method to control exposure to occupational hazards as a fundamental approach to protect workers. The hierarchy is used to determine a feasible and effective set of controls and can be summarized as follows:

- Elimination
- Substitution
- Engineering controls
- Administrative controls
- Personal protective equipment (PPE)

The concept of the hierarchy is that the control methods at the top of the preceding list are potentially more effective and protective than those at the bottom. Elimination and substitution, while most effective at reducing hazards, also tend to be the most difficult to implement in an existing process. Administrative controls and PPE are frequently used with existing processes where hazards are not particularly well controlled, but these methods for protecting workers have proven less effective than other measures and require significant effort by workers to achieve success.

Blood exposure prevention practices can be prioritized following the principles of the Hierarchy of Controls prevention model. In the hierarchy for sharps injury prevention, for example, the first priority is to eliminate and reduce the use of needles and other sharps, where possible. The next step is to isolate the hazard, thereby protecting workers from an otherwise exposed sharp, through the use of an engineering control. When these strategies are not available or will not provide total protection, the focus shifts to work-practice controls and personal protective equipment. Active involvement of the OR team and hospital management is essential because decisions about supplies, immunizations, and training, among other considerations, require continuous team efforts.

From CDC, NIOSH: *NIOSH safety and health topic: engineering controls,* Cincinnati, 2009, available at www.cdc.gov/niosh/topics/engcontrols/. Accessed May 27, 2009; Gomaa A et al: Occupational blood-borne diseases in surgery, excerpta medica (letter to the editor), *Am J Surg* 192(3):408-410, 2006.

leadership. At a minimum, the following must be included in the ECP:

- Determination of employee exposure
- Implementation of exposure control methods, including:
  - Universal Precautions
  - Engineering and work-practice controls
  - Personal protective equipment
  - Housekeeping
- Hepatitis B vaccination
- Postexposure evaluation and follow-up
- Communication of hazards to employees and training
- Recordkeeping
- Procedures to evaluate exposure incidents (ANA, 2002)

If You Sustain an Injury

If a needlestick or other occupational contact (e.g., splashing or spraying) that could result in a bloodborne pathogen exposure does occur, the injured person should begin the following procedures *immediately.*

Immediate Response

- Wash with soap and water all wounds and skin sites that have been contacted by blood or body fluids. Flush mucous membranes with water (CDC, 2001).
- Alert your supervisor and initiate the injury reporting system used in your workplace.

- Identify the source patient; this patient should be tested for HIV, HBV, and HCV infections. Your workplace will begin the testing process by seeking patient consent.
- Immediately report to employee health, the emergency department (ED), or the designated facility.
- Get tested immediately and confidentially for HIV, HBV, and HCV infections.
- Get postexposure prophylaxis (PEP) using CDC guidelines when the source patient is unknown or tests positive for HIV or HBV (currently, there is no PEP for HCV). PEP medications for HIV should be started within 2 hours of exposure. PEP can be started after 2 hours from exposure; however, you should be evaluated as soon as possible after injury.
- Document the exposure in detail, for your own records as well as for the employer and for workers' compensation purposes. Employers must maintain a sharps injury log (described under EPINet below) (ANA, 2002).
- Obtain an immediate evaluation and risk assessment.
- Initiate a postexposure treatment plan, including counseling, education, and follow-up testing.

Follow-Up

- Obtain confidential postexposure testing at 6 weeks, 3 months, 6 months, and (depending on the risk), 1 year.
- Undergo monitoring and follow-up of PEP.
- Take precautions to prevent exposing others until follow-up testing is complete (ANA, 2002).

EPINet

The Exposure Prevention Information Network (EPINet) is a voluntary surveillance system used to record and track PIs and blood and body fluid contacts. The EPINet system consists of a Needlestick and Sharp Object Injury Report (Figure 30-3); Blood and Body Fluid Exposure Report (Figure 30-4); and software to enter and analyze data from the forms (International Healthcare Worker Safety Center [IHWSC], 2008a). Since its introduction in 1992, more than 1500 hospitals in the United States and overseas have acquired EPINet.

The federal Needlestick Safety and Prevention Act of 2000 and the 2001 revised Bloodborne Pathogens Standards require healthcare facilities to maintain a sharps injuries log. The log must include, at a minimum, the type and brand of device involved in the exposure incident, the department where the exposure occurred, and an explanation of how it occurred. EPINet data can be used to help facilities target high-risk devices and products, identify injuries that may be prevented with safer medical devices, and evaluate new technology designed to prevent needlesticks. Data can also be used by institutions to share and compare information and successful prevention measures (International Healthcare Worker Safety Center, 2008b).

A CULTURE OF SAFETY

A healthcare institution's culture of safety profoundly impacts its success or failure in reducing employees' blood exposure risk. For sharps safety in particular, success factors include effective systematic review of exposure data, workers' perceptions of exposure risk, availability and use of safety devices, and comprehensive education on bloodborne pathogen exposure risk and safety device use (CDC, 2008b).

Protecting Yourself

You can take significant measures toward ensuring your personal safety and avoiding injuries from sharps if you do the following: Adopt and incorporate safe habits into daily work activities when preparing and using sharp devices. Observe local, state, and federal (OSHA) regulations. Comply with methods to protect yourself from disease transmission (e.g., get the hepatitis B vaccination). Participate in education about bloodborne pathogens, and follow recommended infection prevention practice. Know the location in your department of the exposure control plan. Finally, follow the exposure control policy if injured, including *immediate* reporting of the incident and commencement of exposure response procedures (AORN, 2009a).

WASTE ANESTHETIC GASES

Scope and Significance of Problem

Surgical anesthesia was first used in the United States when diethyl ether was administered to a patient in 1942 (OSHA, 2000). Since then, many anesthetic agents have been administered to patients to provide freedom from pain during surgical procedures. Advances in anesthetic agents have eliminated the risk of explosion caused by anesthetic agents such as diethyl ether, cyclopropane, and ethylene (OSHA, 2000). Developments in chlorofluorocarbon chemistry have resulted in halogenated, nonflammable, volatile agents; these have reduced the risk of explosion and flammability, but nonetheless are responsible for an occupational hazard and risk estimated to expose 200,000 healthcare professionals (OSHA, 2000). Those OR workers at occupational risk include anesthesia care providers, perioperative nurses, surgical technologists, postanesthesia care unit (PACU) nurses, and others who work in settings where anesthetics are administered (CDC, NIOSH, 2007).

Waste anesthetic gases (WAGs) are small amounts of gases that may leak either from the patient's anesthetic breathing circuit into the OR air while anesthesia is being administered or from exhalation of the patient during recovery. Both mechanisms of exposure create risks for OR personnel. Therefore OR workers must know the risks, potential health effects, and precautions that should be taken.

OR personnel are more prone to being exposed to WAGs in facilities either with no automatic scavenging systems or with no automated ventilation, in facilities with anesthesia systems in poor working order, or in recovery areas such as the PACU with inadequate systems. Where scavenging and ventilation systems are in place, OR personnel nevertheless can be exposed when leaks occur in the anesthetic breathing circuits because of poor maintenance of tubing, connectors, or valves, or because of circuits with loose connections. Gases can also escape during connection and disconnection of the system. In addition, poor-fitting patient masks or endotracheal tube connections can cause gases to escape into the air, making induction of anesthesia another occasion when gas leakage places OR personnel at risk (CDC, NIOSH, 2007). Other mechanisms of potential exposure include defects in rubber and plastic tubing and hoses; selected anesthesia techniques; improper practices such as gas flow control valves being left open after use; liquid anesthetic spills; and improperly inflated tracheal

Text continued on p. 1273.

Needlestick & Sharp Object Injury Report/OR

EPINet™ FOR MICROSOFT® ACCESS
EXPOSURE PREVENTION▶ INFORMATION NETWORK▶

EPINet is a trademark of the University of Virginia.
Windows is a registered trademark of Microsoft Corporation in the United States and/or other countries.
Operates in Windows 95 and Windows 98 Environments.
© 2000 Becton, Dickinson and Company.
V1.2/US OR, L&D 1/2002

Last Name: _____ First Name: _____

Injury ID: *(for office use only)* S_____ Facility ID: *(for office use only)* _____ **Completed By:** _____

1) Date of Injury: ☐☐ ☐☐ ☐☐☐☐ **2) Time of Injury:** ☐☐ ☐☐

3) Surgical service: _____

- ☐ 1 General
- ☐ 2 Cardiovascular
- ☐ 3 OB/C-Section
- ☐ 4 Gynecology
- ☐ 5 Orthopedic
- ☐ 6 ENT
- ☐ 7 Neurosurgery
- ☐ 8 Plastic
- ☐ 9 Urology
- ☐ 10 Oral/Dental
- ☐ 11 Transplants
- ☐ 12 Ophthalmology
- ☐ 13 Thoracic
- ☐ 99 Other service, describe: _____

4) Surgical procedure being performed: _____

4a) Was it an endoscopic/laparoscopic procedure?
☐ 1 Yes ☐ 2 No ☐ 3 Unknown ☐ 4 Not Applicable

5) What is the job category of the injured worker: (check one box only)

- ☐ 1 Surgeon *(attending)* specify specialty _____
- ☐ 2 Surgeon *(resident)* specify specialty _____
- ☐ 3 Ob/Gyn *(attending)*
- ☐ 4 Ob/Gyn *(resident)*
- ☐ 5 Anesthesiologist *(attending)*
- ☐ 6 Anesthesiologist *(resident)*
- ☐ 7 Nurse Anesthetist
- ☐ 8 Med Student, mark rotation→ ☐ surg ☐ anesth ☐ ob-gyn
- ☐ 9 Circulating nurse at time of incident → ☐ 1 RN ☐ 2 ORT ☐ 3 UAP
- ☐ 10 Scrub nurse at time of incident → ☐ 1 RN ☐ 2 ORT ☐ 3 UAP
- ☐ 11 Other Nurse
- ☐ 12 Nursing Student
- ☐ 13 OR Attendant
- ☐ 14 Housekeeper
- ☐ 99 Other, describe: _____

6) Where did the injury occur? (check one box only)

- ☐ 1 Pre-operative area
- ☐ 2 At the mayo *(instrument)* stand
- ☐ 3 At the back table
- ☐ 4 In the operative site/wound
- ☐ 5 On the surgical field *(near operative site)*
- ☐ 6 On anesthesia machine
- ☐ 7 On anesthesia cart
- ☐ 8 At patient's puncture site *(intro of vascular cath/injection,etc)*
- ☐ 9 At site of injection into IV equipment
- ☐ 10 on OR floor
- ☐ 11 in the OR utility room
- ☐ 12 Post anesthesia care unit *(recovery room)*
- ☐ 99 Other, describe: _____

7) Was the source patient's identity known? (check one box only)
☐ 1 Yes ☐ 2 No ☐ 3 Unknown ☐ 4 Not Applicable

8) For what purpose was the sharp item originally used? (check one box only)

- ☐ 1 Unknown/not applicable
- ☐ 2 Injection, intra-muscular/subcutaneous, or other injection through the skin *(syringe)*
- ☐ 3 To start IV or set up heparin lock *(IV catheter or winged set-type needle)*
- ☐ 4 To connect IV line *(intermittent IV/piggyback/IV infusion/other IV line connection)*
- ☐ 5 Injection into (or aspiration from) IV injection site or IV port
- ☐ 6 To place an arterial line/catheter
- ☐ 7 To place a central line/catheter
- ☐ 8 To place other non-vascular line/catheter
- ☐ 9 To draw venous blood sample
- ☐ 10 To draw arterial blood sample ⟹ ▶ **if used to draw blood was it?** ☐ 1 Direct stick? ☐ 2 Draw from a Line?
- ☐ 11 To obtain a body fluid or tissue sample *(urine/CSF/amniotic fluid/other fluid, biopsy)*
- ☐ 12 Cutting *(surgery)*
- ☐ 13 Suturing muscle/fascia
- ☐ 14 Suturing skin
- ☐ 21 Suturing tissue not listed above, describe: _____
- ☐ 15 Electrocautery
- ☐ 16 Drilling/sawing
- ☐ 17 Retracting tissue/bone
- ☐ 18 Wiring/fixing
- ☐ 19 Using as a tool, not on patient
- ☐ 20 To contain a specimen or pharmaceutical *(glass items)*
- ☐ 99 Other; describe _____

9) Did the injury occur? (check one box only)

- ☐ 1 Before use of item *(item broke/slipped, assembling device, etc.)*
- ☐ 2 During use of item *(item slipped, patient/colleague jarred item, etc)*
- ☐ 3 While manually retracting tissue in operative site
- ☐ 4 While retracting tissue using retractor or other instrument
- ☐ 5 Passing instruments, hand-to-hand
- ☐ 6 Passing instruments, hand-free transfer
- ☐ 7 Between incremental injections
- ☐ 8 In between uses of devices
- ☐ 9 Disassembling device or equipment
- ☐ 10 Sorting, disinfecting, and/or sterilizing instruments
- ☐ 11 While recapping a used needle
- ☐ 12 Withdrawing needle from rubber or resistant material
- ☐ 13 Other after use-before disposal *(in transit to trash, cleaning, left on bed, table, floor, or other inappropriate place, etc.)*
- ☐ 14 From item left on or near disposal container
- ☐ 15 While putting item into disposal container
- ☐ 16 After disposal, stuck by item protruding from opening of disposal container
- ☐ 17 Item pierced side of disposal container
- ☐ 18 After disposal, item protruded from **trash bag** or **inappropriate** waste container
- ☐ 99 Other, describe: _____

FIGURE 30-3 Needlestick and sharp object injury report for the OR.

10) If the injury was sustained by an anesthesia team member, what anesthesia task was being performed at the time of injury?
Describe: _____

11) At the time of the injury, was the sharp instrument/item? (check one box only)
- ☐ 1 Held by another person
- ☐ 2 Held by injured person
- ☐ 3 Not held by anyone

12) The sharp item was: (check one box only)
- ☐ 1 Contaminated (known exposure to patient or contaminated equipment) ⟹ **was there blood on the device?** ☐ 1 Yes ☐ 2 No
- ☐ 2 Uncontaminated (no known exposure to patient or contaminated equipment)
- ☐ 3 Unknown

13) What type of device caused the injury? (check one box only)
- ☐ Needle-*Hollow Bore*
- ☐ Surgical
- ☐ Glass

Which device caused the injury? (check one box from one of the three sections only)

Needles *(for suture needles see "**surgical instruments**")*

- ☐ 1 Disposable Syringe *(includes standard, insulin, tuberculin, etc)*
- ☐ 2 Pre-filled cartridge syringe (*includes Tubex™ *, Carpuject ™* -type syringes)*
- ☐ 3 Blood gas syringe *(ABG)*
- ☐ 4 Syringe, other type
- ☐ 5 Needle on IV line *(includes piggybacks & IV line connectors)*
- ☐ 6 Winged steel needle *(includes winged-set type devices)*
- ☐ 7 IV catheter stylet
- ☐ 8 Vacuum tube blood collection holder/needle *(includes Vacutainer™ *–type device)*
- ☐ 9 Spinal or epidural needle
- ☐ 10 Unattached hypodermic needle
- ☐ 11 Arterial catheter introducer needle
- ☐ 12 Central line catheter introducer needle
- ☐ 13 Drum catheter needle
- ☐ 14 Other vascular catheter needle *(cardiac etc.)*
- ☐ 15 Other non-vascular catheter needle *(ophthalmology, etc.)*
- ☐ 16 Huber-type needle
- ☐ 28 Needle, not sure what kind
- ☐ 29 Other needle, please describe: _____

Surgical instrument or other sharp items *(for glass items see "**glass**")*

- ☐ 30 Lancet (finger or heel sticks)
- ☐ 31 Suture needle
- ☐ 32 Scalpel blade, reusable handle
- ☐ 45 Scalpel blade, disposable scalpel
- ☐ 33 Razor
- ☐ 34 Pipette *(plastic)*
- ☐ 35 Scissors
- ☐ 360 Electro-cautery device, needle tip
- ☐ 361 Electro-cautery device, blade tip
- ☐ 362 Electro-cautery device, loop tip
- ☐ 37 Bone cutter
- ☐ 38 Bone chip
- ☐ 39 Perforating towel clip
- ☐ 40 Microtome blade
- ☐ 41 Trocar
- ☐ 42 Vacuum tube *(plastic)*
- ☐ 43 Specimen/Test tube *(plastic)*
- ☐ 44 Fingernails/Teeth
- ☐ 46 Retractors, skin/bone hooks
- ☐ 47 Staples/Steel sutures
- ☐ 48 Wire *(suture/fixation/guide wire)*
- ☐ 49 Pin *(fixation, guide pin)*
- ☐ 50 Drill bit/bur
- ☐ 51 Pickups/Forceps/Hemostats/Clamps
- ☐ 58 Sharp item, not sure what kind
- ☐ 59 Other sharp item: Describe: _____

Glass

- ☐ 60 Medication ampule
- ☐ 61 Medication vial *(small volume with rubber stopper)*
- ☐ 62 Medication/IV bottle *(large volume)*
- ☐ 63 Pipette *(glass)*
- ☐ 64 Vacuum tube *(glass)*
- ☐ 65 Specimen/Test tube *(glass)*
- ☐ 66 Capillary tube
- ☐ 67 Glass slide
- ☐ 78 Glass item, not sure what kind
- ☐ 79 Other glass item: Describe: _____

13a) Brand/Manufacturer of product: (e.g. ABC Medical Company) _____

13b) Model:
☐ 98 Known: Please specify: _____ ☐ 99 Unknown

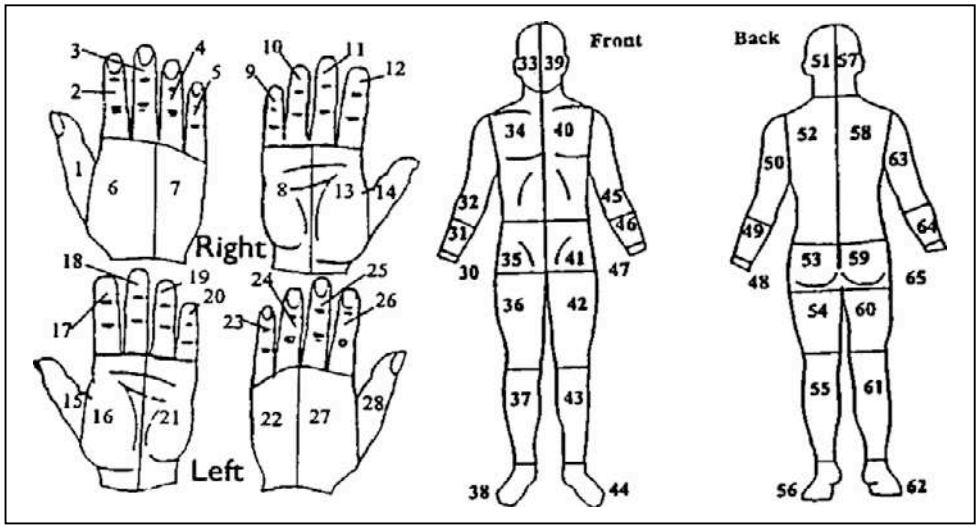
14) If the item causing the injury was a needle or sharp medical device, was it a" safety design" with a shielded, recessed, retractable, or blunted needle or blade?
☐ 1 Yes ☐ 2 No ☐ 3 Unknown

14a) Was the protective mechanism activated?
☐ 1 Yes, fully ☐ 2 Yes, partially ☐ 3 No ☐ 4 Unknown

14b) Did incident happen?
- ☐ 1 Before activation
- ☐ 2 During activation
- ☐ 3 After activation
- ☐ 4 Unknown

FIGURE 30-3, cont'd Needlestick and sharp object injury report for the OR.

Mark the location of the injury:



15) Was the injury?
- ☐ 1 Superficial *(little or no bleeding)*
- ☐ 2 Moderate *(skin punctured, some bleeding)*
- ☐ 3 Severe *(deep stick/cut, or profuse bleeding)*

16) If injury was to the hand, did the sharp item penetrate?
- ☐ 1 Single pair of gloves
- ☐ 2 Double pair of gloves
- ☐ 3 No gloves

17) Dominant hand of the injured worker:
- ☐ 1 Right-handed
- ☐ 2 Left-handed

18) Describe the circumstances leading to this injury *(please note if a device malfunction was involved)*:

_____
_____
_____
_____
_____
_____

Cost:

Lab charges (Hb, HCV, HIV, other)
_____ Healthcare worker
_____ Source
Treatment prophylaxis (HBIG, Hb vaccine, tetanus, other)
_____ Healthcare worker
_____ Source
_____ **Service charges** (Emergency Dept, Employee Health, other)
_____ **Other costs** (Worker's Comp, surgery, other)
_____ **TOTAL** (round to nearest dollar)

Is this incident OSHA reportable?
☐ 1 Yes ☐ 2 No ☐ 3 Unknown
If yes, days away from work? _____
Days of restricted work activity? _____

Does this incident meet the FDA medical device reporting criteria? (Yes if a device defect caused serious injury necessitating medical or surgical intervention, or death occurred within 10 works days of incident.)
☐ 1 Yes *(If yes, follow FDA reporting protocol.)* ☐ 2 No

* Tubex™ is a trademark of Wyeth Ayers; Carpuject™ is a trademark of Sanofi Winthrop; VACUTAINER™ is a trademark of Becton Dickinson. Identification of these products does not imply endorsement of these specific brands.

FIGURE 30-3, cont'd Needlestick and sharp object injury report for the OR.

Blood and Body Fluid Exposure Report/OR

EPINet™ FOR MICROSOFT® ACCESS
EXPOSURE PREVENTION ▶ INFORMATION NETWORK ▶

EPINet is a trademark of the University of Virginia.
Windows is a registered trademark of Microsoft Corporation in the United States and/or other countries.
Operates in Windows 95 and Windows 98 Environments.
© 2000 Becton, Dickinson and Company.
V1.2/US OR, L&D 1/2002

Last Name: _____ First Name: _____

Exposure ID: *(for office use only)* B_____ Facility ID: *(for office use only)* _____

1) Date of exposure: ☐☐ ☐☐ ☐☐☐☐ **2) Time of exposure:** ☐☐ ☐☐

3) Surgical service: _____

☐ 1 General ☐ 6 ENT ☐ 11 Transplants
☐ 2 Cardiovascular ☐ 7 Neurosurgery ☐ 12 Ophthalmology
☐ 3 OB/C-Section ☐ 8 Plastic ☐ 13 Thoracic
☐ 4 Gynecology ☐ 9 Urology
☐ 5 Orthopedic ☐ 10 Oral/Dental ☐ 99 Other service, describe: _____

4) Surgical procedure being performed: _____

4a) Was it an endoscopic/laparoscopic procedure?
☐ 1 Yes ☐ 2 No ☐ 3 Unknown ☐ 4 Not Applicable

5) What is the job category of the injured worker: (check one box only)
☐ 1 Surgeon *(attending)* specify specialty _____
☐ 2 Surgeon *(resident)* specify specialty _____
☐ 3 Ob/Gyn *(attending)*
☐ 4 Ob/Gyn *(resident)*
☐ 5 Anesthesiologist *(attending)*
☐ 6 Anesthesiologist *(resident)*
☐ 7 Nurse Anesthetist
☐ 8 Med Student, mark rotation→ ☐ surg ☐ anesth ☐ ob-gyn
☐ 9 Circulating nurse at time of incident → ☐ 1 RN ☐ 2 ORT ☐ 3 UAP
☐ 10 Scrub nurse at time of incident → ☐ 1 RN ☐ 2 ORT ☐ 3 UAP
☐ 11 Other Nurse
☐ 12 Nursing Student
☐ 13 OR Attendant
☐ 14 Housekeeper
☐ 99 Other, describe: _____

6) If the injury was sustained by an anesthesia team member, what anesthesia task was being performed at the time of injury?
Describe: _____

7) Where Did the Exposure Occur? (check one box only)
☐ 1 Pre-operative area
☐ 2 At the mayo *(instrument)* stand
☐ 3 At the back table
☐ 4 In the operative site/wound
☐ 5 On the surgical field *(near operative site)*
☐ 6 On anesthesia machine
☐ 7 On anesthesia cart
☐ 8 At patient's puncture site *(intro of vascular cath/injection,etc)*
☐ 9 At site of injection into IV equipment
☐ 10 On OR floor
☐ 11 In the OR utility room
☐ 12 Post anesthesia care unit *(recovery room)*
☐ 99 Other, describe: _____

8) Was the source patient's identity known? (check one box only)
☐ 1 Yes ☐ 2 No ☐ 3 Unknown ☐ 4 Not Applicable

9) Which body fluids were involved in the exposure? (check all that apply)
☐ Blood or blood products
☐ Vomit/gastric contents
☐ Sputum
☐ Saliva
☐ CSF
☐ Peritoneal fluid
☐ Pleural fluid
☐ Amniotic fuid
☐ Urine
☐ Other, describe: _____

Was the body fluid visibly contaminated with blood? ☐ Yes ☐ No ☐ Unknown

10) Was the exposed part: (check all that apply)
☐ Intact skin
☐ Non-intact skin
☐ Eyes *(conjunctiva)*
☐ Nose *(mucosa)*
☐ Mouth *(mucosa)*
☐ Other, describe: _____

11) Did the blood or body fluid: (check all that apply)
☐ Touch unprotected skin
☐ Touch skin between gap in protective garments
☐ Touch skin through tear in glove
☐ Soak through barrier garment or protective garment
☐ Soak through clothing/undergarments

12) Which barrier garments were worn at the time of exposure: (check all that apply)
☐ Single pair latex/vinyl gloves
☐ Double pair latex/vinyl gloves
☐ Goggles
☐ Eyeglasses *(not a protective item)*
☐ Eyeglasses with side shields
☐ Face shield
☐ Surgical mask
☐ Surgical mask with attached eyeshield
☐ Surgical gown, disposable
☐ Surgical gown, reusable
☐ Other, describe: _____

12a) If surgical gown, was it?
☐ 1 Fabric, standard single layer
☐ 2 Fabric, reinforced
☐ 3 Plastic, reinforced/coated
☐ 4 Composite construction *(multi-layer laminate)*

FIGURE 30-4 Blood and body fluid exposure report for the OR.

13) Was the exposure the result of: (check one box only)

- ☐ 1 Direct patient contact
- ☐ 2 Touched contaminated equipment/surface
- ☐ 3 Touched contaminated drapes/sheets/gowns, etc.
- ☐ 4 Specimen container leaked/spilled/broke
- ☐ 5 Tubing *(blood,suction,drain,etc.)* leaked/disconnected/broke
- ☐ 6 Bag/pump leaked/spilled/broke
- ☐ 7 Trach/NG tubing broke/sprayed
- ☐ 8 Suction canister spilled/leaked/broke
- ☐ 9 Other irrigation/fluid container spilled/leaked/broke
- ☐ 10 Other equipment/operator failure
- ☐ 11 Unknown
- ☐ 99 Other, describe: _____

If equipment failure, please specify: **Equipment type**: _____

Manufacturer: _____

14) For how long was the blood or body fluid in contact with your skin or mucous membranes? (check one)

- ☐ 1 Less than 5 minutes
- ☐ 2 5-14 minutes
- ☐ 3 15 minutes to 1 hour
- ☐ 4 More than 1 hour

15) How much blood/body fluid came in contact with your skin or mucous membranes? (check one)

- ☐ 1 Small amount (up to 5 cc, or up to 1 teaspoon)
- ☐ 2 Moderate amount (up to 50 cc, or up to quarter cup)
- ☐ 3 Large amount (more than 50 cc)

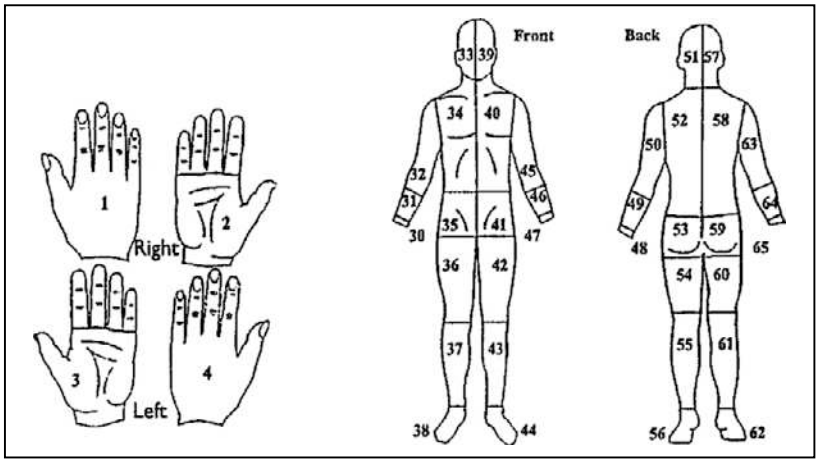
16) Location of the exposure:

Write the number of the location of up to three exposed body parts in the blanks below.

Largest area of exposure: _____

Middle area of exposure: _____

Smallest area of exposure: _____



17) Describe the circumstances leading to this exposure *(please note if a device malfunction was involved)*:

_____
_____
_____
_____
_____
_____
_____
_____

Cost:

_____ **Lab charges** *(Hb, HCV, HIV, other tests)*
_____ Healthcare worker
_____ Source
_____ **Treatment prophylaxis** *(HBIG, Hb vaccine, tetanus, other)*
_____ Healthcare worker
_____ Source
_____ **Service charges** *(Emergency Dept, Employee Health, other)*
_____ **Other costs** *(Worker's Comp, surgery, other)*
_____ **TOTAL** *(round to nearest dollar)*

Is this incident OSHA reportable? ☐ 1 Yes ☐ 2 No ☐ 3 Unknown

If yes, days away from work? _____

Days of restricted work activity? _____

Does this incident meet the FDA medical device reporting criteria? (Yes if a device defect caused serious injury necessitating medical or surgical intervention, or death occurred within 10 works days of incident.)

☐ 1 Yes (If yes, follow FDA reporting protocol) ☐ 2 No

FIGURE 30-4, cont'd Blood and body fluid exposure report for the OR.

tubes, which can allow WAGs to escape into the ambient OR air (OSHA, 2000).

PACU personnel are exposed to WAGs from patients who have received anesthetics and then are admitted to the PACU or another postanesthesia recovery area. These postoperative patients eliminate anesthetics through their respiratory tracts by simply exhaling. Because of PACU nurses' close proximity (i.e., in the nurses' breathing zone) to their patients while providing monitoring, they are being exposed to varying concentrations of anesthetic agents (OSHA, 2000). In contrast to the OR, ambient air in the PACU may contain multiple WAGs, which include nitrous oxide, halothane, enflurane, isoflurane, desflurane, and sevoflurane (OSHA, 2000). Detection of the levels of WAGs without monitoring air samples in the breathing zone is very deceiving because one study found that less than 50% of the population were able to detect the presence of halothane until the concentrations were above 125 times the NIOSH-recommended exposure limit (OSHA, 2000).

Exposure to high concentrations of waste anesthetic gases can result in headaches, fatigue, irritability, nausea, drowsiness, liver and kidney disease, and difficulties with judgment and coordination (CDC, NIOSH, 2007). Some studies show that long-term exposure to low concentrations of WAGs appears to have no adverse health effects, while other studies have shown links to miscarriage, genetic damage, and cancer for perioperative personnel (and their spouses), with further links to birth defects in their children (CDC, NIOSH, 2007). In light of these latter studies, responsible approaches to limit exposure to WAGs are needed (OSHA, 2000).

A list of strategies designed to help healthcare workers reduce their exposure to WAGs is presented in the Risk Reduction Strategies box.

CHEMICALS

Chemicals are used in OR settings for many purposes, including sterilization and disinfection of equipment, cleaning, specimen preservation, and anesthesia. Some commonly used chemicals found in ORs include ethylene oxide, aqueous glutaraldehyde, formalin, formaldehyde, peracetic acid, and methyl methacrylate. Exposure to chemicals can occur through several routes. Toxic exposure effects can be limited to the site of exposure or result in a systemic effect. The following are the three main routes of exposure to toxic chemicals (OSHA, 2005):

1. *Inhalation* is the introduction of toxic chemicals, radioisotopes, or pathogens via the respiratory tract. Gases or vapors of volatile liquids are the most commonly inhaled chemicals, although it is possible to inhale chemicals as aerosols or dusts. Chemical agents inhaled are generally quickly absorbed because of the vascularity and large surface area of lungs, with symptoms of exposure manifesting within 1 to 3 days after exposure.
2. *Skin contact or absorption through mucous membranes* is slower than inhalation. Mucous membranes include mouth, eyes, and nose. Nonintact skin integrity can also lead to exposures.
3. *Ingestion* is the least common route of exposure. Ingestion may be the result of unintentional exposures from the hand (including nail biting) or mouth, such as swallowing saliva containing trapped airborne particles.

The amount of chemical absorbed by the body can vary, depending on duration of exposure, concentration of the chemical, time of exposure, and environmental factors (OSHA, 2005). Toxicity can be acute or chronic. Acute toxicity usually results from an accidental spill of a chemical substance. Exposure is sudden and results in an emergency. Chronic toxicity results from repeated exposure to low levels of the chemical over a prolonged period (CDC, 2008a).

Exposure limits for many chemicals used in healthcare help to provide a safe environment. Exposure limits published by OSHA are the only legally recognized regulatory limits (CDC, 2008a). OSHA defines a permissible exposure limit (PEL) as the amount of exposure to a chemical permitted as a time-weighted average (TWA), based on an average concentration for an 8-hour workday and a 40-hour workweek, to which workers can be repeatedly exposed without adverse health effects (CDC, 2008a). Recommended exposure limits

RISK REDUCTION STRATEGIES

Steps to Reduce Exposure to Waste Anesthetic Gases (WAGs) before Beginning Anesthesia

- Inspect the anesthetic delivery system before each use, looking for irregularities or breaks in the system.
- Check the patient's breathing circuit for negative-pressure and positive-pressure relief as part of daily machine checklist.
- Activate the room or local ventilation system.
- Ensure scavenging equipment is properly connected.
- Connect the gas outlet to central scavenging system.
- Start the gas flow after the laryngeal mask or endotracheal tube is in place.
- Fill vaporizers under a ceiling-mounted hood with an active evacuation system before or after the procedure.
- Be certain that uncuffed endotracheal tubes create a completely sealed airway.
- Use the lowest anesthetic gas flow rates possible for proper functioning of the anesthesia delivery system and for patient safety.
- Avoid very high anesthetic gas flow rates to prevent leaks because high flow rates generate more waste anesthetic gases than low flow rates.
- Do not deliver anesthetic by open-drop method (i.e., dripping liquid, volatile anesthetic onto gauze).
- Make sure the mask, if used, fits the patient well. Have several sizes available to select the proper-fitting mask for the patient.
- Before disconnecting a patient from a breathing system, eliminate residual gases through the scavenging system as much as possible.
- Turn the gas off first before turning off the breathing system.

Adapted from CDC, NIOSH: *Waste anesthetic gases: occupational hazards in hospitals,* Publication No. 2007-151, Cincinnati, 2007, Author.

(RELs) are occupational exposure limits developed and recommended by NIOSH, providing protection over a working lifetime. NIOSH uses a TWA for up to a 10-hour workday during a 40-hour workweek (CDC, NIOSH, 2005). A short-term exposure limit (STEL) is a designated value that should not be exceeded anytime during the workday, based on a 15-minute TWA (CDC, NIOSH, 2005). For example, for glutaraldehyde, the NIOSH REL is 0.2 parts per million, with an OSHA PEL of zero (CDC, NIOSH, 2005).

Responsibility to inform workers about chemical hazards and to use control measures, including providing PPE, rests with the employer. The OSHA Hazard Communication Standard (29 CFR 1910.1200, 1915.99, 1917.28, 1918.90, 1926.59, and 1928.21) requires all manufacturers and importers of hazardous chemicals to develop Material Safety Data Sheets (MSDSs) for all chemicals and mixtures of chemicals (OSHA, 2009). Employers must make these data sheets readily available to all employees who work with the products to which they could be exposed (CDC, 2008a).

The purpose of the OSHA Standards is to ensure that all hazards of chemicals produced or imported are evaluated and that information concerning hazards is transmitted to employers and employees. This transmittal must be accomplished by comprehensive hazard communication programs that must include container labeling and other forms of warning, MSDSs, and employee training (OSHA, 2009). MSDSs initially were written as tools for workers with health and safety roles in the chemical industry. With the expansion of the federal and state right-to-know regulations, however, the need for information on the MSDSs expanded to the healthcare industry.

A typical MSDS includes the following sections:

- Material identity, including chemical and common names
- Hazardous ingredients
- Cancer-causing ingredients
- List of physical and chemical hazards and characteristics
- List of health hazards, including acute and chronic effects
- Whether the material is listed as a carcinogen by OSHA, the International Agency for Research on Cancer, or the National Toxicology Program
- Limits to which a worker can be exposed
- Routes of entry
- Specific target organs likely to be damaged with exposure, and medical problems exacerbated by exposure
- Precautions and safety equipment
- Emergency and first aid procedures
- Firefighting information
- Procedures for cleanup of leaks and spills
- Safe handling precautions
- Identity of the organization responsible for the MSDS, date of issue, and emergency phone number

An additional source of information about chemical exposures is the *NIOSH Pocket Guide to Chemical Hazards,* which offers useful information about several hundred chemicals. This guide, Publication No. 2005-149 (CDC, NIOSH, 2005), can also be found at www.cdc.gov/niosh/npg/.

It is important that healthcare workers are aware of chemicals they are exposed to in their work settings and take necessary precautions to use PPE and other means to eliminate or reduce their occupational risks. Measures may include attending training provided by the employer and being familiar with information about occupational exposures, such as the chemicals inventoried on their work unit. These inventories should be located on each unit and be easily accessible.

Another form of chemical exposure in perioperative settings is exposure to hazardous drugs. Hazardous drugs are defined by NIOSH using the definition developed in 1990 by the American Society of Hospital Pharmacists as meeting one or more of the following characteristics in humans or animals (CDC, NIOSH, 2004):

- Carcinogenicity
- Teratogenicity or other developmental toxicity
- Reproductive toxicity
- Organ toxicity at low doses
- Genotoxicity
- Structure and toxicity profiles of new drugs that mimic existing drugs determined hazardous by the above criteria

Exposure can result from handling of hazardous drugs as well as working near the sites where they are used. The drugs can be in the air, on surfaces in the work area, on medical equipment, or in the urine or feces of patients. Healthcare workers functioning with or near hazardous drugs can experience skin rashes, infertility, miscarriages, birth defects of offspring, and cancers such as leukemia (CDC, NIOSH, 2004). Currently, no NIOSH REL or OSHA PEL is established for hazardous drugs; however, there are OSHA guidelines, Environmental Protection Agency (EPA) regulations, and CDC and National Institutes of Health (NIH) guidelines (CDC, NIOSH, 2004). Work practices and training are important to minimize occupational risks of hazardous drug exposure.

Related to hazardous drug exposure and chemical risk are reproductive hazards found in perioperative patient care settings, with implications for both males and females. Occupational exposure to reproductive hazards can result in effects before or after conception, with different outcomes. Before conception, exposure effects include reduced fertility, unsuccessful fertilization, implantation problems, fetal abnormality, reduced libido, or menstrual dysfunction. Maternal exposure can result in low-birth-weight infants, birth defects, developmental difficulties, behavioral difficulties, cancer, or even fetal demise (OSHA, 2008d). Male workers who suffer workplace exposure can introduce harm to a woman's reproductive system and offspring (OSHA, 2008d). Awareness of reproductive hazards, prevention strategies, and work practices to minimize risks is instrumental in dealing with reproductive hazards in the workplace.

Currently, there are also new bioengineered drugs that target specific locations in the human body. These are evolving and potentially creating new hazardous risks to healthcare workers.

As healthcare facilities become more environmentally sensitive, they take more steps to reduce chemical exposures by eliminating or reducing the use of chemicals, seeking safer alternatives for substances such as cleaning agents, using engineering controls such as ventilation, and using chemical storage to isolate chemicals (Health Care Without Harm [HCWH], 2006).

UNIVERSAL AND STANDARD PRECAUTIONS

Universal Precautions

In 1985, in response to growing numbers of individuals testing positive for HIV, the CDC published a set of recommendations for the use of *Universal Precautions*. Reports of hospital

personnel becoming infected with HIV after a needlestick or skin exposure to a patient's blood created an urgent need for new and better measures to protect personnel. Recognizing that many patients with bloodborne infections are undiagnosed, the CDC's Universal Precautions, for the first time, applied Blood and Body Fluid Precautions (one of the categories in the later 1993 *Guidelines for Isolation Precautions in Hospitals*) to all individuals, regardless of infection status (CDC, 1996). Universal Precautions expanded the Blood and Body Fluid Precautions by recommending masks and eye protection to prevent mucous membrane exposure, in addition to routine use of barrier protection, such as gowns and gloves. Universal Precautions also emphasized prevention of needlestick injuries and use of ventilation devices during resuscitation.

The CDC continued to recommend Universal Precautions until 1987, when a new system of isolation called *Body Substance Isolation* (BSI) was proposed. BSI directed isolation of *all* moist and potentially infectious body substances (i.e., blood, feces, urine, sputum, saliva, wound drainage, and other body fluids) for all individuals, regardless of their infection status. This was accomplished primarily with the use of gowns and gloves. With multiple similarities and differences between Universal Precautions and BSI isolation, confusion reigned.

Standard Precautions

By the early 1990s the controversy regarding Universal Precautions and BSI had escalated. There was considerable confusion about which body fluids required special care under either Universal Precautions or Body Substance Isolation. There were also concerns about the need for additional precautions to prevent airborne, droplet, and contact transmission of other infectious agents. With this need in mind, the CDC developed a single set of precautions incorporating the major features of Universal Precautions and BSI (CDC, 1996). These precautions became *Standard Precautions,* designed to reduce the transmission risk of bloodborne and other pathogens. Additional precautions, based on routes of transmission for patients known or suspected to be infected or colonized with highly transmissible or epidemiologically significant pathogens, are included in the CDC document.

Standard Precautions aim to reduce transmission of microorganisms from recognized and unrecognized sources of infection. Standard Precautions should be applied to all patients receiving care, regardless of their diagnosis or presumed infection status. They are considered the first, and most important, tier of precautions; as such, they are a primary strategy for successful infection prevention and control. Standard Precautions apply to: (1) blood; (2) all body fluids, secretions, and excretions (except sweat), regardless of whether they contain visible blood; (3) mucous membranes; and (4) nonintact skin. Perioperative personnel historically have relied on numerous types of precautions to protect themselves and others from bloodborne pathogens and other infectious diseases (History box). Consistent application of these precautions and frequent handwashing by all members of the perioperative team serve to protect the healthcare provider and to minimize cross-infection of pathogens among patients (Research Highlight) (Refer to Chapter 3 for further discussion of Standard- and Transmission-Based Precautions).

HISTORY

The Origins of Hand Hygiene

While handwashing with soap and water has been a measure of personal hygiene for generations, the concept of cleansing hands with an antiseptic agent probably did not emerge until the nineteenth century. In 1846 Ignaz Semmelweis observed that women whose babies were delivered by students and physicians in the First Clinic at the General Hospital of Vienna consistently had a higher death rate than those whose babies were delivered by midwives in the Second Clinic. He noted that physicians who went directly from the autopsy suite to the obstetrics ward had a disagreeable odor on their hands, despite washing their hands with soap and water upon entering the obstetrics clinic. Semmelweis postulated that the puerperal fever that affected so many parturient women was caused by "cadaverous particles" transmitted from the autopsy suite to the obstetrics wards via the hands of students and physicians. In 1847 he insisted that students and physicians clean their hands with a chlorine solution between the treatment of each patient in the clinic. The maternal death rate in the First Clinic subsequently dropped dramatically and remained low for years (Boyce and Pittet, 2002).

Today, hand hygiene remains the most important factor in preventing the spread of infection. Many studies have shown that bacteria that cause healthcare-associated infections (HAIs) (formerly referred to as "nosocomial" or "hospital-acquired") are most frequently spread from one patient to another on the hands of healthcare workers. The most common infections are caused by staphylococci and multidrug-resistant pathogens, such as MRSA (methicillin-resistant *Staphylococcus aureus*), VRE (vancomycin-resistant *Enterococcus*), and resistant gram-negative rods. Nearly 20,000 patients die each year as a direct result of these infections. Patients may become ill with bloodstream infections, surgical site infections, urinary tract infections, and pneumonia. Nurses and other healthcare workers are exposed to bacteria by doing simple tasks such as moving patients in bed, measuring a blood pressure or pulse rate, or simply touching equipment.

Hands must be washed whenever they contact blood, body fluids, secretions, excretions, and contaminated items, whether or not gloves are worn. Hands are washed immediately after gloves are removed, between patient contacts, and when otherwise indicated to avoid transfer of microorganisms to other patients or environments. Sometimes it is necessary to wash hands between tasks and procedures on the same patient to prevent cross-contamination of different body sites. A plain (nonantimicrobial) soap should be used for routine handwashing. When special circumstances such as hyperendemic conditions occur, an antimicrobial soap or antiseptic hand rub (waterless antiseptic agent) should be used. Hand rub antiseptic agents are most effective when hands are clean before agents are applied. For effectiveness, a sufficient amount of the agent must be used in accordance with manufacturers' written instructions.

Adapted from Boyce JM, Pittet D: Guidelines for hand hygiene in health-care settings, *Morbid Mortal Wkly Rep MMWR* 55:1-44, Oct 25, 2002, available at www.cdc.gov/mmwr/preview/mmwrhtml/rr5116a1.htm. Accessed May 27, 2009; Hand Hygiene Resource Center: *Hand hygiene: frequently asked questions (FAQs),* 2009, available at www.handhygiene.org/. Accessed May 28, 2009.

RESEARCH HIGHLIGHT

Use of a Hand Hygiene Device

Hand hygiene is perhaps the single most important strategy to reduce healthcare-associated infections (HAIs), but compliance remains low. Researchers in this study from Dartmouth-Hitchcock Medical Center hypothesized that improvements in compliance with intraoperative hand hygiene would reduce transmission of bacteria to surgical patients and reduce the incidence of HAIs. To test their hypothesis, researchers used the Sprixx GJ device (Harbor Medical Inc., Santa Barbara, Calif)—a personal alcohol-based sanitizer dispenser with tracking electronics that prompted anesthesia providers to perform hand hygiene every 6 minutes and documented its use. The device is clipped to clothing and is operated with one hand.

Use of the device reduced bacterial contamination in the anesthesia workspace and on peripheral intravenous tubing. HAIs were reduced from 17.2% (control group) to 3.8% (device group). Intravenous tubing contamination was identified in 32.8% of cases in the control group and 7.5% in the device group. There were no significant differences in risk factors between groups. The researchers therefore concluded that improved hand hygiene compliance in the OR through the use of a hand sanitation strategy reduces the risk of intraoperative bacterial transmission and HAIs.

Adapted from Koff MD et al: Reduction in intraoperative bacterial contamination of peripheral intravenous tubing through the use of a novel device, *Anesthesiology* 110:978-985, 2009.

IMMUNIZATIONS AND INFECTIOUS DISEASE EXPOSURE

Contact with infected patients or infectious material puts healthcare workers at risk for occupational-acquired infection. Hospital-acquired and healthcare-associated transmission of disease is well documented (CDC, 1997). Many diseases and infections can be prevented through immunizations and vaccines. It is therefore essential for nurses and other healthcare workers to prevent infections by establishing and maintaining their immunity in cooperation with their employers. Healthcare organizations providing direct patient care should develop a comprehensive immunization program for workers. Healthcare workers are found to be at risk for acquiring or transmitting HBV, influenza, measles, mumps, rubella, varicella (CDC, 1997), and pertussis (CDC, 2006b).

HBV is a major infectious risk for healthcare workers as a result of percutaneous and permucosal exposure to blood or other potentially infectious material (CDC, 1997). Through a joint advisory notice in 1987, the Departments of Labor and Health and Human Services initiated rulemaking to regulate exposure to HBV. The resulting federal standard issued in December 1991 mandated that hepatitis B vaccine be made available at the employer's expense to all healthcare workers occupationally exposed to blood or other potentially infectious materials (CDC, 1997). It is important for healthcare workers to have a hepatitis B antibody titer to evaluate their immune response to a vaccine series. Once immunity is documented, there is no need for booster doses even if titer levels drop.

Seasonal influenza and its complications are responsible for more than 36,000 deaths and more than 200,000 hospitalizations each year (ANA, 2008a). Despite the well-documented seriousness of seasonal influenza cases, according to the CDC less than 50% of healthcare workers are vaccinated annually (ANA, 2008a). Influenza has been transmitted to healthcare workers from patients, and healthcare workers who are clinically or subclinically infected with influenza can transmit seasonal influenza to patients or others (CDC, 2006a). Studies have demonstrated seasonal influenza antibodies in healthcare workers who did not recall even having a respiratory tract infection. By receiving the seasonal influenza vaccination, healthcare workers protect themselves, their patients, and their families.

Inactivated influenza vaccine and live attenuated influenza vaccine (LAIV) are currently available for workers in the healthcare professions. LAIV is approved only for nonpregnant healthy persons ages 5 to 49 years (CDC, 2006a). Healthcare workers caring for severely immunocompromised patients should not receive LAIV. Instead, the inactivated influenza vaccine is the preferred vaccine when workers come in direct contact with this group of patients (CDC, 2006a). Workers can secure guidance on which vaccine to take from their occupational or employee health department.

In January 2007 The Joint Commission (TJC) issued a standard requiring accredited organizations to offer influenza vaccinations to staff, including volunteers and licensed independent practitioners with close patient contact (ANA, 2008a). Accredited organizations are required to establish annual immunization programs to educate employees about influenza and offer the vaccine on site (ANA, 2008a).

Healthcare-associated infections (HAIs) with measles, mumps, and rubella have all been documented. The risk for measles infection in healthcare workers is estimated to be 13 times greater than that for the general population (CDC, 1997). Previously, birth before 1957 was considered acceptable evidence of measles immunity. However, serologic studies of healthcare workers have discovered that 5% to 9% of those born before 1957 are not immune to measles (CDC, 1997).

Healthcare-associated infections from varicella zoster virus (VZV) have also been well documented. Patients who are at increased risk for varicella infection are pregnant women; premature infants born to susceptible mothers; infants born at less than 28 weeks' gestation or who weigh less than 1000 grams, regardless of maternal immune status; and immunocompromised persons of all ages (including persons who are undergoing immunosuppressive therapy, have malignant disease, or are immunodeficient) (CDC, 1997). Sources of healthcare-associated varicella infection include patients, hospital employees, and hospital visitors who are infected with either varicella or zoster (CDC, 1997).

Generally, a reliable history of chickenpox is a valid measure of VZV immunity. That reliability was serologically tested, and it was found that, among adults, 97% to 99% of persons with a positive history of varicella were seropositive (CDC, 1997). In addition, adults with negative or uncertain histories are seropositive (range: 71% to 93%) (CDC, 1997). Serologic testing of healthcare workers with a negative or unknown history of varicella has been shown to be cost-effective (CDC, 1997).

Recent increases in rates of pertussis (an acute, infectious cough illness) among healthcare workers led to a recommendation in 2006 that they receive one dose of tetanus, diphtheria, and pertussis (Tdap) (CDC, 2006b). Pertussis rates among healthcare workers were found to be nearly double those in the general population in a Canadian study (CDC, 2006b).

Immunity to pertussis wanes 5 to 10 years after childhood immunization, leading to susceptibility to pertussis among adults (CDC, 2006b). Costs for an outbreak and exposure investigation in a healthcare setting are estimated to be from $74,870 to $174,327 per outbreak (CDC, 2006b). The recommended schedule of Tdap is one single dose to replace one dose of Td for active boosting of tetanus, diphtheria, and pertussis if the worker received the last dose of Td more than 10 years earlier, with additional doses being received every 10 years (CDC, 2006b). A healthcare worker who has not had a previous dose of Tdap may receive a dose 2 years from the last dose of Td or as soon as feasible (CDC, 2006b).

Routine immunization of healthcare workers against tuberculosis, HAV, meningococcal disease, typhoid fever, or vaccinia is not currently recommended by the Advisory Committee on Immunization Practices (CDC, 1997). However, based on job responsibilities and risks at the employer's facility, other immunizations may be recommended or required. There is currently no vaccination for HCV. It remains imperative that healthcare workers follow recommended bloodborne pathogen precautions.

Should an exposure to an infectious or communicable disease occur in the clinical area, chemoprophylaxis may be available. Healthcare workers should report the exposure to their occupational health department or other provider according to the facility's procedures and receive proper follow-up. Infectious exposures outside the workplace should also be reported for the protection of patients and co-workers. Postexposure work restrictions may range from restricting contact with high-risk patients to furlough for healthcare workers without immunity.

Exposure of healthcare workers to diphtheria, pneumococcal disease, or tetanus is not significantly more than that of the general population; therefore healthcare professionals should elect to receive these immunizations from their primary care providers (CDC, 1997). In addition to immunization records maintained by the employer for healthcare workers, healthcare workers should also maintain accurate records of all their immunizations and exposures, including any prophylaxis or laboratory studies.

Immunizations are part of a comprehensive workplace infection control program. Guidance for development of a program is available from OSHA, CDC, and the Department of Health in the state in which the facility is located. The recommended and required vaccinations vary by state and depend on legislation at either the state or the federal level. To further evaluate compliance with recommended or required vaccinations, healthcare workers should consult with the occupational or employee health department at their workplace.

RADIATION SAFETY

Radiologic imaging studies are invaluable diagnostic and treatment tools. Radiation presents environmental safety concerns for patients and staff. Many surgical procedures use radiologic studies performed immediately before, during, or after surgery, increasing the potential for radiation exposure. X-rays of all frequencies can damage tissues and may produce long-term effects. The effects of radiation are dose-dependent and cumulative: the larger the dose or the more frequent the exposure, the greater the risk of the effects of radiation.

Sources of radiation exposure in the OR include (1) ionizing sources—portable radiography (x-ray) machines and portable fluoroscopy units (C-arm)—and (2) nonionizing sources—lasers (laser safety is discussed more extensively in Chapter 7). Ionizing radiation is used in diagnostic, interventional, and therapeutic procedures, but can damage living tissues and may produce long-term effects (AORN, 2009c). Expanding use of x-ray imaging during interventional surgery has dramatically increased exposure of many OR personnel to ionizing radiation in recent years (Chapter 28 discusses interventional radiology departments and procedures). Acute exposure to ionizing radiation can result in dermatitis and reddening of the skin (erythema) at the point of exposure, while large, full-body exposures can lead to radiation poisoning, symptoms of which may include nausea, vomiting, diarrhea, weakness, and death. Ionizing radiation at high doses may also lead to cancer and mental retardation in children of mothers exposed during pregnancy, and it has been linked to other health effects such as heart disease and stroke (ANA, 2007).

In radiation protection, the guiding philosophy is ALARA—As Low As Reasonably Achievable. Typically, reducing the patient dose also reduces the dose to healthcare workers. Therefore performing optimized procedures is an important aspect of radiation protection. Optimization includes performing only medically necessary studies and performing them sufficiently well that they do not need to be repeated (Brateman, 1999).

In diagnostic radiology, the main source of occupational dose is radiation that scatters as the x-ray beam passes through the patient, particularly from fluoroscopically guided procedures. Healthcare workers who do not protect themselves from scatter radiation are especially at risk when performing interventional procedures, given significantly increased exposure time and close proximity during the procedure (AORN, 2009c). Personnel stand near patients for long times, and angulated geometrics with C-arm equipment may result in high personnel doses from backscatter. For all procedures, time, distance, and shielding affect dose levels sustained (Brateman, 1999).

Accordingly, guidelines for radiation safety are based on the principles of time, distance, and shielding. When exposed to radiation at a constant rate, the total dose equivalent received depends on the length of time exposed. If the distance from the point source of radiation is doubled, exposure is quartered. Passage through materials also reduces the amount of radiation (AORN, 2009c).

Members of the surgical team should avoid unnecessary exposure to radiation sources and comply with practices that reduce potential exposure. Personnel present in the OR must maintain the greatest practical distance (at least 6 feet) from the radiation source or remain behind leaded shielding when ionizing radiation is used during surgery. Personnel assisting with radiologic procedures should not hold the patient manually for a study because of the risk of exposure by the direct beam (AORN, 2009c). Members of the sterile scrub team should wear protective devices and move as far from the radiation source as possible, while still adhering to aseptic technique. Nonessential personnel should leave the room.

Protective equipment reduces the intensity of radiation exposure. Radiation safety devices include mobile rigid shields on wheels; ceiling-suspended transparent barriers; flexible leaded aprons (e.g., wraparound), vests, skirts, thyroid shields,

and gloves; and leaded safety eyeglasses with side shields (AORN, 2009c). AORN recommends that personnel who may have to stand with their back to the radiation beams wear wraparound aprons to decrease their risk of exposure, and that personnel nearest to the radiation beam shield their upper chest and neck, and upper legs.

OSHA has established enforceable, health-based limits on occupational exposure to ionizing radiation and provides a series of guidelines that hospitals can use to protect staff from excess radiation exposure. OSHA also requires that employees working with radiation sources be monitored for exposures and be informed of their levels of exposure at least once a year (ANA, 2007).

OSHA also recommends that film badges or an equivalent be used for long-term monitoring. A film badge is a passive dosimeter for personal exposure monitoring that should be worn whenever an employee works with x-ray equipment, radioactive patients, or radioactive materials. Depending on the work setting, dosimeters may be worn at collar, chest, or waist level. Personnel who work in high-dose fluoroscopy settings may be asked to wear two badges for additional monitoring. Ring badges (used to measure beta and gamma doses to the hand) should be worn on the hand closest to radiation sources (OSHA, 2008a).

Leaded garments should be handled carefully and examined regularly to ensure the integrity of shielding; they should not be folded during storage, and they should undergo regular radiologic testing. Staff-development programs on radiation safety should be conducted periodically to reinforce radiation safety practices and to correct misconceptions or unrealistic practices relating to radiation exposure and monitoring.

The American College of Radiology (ACR) recommends that facilities adopt the following safety measures to protect personnel:

- Implement a radiation-exposure monitoring program, as required by the Nuclear Regulatory Commission or appropriate state agencies.
- Perform systematic inspection of interlock systems.
- Provide appropriate room shielding.
- Perform routine leak testing of all sealed sources, as required by regulatory agencies.
- Furnish appropriate safety equipment for use of sealed sources (ACR, 2004).

LATEX ALLERGY

Natural rubber latex allergy is a serious medical problem for a growing number of patients and a disabling occupational disease among healthcare workers. Latex allergy develops from exposure to natural rubber latex and plant cytosol, used extensively to manufacture medical gloves and other devices, as well as numerous consumer products. Allergic reactions to latex range from skin disease to asthma and anaphylaxis that can result in chronic illness, disability, career loss, hardship, and death (ANA, 1997).

Historically, latex has been the material of choice for surgical gloves because it is flexible and maintains tactile sensitivity for the wearer. Although natural rubber latex has been a common component in thousands of medical and consumer products for many years, latex sensitivity is a relatively new problem for patients and healthcare personnel. Clinicians were aware of contact dermatitis from chemicals in rubber as early as the 1930s; however, they did not recognize systemic allergic reactions to latex proteins until the 1970s. Latex allergy erupted in the United States shortly after the CDC introduced Universal Precautions in 1985. Today, researchers hypothesize that the latex allergy outbreak is the result of multiple factors, including increased latex exposure and deficiencies in manufacturing processes, among others. Latex allergy affects between 8% and 12% of workers in all health disciplines. However, it affects only about 1% of the general population (ANA, 1997).

Individuals can experience three types of reactions to latex. *Irritant contact dermatitis* is the most common type of reaction and is characterized by dry, reddened, itchy, or cracked hands. Irritant contact dermatitis is not a true allergic reaction. *Allergic contact dermatitis* (also called *chemical contact dermatitis*) is a delayed cell-mediated type IV localized allergy caused by chemicals used to manufacture rubber products. The most common contact sensitizers are the accelerators: thiurams, mercaptobenzothiazoles (MBTs), and carbamates (ANA, 1997). Allergic contact dermatitis is a delayed reaction, usually appearing 6 to 48 hours after exposure. Symptoms are similar to those from irritant contact dermatitis (i.e., pruritus, edema, erythema, vesicles, drying papules, crusting and thickening of the skin), except that the reaction may extend beyond the actual point of contact.

A *true latex allergy* is a type I IgE-mediated hypersensitivity reaction that involves systemic antibody formation to proteins in products made from natural rubber latex. Natural rubber latex contains up to 240 potentially allergenic protein fragments, and different persons may be sensitized to different combinations of latex allergens. Synthetic latexes are not involved in latex allergy (ANA, 1997). A true latex allergic response is immediate, IgE-mediated, and anaphylactic. The onset of anaphylactic reaction usually occurs within minutes of contact with the proteins, with symptoms that may include generalized urticaria, wheezing, dyspnea, laryngeal edema, bronchospasm, tachycardia, angioedema, hypotension, and cardiac arrest. Many serious anaphylactic reactions have occurred when a latex product (e.g., surgical gloves) directly contacts mucous membranes during surgical procedures. This situation permits a rapid introduction of latex antigen directly into the vascular circulation.

Traditionally, it was assumed that sensitization to latex resulted only from cutaneous absorption in healthcare workers or from direct mucosal contact during clinical treatment. Recent studies confirm that latex protein allergens effectively bind to glove powder and, when airborne, can remain suspended for prolonged periods. Inhalant exposure is an additional risk factor for sensitization to latex allergens.

Healthcare professionals should employ the following strategies to reduce their risk of allergic reaction to latex:

- Use powder-free gloves that are low in protein and chemical allergens (ANA, 1996).
- Use nonlatex gloves for activities that are not likely to involve contact with infectious materials (OSHA, 2008b).
- Be aware that hypoallergenic gloves do not reduce the risk of latex allergy, although they may reduce reactions to chemical additives in the latex (CDC, NIOSH, 1997).
- When wearing latex gloves, do not use oil-based hand creams or lotions, which can cause glove deterioration (ANA, 1996).

- After removing latex gloves, wash hands with a mild soap and dry thoroughly (CDC, NIOSH, 1997).
- Learn to recognize the symptoms of latex allergy, including skin rashes; urticaria; flushing; pruritus; nasal, eye, or sinus symptoms; asthma; and shock (CDC, NIOSH, 1997).

Institutions need to develop strategies for limiting healthcare workers' occupational exposure to latex. If a latex-free environment cannot be created, the goal is to create a latex-safe environment, in which all reasonable efforts are made to remove high-allergen and airborne latex sources. This includes switching to low-allergen, powder-free gloves. Cornstarch powder on powdered latex gloves is an efficient allergen carrier and contributes to airborne contamination, especially in ORs and invasive-procedure rooms where glove use is high. The use of low-allergen, powder-free gloves reduces airborne latex allergen sources to below detectable levels, reducing occupational exposure. In addition, appropriate latex-free gloves should be provided for healthcare workers with known latex sensitivity or for procedures in which patients have known sensitivity or allergy.

Box 30-4 provides valuable information on latex allergy.

WORKPLACE VIOLENCE

Violence in the workplace impacts patient care and healthcare workers and undermines a culture of safety. The Occupational Safety and Health Act of 1970 assures every working person a safe and healthful workplace, free from recognized hazards that may cause death or serious physical harm. NIOSH and OSHA define *workplace violence* as any physical assault, threatening behavior, or verbal abuse occurring in the workplace (ANA, 2006). The World Health Organization (WHO) defines workplace violence as the intentional use of power, threatened or actual, against another person or group in work-related circumstances that either results in or has a substantial likelihood to result in injury, death, psychologic harm, maldevelopment, or deprivation (WHO, 2002).

The U.S. Bureau of Labor Statistics reported in 2007 there were 27.3 assaults and violent acts per 10,000 full-time workers in the healthcare sector (U.S. Bureau of Labor Statistics, 2009). In 2006 the healthcare sector led all other industries in workplace violence, with 45% of all nonfatal assaults against workers resulting in lost workdays in the United States (U.S. Bureau of Labor Statistics, 2007). OSHA has no federal standard on workplace violence (ANA, 2006).

Workplace violence can occur in various forms, from bullying and verbal abuse to physical abuse and even homicide. Patients are the main perpetrators of physical violence, while staff are the main perpetrators of psychologic violence (ICN, 2007).

Prevention of workplace violence can best be accomplished after conducting an analysis of workplace risk factors and incidence rates at the facility. Risk factors and solutions include environmental, work-practice, and training solutions (ANA, 2006). Environmental risk factors include the availability of guns or other weapons among patients and visitors; presence of mentally ill patients with little or no follow-up care; availability of medications or money; unrestricted movement of the general public throughout facilities; presence of gang members, drug or alcohol abusers, trauma patients, or distraught family members; and poorly lit parking areas (ANA, 2006). Work practices contributing to workplace violence include long waits in emergency or clinic areas; low staffing levels; isolated work with patients during examinations or treatment; and lack of staff training in recognizing and managing aggressive behavior (ANA, 2006). Victims are often untrained or newly hired staff nurses (ANA, 2006). Perpetrators often have a history of violent behavior and have been diagnosed with psychosis, substance abuse disorders, or dementia (ANA, 2006).

Workplace violence can be prevented and is never acceptable. Environmental solutions include controlled access doors, metal detectors, alarm systems, panic buttons, handheld noise devices, and cell phones; lockable staff areas, such as lounges and bathrooms; curved mirrors and adequate lighting; and well-lit parking areas (ANA, 2006). Work practices that help prevent workplace violence include identification of high-risk patients, including flagging charts, both hard copy and electronic; proper training of staff; avoidance of employees working alone, particularly in secluded areas; easy and effective processes for reporting suspicious behavior, harassment, threats, or violent assaults; careful supervision of the movement of psychiatric patients within the facility; and use of a team approach to prevent workplace violence (ANA, 2006). Training should include review of prevention policies, reporting procedures, support systems, and action plans; identification of risk factors that cause or contribute to violence; early identification of warning signs of escalating behavior; tools for diffusing violent situations; and review of system and policy failures (ANA, 2006).

Workplace bullying, which is now increasing in healthcare settings, is another form of workplace violence. The International Labour Organization (ILO) defines *bullying* as offensive behavior through vindictive, cruel, malicious, or humiliating attempts to undermine individuals or groups of employees (International Centre for Human Resources in Nursing [ICHRN], 2009). Colleagues, employers, management, patients, patients' families, or visitors can be responsible for bullying in the healthcare setting. Behaviors can be exhibited as sadistic or aggressive behavior over time; exclusion from meetings; reduced opportunities for advancement; humiliation; ridicule; private or public unwarranted criticism; changing work responsibilities unreasonably or without justification; deliberately withholding information to affect work performance; punishing others for being competent; and overworking or overloading to punish (ICHRN, 2009).

Harmful effects of bullying include a decline in the quality of patient care delivery; poor staff relations; low morale; increase in stress and stress-related illness; feelings of shock, disbelief, shame, guilt, anger, fear, and powerlessness; depression; self-blame with decreased self-confidence that can endanger patients; sleeplessness and loss of appetite; increased cost to employers and the healthcare system; increased absenteeism and use of sick time; poor performance; reduced productivity; loss of creative problem-solving capacity; and attrition (ICHRN, 2009).

Bullying risk factors in the workplace include stress, tension, and frustration; poor management skills; inadequate or absent policies; lack of training to recognize or cope with bullying; shift work and demanding workloads; working alone (ICHRN, 2009); and lack of reporting systems or punishment of perpetrators (Hughes, 2008).

BOX 30-4

Latex Allergy

Latex allergy is an immunoglobulin E (IgE)-mediated reaction to proteins retained in finished natural rubber latex products.

ETIOLOGY AND INCIDENCE

Latex is the milky sap of the rubber tree *Hevea brasiliensis*. This natural rubber product contains proteins. Latex allergy is the reaction to certain proteins in the latex rubber. These allergies emerged in the 1990s as one of the most pervasive problems in healthcare. It remains a serious and growing problem, and healthcare workers are at increasing risk to acquire latex allergies. It is currently estimated that an allergy caused by repeated exposure to latex protein allergens develops in approximately 1 in 10 healthcare professionals; indeed, 53% of healthcare workers reported some reaction to latex gloves when surveyed. Children with spina bifida and individuals with chronic illnesses who require frequent operations are especially susceptible to latex allergy.

PATHOPHYSIOLOGY

The amount of latex exposure necessary to produce sensitization or an allergic reaction is unknown. Increasing exposure to latex proteins increases the risk of developing allergic symptoms. Although latex-containing products have only 2% to 3% protein, this protein is thought to be the allergen in type I hypersensitive individuals. The precise protein responsible for causing allergic contact dermatitis latex type I hypersensitivity remains unknown and may differ among individuals.

RISK FACTORS BY OCCUPATIONAL STATUS

- Healthcare professionals: surgery personnel, emergency care workers, and obstetrics workers are at highest risk
- Children with spina bifida or others with conditions requiring frequent operations
- Persons with congenital urogenital abnormalities requiring indwelling catheters
- Employees in the rubber industry
- Persons with history of other IgE-dependent allergies (e.g., rhinitis, asthma, or food allergies) with a positive skin test

CLINICAL MANIFESTATIONS

Clinical signs include local skin redness, dryness, and itching after contact with latex. Inhalation of particles results in respiratory symptoms, such as rhinitis, sneezing, itchy eyes, scratchy throat, or asthma. More severe manifestations include anaphylaxis with bronchospasm, laryngeal edema, respiratory distress, or respiratory failure.

COMPLICATIONS

Complications may include anaphylactic shock, and respiratory and cardiac arrest leading to death.

DIAGNOSTIC TESTS

History

Diagnostic significance in an individual's history includes atopic history, hives under rubber or latex gloves, hand dermatitis related to gloves, allergic conjunctivitis after rubbing eyes following hand contact with latex, swelling around mouth after dental procedures or inflation of a balloon, and vaginal burning after pelvic examination or contact with latex condom.

Immunologic Evaluation

Immunologic evaluation comprises skin prick, intradermal, and patch contact skin tests and serologic testing (e.g., radioallergosorbent test [RAST] or enzyme-linked immunosorbent assay [ELISA]). The FDA has approved a standardized latex reagent for skin testing for research only, not for public use.

THERAPEUTIC MANAGEMENT

Medications

Medications include epinephrine for reaction (may be autoinjector and carried by individual), β-agonist inhaler, prednisone, and other anaphylactic life-supporting medications.

General

Immediate assessment and interventions for acute reaction include cardiac monitoring and, if needed, respiratory support.

Prevention and Promotion

For latex-sensitive individuals:

- Avoid latex products.
- Avoid environments with high levels of circulating aeroallergens (e.g., ORs, ERs, blood banks).
- Wear MedicAlert bracelet or tag.
- Carry autoinjector for use at first signs of anaphylaxis.

To address this serious issue, on January 1, 2009, TJC instituted a new leadership standard (LC.03.01.01) that addresses disruptive and inappropriate behaviors (Hughes, 2008). Hospitals and organizations are required to have a code of conduct defining acceptable and disruptive or inappropriate behaviors (Hughes, 2008). Under this standard, leaders are expected to create and implement a process for managing disruptive and inappropriate behaviors (Hughes, 2008).

Workplace violence in any form negatively impacts healthcare workers and patients. It harms workers professionally and personally, and it alters the quality of care provided to patients. The perioperative area is not excluded from the impact or incidence of workplace violence. Nurses and other healthcare workers in this setting must be educated and trained to recognize workplace violence in all forms, including lateral violence (violence between co-workers), in order to create a safe working environment that promotes teamwork and collaboration in the perioperative setting (Research Highlight).

RESEARCH HIGHLIGHT

Measuring Teamwork in the OR

Teamwork is a major component of OR efficiency, quality of care, and patient safety. The Joint Commission has reported breakdowns in communication as a leading cause of adverse events and errors. While surgical departments across the United States work on initiatives to prevent negative outcomes, they seek reliable tools to measure improvements in OR teamwork that demonstrate that their initiatives are effective. The goals of this study were to test the reliability and validity of a teamwork climate scale in the OR and to provide benchmarking information on OR teamwork climate by hospital and caregiver type. The researchers designed a Safety Attitudes Questionnaire and administered it to OR personnel in 60 U.S. hospitals—222 surgeons, 1058 OR nurses, 564 surgical technologists, 170 anesthesiologists, and 121 certified registered nurse anesthetists (CRNAs). The response rate was 77.1%, with OR nurses having the highest response rate (79%) and CRNAs the lowest (67%).

The teamwork climate domain of the survey included the following six items:

1. Difficulty speaking up
2. Conflict resolution
3. Nurse-physician collaboration
4. Feeling supported by others
5. Asking questions
6. Heeding nurse input

In analyzing their data, researchers found strong evidence for grouping individual-level respondents to the hospital OR level. OR teamwork climate variability was greater between than within hospital OR levels, and a consistent pattern occurred across the hospitals studied. Thus the response according to caregiver types (e.g., between surgeon and nurse) had discrepant attitudes about teamwork with each other. Surgeons and anesthesiologists were more satisfied with physician-nurse collaboration than nurses were. OR nurses and CRNAs did not reciprocate the high ratings of teamwork climate given by physicians.

This research validates that assessment of teamwork climate is possible using the same questionnaire used in the study. The findings of this study add a research tool for assessing teamwork in the OR and include greater detail to more general reports of discrepant attitudes about collaboration between physicians and nurses.

Modified from Sexton JB et al: Teamwork in the operating room: frontline perspectives among hospitals and operating room personnel, *Anesthesiology* 105:869-870, 2006.

REFERENCES

American College of Radiology (ACR): *ACR practice guideline for radiation oncology,* Reston, VA, 2004, available at www.guideline.gov/summary/summary.aspx?ss=15&;doc_id=9422. Accessed May 23, 2009.

American College of Surgeons (ACS): Statement on blunt suture needles, *Bulletin of the American College of Surgeons*, Vol 90, No 11 (November):24, 2005.

American Nurses Association (ANA): *Latex allergy: protect yourself, protect your patients*, Washington, DC, 1996, Workplace Information Series.

American Nurses Association: Position statement—latex allergy, *ANA*NET**, 1997.

American Nurses Association: *Needlestick prevention guide,* Washington, DC, 2002.

American Nurses Association: *ANA launches "handle with care" ergonomics campaign* (9/17/03), 2003, available at www.nursingworld.org/FunctionalMenuCategories/MediaResources/PressReleases/2003/HandleWCarePressRelease.aspx. Accessed May 28, 2009.

American Nurses Association: *Preventing workplace violence,* Occupational Health and Safety Series, Washington, DC, 2006.

American Nurses Association: Environmental Working Group: Nurses' health: a survey on health and chemical exposures, 2007, available at www.ewg.org/sites/nurse_survey/analysis/chempage.php. Accessed May 23, 2009.

American Nurses Association: *ANA backgrounders: influenza season, 2008–2009, 2008a,* available at www.nursingworld.org/MainMenuCategories/OccupationalandEnvironmental/occupationalhealth/Influenza/20082009InfluenzaBackgrounder.aspx. Accessed May 21, 2009.

American Nurses Association: *Safe patient handling and movement* (pamphlet), Washington, DC, 2008b.

American Nurses Association: Handle with care backgrounder, 2009, available at www.nursingworld.org/MainMenuCategories/OccupationalandEnvironmental/occupationalhealth/handlewithcare/Backgrounder.aspx. Accessed May 28, 2009.

Association of periOperative Registered Nurses (AORN): *Guidance statement: Safe patient handling and movement in the perioperative setting*, Denver, 2007, The Association.

Association of periOperative Registered Nurses (AORN): *Guidance statement: Sharps injury prevention in the perioperative setting.* In *Perioperative standards and recommended practices,* Denver, 2009a, The Association.

Association of periOperative Registered Nurses (AORN): *Recommended practices for prevention of transmissible infections in the perioperative practice setting.* In *Perioperative standards and recommended practices,* Denver, 2009b, The Association.

Association of periOperative Registered Nurses (AORN): *Recommended practices for reducing radiological exposure in the perioperative practice setting.* In *Perioperative standards and recommended practices,* Denver, 2009c, The Association.

Bell JL et al: Evaluation of a comprehensive slip, trip and fall prevention programme for hospital employees, *Ergonomics* 51(12):1906–1925, 2008.

Berenholtz SM et al: Implementing standardized operating room briefings and debriefings at a large regional medical center, *Jt Comm J Qual Patient Saf* 35(8):391–397, 2009.

Berguer R, Heller P: Preventing sharps injury in the operating room, *J Am Coll Surg* 199(3):462–467, 2004.

Brateman L: Radiation safety considerations for diagnostic radiology personnel, *RadioGraphics* 19:1037–1055, 1999, available at www.radiographics.rsnajnls.org/cgi/content/abstract/19/4/1037. Accessed May 23, 2009.

Brogmus G et al: Best practices in OR suite layout and equipment choices to reduce slips, trips, and falls, *AORN J* 86(3):384–398, 2007.

Centers for Disease Control and Prevention (CDC): Guideline for isolation precautions in hospitals, *Infection Control and Hospital Epidemiology* 17(1):53–80, 1996, available at http://wonder.cdc.gov/wonder/prevguid/p0000419/p0000419.asp. Accessed June 1, 2009.

Centers for Disease Control and Prevention (CDC): Immunization of health-care workers: recommendations of the Advisory Committee on Immunization Practices (ACIP) and the Hospital Infection Control Practices Advisory Committee (HICPAC), *MMWR* 46:1–42, 1997.

Centers for Disease Control and Prevention (CDC): Updated U.S. Public Health Service guidelines for the management of occupational exposures to HBV, HCV, and HIV and recommendations for postexposure prophylaxis, *MMWR Recommendations and Reports*. 50:1–42, June 29, 2001, available at www.cdc.gov/mmwr/preview/mmwrhtml/rr5011al.htm. Accessed May 28, 2009.

Centers for Disease Control and Prevention (CDC): Influenza vaccination of health-care personnel, *MMWR* 55:1–16, 2006a, available at www.cdc.gov/mmwr/preview/mmwrhtml/rr5502al.htm. Accessed May 28, 2009.

Centers for Disease Control and Prevention (CDC): Preventing tetanus, diphtheria, and pertussis among adults: use of tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis vaccine, *MMWR* 55:1–33, 2006b, available at www.cdc.gov/mmwr/preview/mmwrhtml/rr5517al.htm. Accessed May 28, 2009.

Centers for Disease Control and Prevention (CDC): *Guideline for disinfection and sterilization in healthcare facilities,* 2008a, available at www.cdc.gov/ncidod/dhqp/pdf/guidelines/Disinfection_Nov_2008.pdf. Accessed April 30, 2009.

Centers for Disease Control and Prevention (CDC): *Workbook for designing, implementing, and evaluating a sharps injury prevention program,* 2008b, available at www.cdc.gov/sharpssafety/index.html. Accessed April 1, 2009.

CDC, National Institute for Occupational Safety and Health (NIOSH): *Preventing allergic reactions to natural rubber latex in the workplace,* NIOSH Publication No. 97–135, 1997, available at www.cdc.gov/niosh/latexalt.html. Accessed May 22, 2009.

CDC, NIOSH: *NIOSH alert: Preventing occupational exposure to antineoplastic and other hazardous drugs in health care settings,* Publication No. 2004-165, Cincinnati, 2004, available at www.cdc.gov/niosh/docs/2004-165/. Accessed April 30, 2009.

CDC, NIOSH: *NIOSH pocket guide to chemical hazards,* Publication No. 2005-149, Cincinnati, 2005, also available at www.cdc.gov/niosh/npg/. Accessed April 30, 2009.

CDC, NIOSH: *Waste anesthetic gases: occupational hazards in hospitals,* NIOSH Publication No. 2007-151, Cincinnati, 2007, available at www.cdc.gov/niosh/docs/2007-151/. Accessed April 22, 2009.

Clarke SP et al: Sharp-device injuries to hospital staff nurses in 4 countries, *Infect Control Hosp Epidemiol* 28:473–478, 2007.

Collins JW, Bell JL: Prevention of slip, trip, and fall (STF) hazards for workers in hospital settings. In Charney W, editor: *Essentials of modern hospital safety*, ed 4, Los Angeles, 2009, Lewis.

Collins JW et al: *Slip, trip and fall (STF) prevention in health care workers*. In NORA symposium 2006: awards, 2006, CDC/NIOSH, available at www.cdc.gov/niosh/nora/symp06/award06.html. Accessed May 5, 2009.

Collins JW et al: Multidisciplinary research to prevent slip, trip, and fall (STF) incidents among hospital workers. In *Contemporary ergonomics 2008*, Nottingham, U.K., 2008, Taylor and Francis.

Davis MS: Sharps safety in the operating room, advances in engineered sharps injury prevention technology: suturing, 1–24, 2006. Adapted from Davis, MS: *Advanced precautions for today's OR: the operating room professional's handbook for the prevention of sharps injuries and blood borne exposures,* ed 2, Atlanta, 2001, Sweinbinder.

de Castro AB: Handle with Care[R]: the American Nurses Association's campaign to address work-related musculoskeletal disorders, *Online Journal of Issues in Nursing,* Vol 9, No 3 (September): 2004, available at www.nursingworld.org/MainMenuCategories/ANAMarketplace/ANAPeriodicals/OJIN/TableofContents?Volume92004/No3Sept04/HandlewithCare.aspx. Accessed March 9, 2009.

Edlich RF et al: Devastating injuries in healthcare workers: description of the crisis and legislative solution to the epidemic of back injury from patient lifting, *J Long Term Eff Med Implants,* Vol 15, No 2:225–241, 2005.

Health Care Without Harm (HCWH): *Risks to asthma posed by indoor health care environments: a guide to identifying and reducing problematic exposures*, Arlington, VA, 2006, Health Care Without Harm, available at www.hcwh.org/details.cfm?type=document&;id=1315. Accessed May 28, 2009.

Hughes NL: Bullies in health care beware, *Am Nurs Today* 3(11):44–45, 2008.

Hughes NL: Slips, trips, and falls of healthcare workers, *Am Nurs Today* 4(3):38, 2009.

International Centre for Human Resources in Nursing (ICHRN): *Workplace bullying in the health sector,* 2009. Available at www.icn.ch/matters_bullying.htm. Accessed May 22, 2009.

International Council of Nurses (ICN): *Guidelines on coping with violence in the workplace,* 2007, available at www.icn.ch/guide_violence.pdf. Accessed May 21, 2009.

International Healthcare Worker Safety Center (IHWSC): *About EPINet,* 2008a, available at www.healthsystem.virginia.edu/Internet/epinet. Accessed April 3, 2009.

International Healthcare Worker Safety Center: EPINet/Access-OR downloadable Report Forms, 2008b, available at www.healthsystem.virginia.edu/Internet/epinet/OR/epinet8.cfm. Accessed April 3, 2009.

Jagger J et al: A study of patterns and prevention of blood exposures in OR personnel, *AORN J* 7(5):979–987, 1998.

Misteli H et al: Surgical glove perforation and the risk of surgical site infection, *Arch Surg* 144:553–558, 2009.

Nelson AL, editor: *Safe patient handling and movement: a guide for nurses and other health care providers*, New York, 2006, Springer.

Nelson AL et al: *The illustrated guide to safe patient handling and movement*, New York, 2009, Springer.

Occupational Safety and Health Administration (OSHA): *Anesthetic gases: guidelines for workplace exposures,* Washington, DC, 2000, available at www.osha.gov/dts/osta/anestheticgases/index.html. Accessed April 29, 2009.

Occupational Safety and Health Administration: *OSHA best practices for hospital-based first receivers,* OSHA 3249-08-N, Washington, DC, 2005.

Occupational Safety and Health Administration: *Hospital eTool, clinical services—radiology module,* 2008a, available at www.OSHA.gov/SLTC/etools/hospital/clinical/radiology/radiology.html/#Radiation. Accessed May 23, 2009.

Occupational Safety and Health Administration: *Hospital eTool, healthcare wide hazards module, latex allergy,* 2008b, available at www.OSHA.gov/SLTC/etools/hospital/hazards/latex/latex.html. Accessed May 21, 2009.

Occupational Safety and Health Administration: *Hospital eTool, surgical suite module, slips/trips/falls, 2008c,* available at www.OSHA.gov/SLTC/etools/hospital/surgical/surgical.html#Slips, Trips, Falls. Accessed May 5, 2009.

Occupational Safety and Health Administration: *Reproductive hazards, hazard recognition,* 2008d, available at www.osha.gov/SLTC/reproductivehazards/recognition.html. Accessed April 30, 2009.

Occupational Safety and Health Administration: *Regulations (standards – 29 CFR), hazard communication – 1910.1200,* 2009, available at www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10099. Accessed April 30, 2009.

Peter D. Hart Research Associates: *Safe patient handling:* a report, AFT Healthcare, Washington, DC, 2006, AFT, AFL-CIO.

Staal C et al: Reducing slips, trips, and falls during employee-assisted patient activities, *Rehabil Nurs* 29(6):211–214, 2004.

Stringer B et al: Effectiveness of the hands-free technique in reducing operating theatre injuries, *Occup Environ Med* 59:703–707, 2002.

U.S. Bureau of Labor Statistics (USBLS): *Nonfatal occupational injuries and illnesses requiring days away from work, 2006, 2007,* available at www.bls.gov/iif/oshwc/osh/case/osnr0029.pdf. Accessed May 22, 2009.

U.S. Bureau of Labor Statistics: *Nonfatal occupational injuries and illnesses requiring days away from work, 2007,* 2009, available at www.bls.gov/news.release/pdf/osh2.pdf. Accessed May 22, 2009.

Waters TR: When is it safe to manually lift a patient? *AJN* 107(8):53–58, August 2007.

World Health Organization (WHO): *New research shows workplace violence threatens health services, 2002,* available at www.who.int/mediacentre/news/releases/release37/en/. Accessed May 22, 2009.

Illustration Credits

Nursing Diagnoses—Definitions and Classifications 2009-2011 © 2009, 2007, 2005, 2003, 2001, 1998, 1996, 1994 NANDA International. Used by arrangement with Wiley-Blackwell Publishing, a company of John Wiley and Sons, Inc.

CHAPTER 1

1-1, Courtesy University of Pennsylvania School of Medicine, Philadelphia; **1-3**, **1-4**, From Perioperative Nursing Data Set, ed 3, in press. Copyright 2010 © AORN, Inc. Used with permission. All rights reserved. **1-5**, From Titler MG et al: The Iowa model of evidence-based practice to promote quality care, *Critical Care Nursing Clinics of North America*, 13(4), 497-509, 2001.

CHAPTER 2

2-1, **2-2**, **2-4**, Courtesy Christiana Care Health Services, Newark, DE; **2-3**, From Beare PG, Myers JL: *Principles and practices of adult health nursing*, ed 3, St Louis, 1998, Mosby.

CHAPTER 3

3-1, From Huether SE, McCance KL: *Understanding pathophysiology*, ed 4, St Louis, 2008, Mosby; **3-2**, Courtesy Charleston Area Medical Center, Charleston, WV; **3-4**, In Fuller JR: *Surgical technology*, ed 5, St Louis, 2010, Saunders. Modified from Phillips N: *Berry & Kohn's operating room technique*, ed 11, St Louis, 2007, Mosby; **3-5**, **3-10**, Courtesy STERIS Corp, Mentor, OH; **3-6**, From Fuller JR: *Surgical technology*, ed 5, St Louis, 2010, Saunders; **3-7**, From Fuller JR: *Surgical technology*, ed 4, St Louis, 2005, Saunders.

CHAPTER 4

4-4, Redrawn from Whitten C: *Anyone can intubate,* ed 4, San Diego, 1997, K-W Publications.

CHAPTER 5

5-1, **5-2**, **5-7**, **5-8**, Courtesy Kendall-LTP; **5-5**, Adapted from Martin JT: *Positioning in anesthesia and surgery*, ed 2, Philadelphia, 1987, Saunders; **5-10**, **5-11**, From Fleisher LA: *Anesthesia and uncommon diseases,* ed 5, Philadelphia, 2006, Saunders; **5-18**, Courtesy Allen Medical Systems, Acton, MA; **5-21**, Courtesy Mizuho OSI, Unionville, CA; **5-23**, From Phillips N: *Berry & Kohn's operating room technique*, ed 11, St Louis, 2007, Mosby.

CHAPTER 6

6-2, **6-9**, **6-16**, **6-23**, From Phillips N: *Berry & Kohn's operating room technique*, ed 11, St Louis, 2007, Mosby; **6-3**, **6-4**, **6-5**, **6-6**, **6-11**, **6-12**, From Davis & Geck: *Surgical atlas and suture guide*, ed 2, Wayne, NJ, 1992, American Cyanamid Co; **6-7**, Courtesy 3M, St Paul, MN; **6-8**, **6-13**, **6-26**, From Beth Israel Deaconess Medical Center, Boston, MA; **6-14**, Adapted from Beth Israel Deaconess Medical Center Count Safety Checklist©, Boston, MA. Used with permission; **6-15**, **6-18**, **6-19**, **6-21**, **6-22**, Courtesy Codman & Shurtleff, Inc, Randolph, MA; **6-17**, Courtesy Miltex Instrument Co; **6-20**, Courtesy Shirley M. Tighe, Lake Havasu City, AZ.

CHAPTER 7

7-2, **7-5**, **7-6**, **7-9**, **7-10**, **7-13**, **7-17**, **7-20**, **7-35**, **7-37**, **7-45**, **7-46**, **7-56**, **7-59**, **7-60**, **7-76**, **7-77**, From Ball KA: *Endoscopic surgery*, St Louis, 1997, Mosby; **7-3**, **7-42**, **7-43**, **7-49**, **7-50**, Courtesy Gyrus-ACMI, Southborough, MA; **7-4**, Courtesy HGM Medical Laser Systems, Santa Clara, CA; **7-7**, **7-33**, **7-38**, **7-41**, Courtesy Olympus Surgical America, Orangeburg, NY; **7-8**, Courtesy Endoscopy Support Services, Inc, Brewster, NY; **7-11**, From Brooks-Tighe SM: *Instrumentation for the operating room*, ed 6, St Louis, 2003, Mosby; **7-12**, **7-15**, From Tighe SM: *Instrumentation for the operating room*, ed 7, St Louis, 2007, Mosby; **7-14**, **7-18**, **7-19**, **7-21**, **7-24**, **7-27**, Copyright © 2010 Covidien. All rights reserved. Used with the permission of Covidien. **7-22**, **7-23**, Courtesy Ethicon Endo-Surgery, Cincinnati; **7-29**, Courtesy Medivators, a Minntech Corporation Business Group, Minneapolis, MN, www.medivators.com; **7-31**, Courtesy Circon ACMI, Santa Barbara, CA; **7-48**, **7-61**, Courtesy I. C. Medical Inc., Phoenix, AZ; **7-64**, **7-65**, **7-66**, **7-67**, Courtesy Valleylab, Inc; **7-68**, **7-69**, Courtesy Megadyne Medical Products Inc., Draper, UT; **7-70**, Copyright © 2009 Covidien. All rights reserved. Reprinted with the permission of the Energy Based Devices and Surgical Devices Divisions of Covidien; **7-72**, **7-73**, Courtesy Encision, Boulder, CO.

CHAPTER 8

8-1, From Herlihy B: *The human body in health and illness*, ed 3, St Louis, 2007, Saunders; **8-2**, **8-6**, From Ignatavicius DD, Workman ML: *Medical-surgical nursing: patient-centered collaborative care*, ed 6, St Louis, 2010, Mosby; **8-3**, From Bryant RA: *Acute and chronic wounds*, ed 3, St Louis, 2007, Mosby; **8-4**, Harkreader, H et al: *Fundamentals of nursing: caring and clinical judgment*, ed 3, St Louis, 2007, Saunders; **8-5**, Courtesy KCI, San Antonio, TX; **8-7*C-D***, Courtesy CR Bard, Inc, Murray Hill, NJ.

CHAPTER 9

9-1, **9-2**, From Litwack K: *Post anesthesia care nursing*, ed 2, St Louis, 1995, Mosby; **9-3**, Courtesy Forrest General Hospital, Hattiesburg, MS; **9-4**, **9-5**, From Monahan FD et al: *Phipps' medical-surgical nursing: health and illness perspectives*, ed 8, St Louis, 2007, Mosby; **9-6**, Reproduced with permission. Copyright © 2010 Arizant Healthcare, Inc. All rights reserved. **9-7**, From Nagelhout JJ, Plaus K: *Nurse anesthesia*, ed 4, St Louis, 2010, Saunders; **9-8**, **9-9**, **9-10**, From American Society of PeriAnesthesia Nurses PONV/PDNV Strategic Work Team: ASPAN's evidence-based clinical practice guideline for the prevention and/or management of PONV/PDNV, *J Perianesth Nurs* 21(4):243-245, 2006; **9-11**, From Acute Pain Management Guideline Panel: *Acute pain management in adults: operative procedures: quick reference guide for clinicians, AHCPR Pub No. 92-0019,* Rockville, MD, 1992, Agency for Health Care Policy and Research; **9-12*A-C,*** From Acute Pain Management Guideline Panel: *Acute pain management in adults: operative procedures: quick reference guide for clinicians. AHCPR Pub No. 92-0019,* Rockville, MD, 1992, Agency for Health Care Policy and Research; ***D,*** From Hockenberry MJ, Wilson, D: *Wong's essentials of pediatric nursing,* ed 8, St Louis, 2009, Mosby; **9-13**, Data from McCaffery M, Pasero C: The Agency for Health Care Policy and Research and the American Pain Society. Chris Pasero, MS, RN, Pain Management Educator and Consultant, reviewed and advised the development of this algorithm; **9-14**, From Prospect Working Group: PROSPECT: Procedure Specific Postoperative Pain Management at www.postoppain.org; **9-15**, From Long BC et al: *Medical-surgical nursing: a nursing process approach*, ed 3, St Louis, 1993, Mosby.

CHAPTER 10

10-4, **10-5**, **10-15**, **10-16**, **10-17**, **10-20**, **10-21**, From Thompson JC: *Atlas of surgery of the stomach, duodenum, and small bowel*, St Louis, 1992, Mosby; **10-7**, **10-14**, **10-28**, **10-29**, **10-30**, **10-31**, **10-32**, **10-33**, **10-34**, **10-35**, From Bauer JJ: *Colorectal surgery illustrated,* St Louis, 1993, Mosby; **10-9**, Adapted from Thibodeau GA, Patton KT: *Anthony's textbook of anatomy and physiology,* ed 18, St Louis, 2007, Mosby; **10-22**, Courtesy of Inamed Health, Inc, Santa Barbara, CA. In Townsend CM et al: *Sabiston textbook of surgery: the biological basis of modern surgical practice*, ed 17, Philadelphia, 2004, Saunders; **10-23**, **10-24**, **10-25**, From Townsend CM et al: *Sabiston textbook of surgery: the biological basis of modern surgical practice*, ed 18, Philadelphia, 2007, Saunders; **10-26**, **10-27**, From Marceau P et al: Malabsorptive obesity surgery, *Surgical Clinics of North America* 81:1113-1127,

2001. In Townsend CM et al: *Sabiston textbook of surgery: the biological basis of modern surgical practice*, ed 17, Philadelphia, 2004, Saunders.

CHAPTER 11

11-6, From Townsend CM et al: *Sabiston textbook of surgery*, ed 16, Philadelphia, 2001, Saunders; **11-7,** From Daly JM, Cady B: *Atlas of surgical oncology*, St Louis, 1993, Mosby; **11-13,** From Zuidema G, editor: *Shackelford's surgery of the alimentary tract,* ed 3, Philadelphia, 1996, Saunders; **11-19,** Modified from Moody FG, editor: *Surgical treatment of digestive disease*, ed 2, St Louis, 1990, Mosby; **11-20,** From Motoyama EK, Davis PJ: *Smith's anesthesia for infants and children*, ed 7, St Louis, 2006, Mosby; **11-21, 11-22, 11-23,** Copyright © 1990 Lahey Clinic, Burlington, MA; **11-24,** From Anscher NL et al: In Simmons RL et al, editors: *Manual of vascular access, organ donation, and transplantation*, New York, 1984, Springer-Verlag.

CHAPTER 12

12-1, From Ignatavicius DD, Workman ML: *Medical-surgical nursing: patient-centered collaborative care*, ed 6, St Louis, 2010, Mosby; **12-2,** From Harkreader H, Hogan MA, Thobaben M: *Fundamentals of nursing: caring and clinical judgment*, ed 3, St Louis, 2007, Mosby; **12-12,** From Seidel HM et al: *Mosby's guide to physical examination,* ed 6, St Louis, 2006, Mosby; **12-14,** From Schumpelick V: *Atlas of hernia surgery*, Toronto, 1990, BC Decker; **12-16,** From Liechty RD, Soper RT: *Synopsis of surgery*, St Louis, 1985, Mosby.

CHAPTER 13

13-1, 13-13*B*, 13-14*B*, From Seidel HM et al: *Mosby's guide to physical examination*, ed 6, St Louis, 2006, Mosby; **13-2, 13-8, 13-29,** From Lowdermilk DL, Perry SE: *Maternity and women's health care,* ed 9, St Louis, 2007, Mosby; **13-7, 13-9, 13-10, 13-24, 13-41,** From Hacker NF, Gambone JC, Hobel CJ: *Hacker & Moore's essentials of obstetrics and gynecology*, ed 5, Philadelphia, 2010, Saunders; **13-15,** Redrawn from Symmonds RE: Relaxation of pelvic supports. In Katz VL et al: *Comprehensive gynecology*, ed 5, Philadelphia, 2007, Mosby; **13-11, 13-43,** From Townsend CM et al: *Sabiston textbook of surgery: the biological basis of modern surgical practice*, ed 18, Philadelphia, 2008, Saunders; **13-12, 13-38,** From Ignatavicius DD, Workman ML: *Medical-surgical nursing: patient-centered collaborative care*, ed 6, St Louis, 2010, Mosby; **13-16, 13-17, 13-32,** Katz VL et al: *Comprehensive gynecology*, ed 5, St Louis, 2007, Mosby; **13-23, 13-27, 13-37, 13-45,** From Ball TL: *Gynecologic surgery and urology,* ed 2, St Louis, 1963, Mosby. Daisy Stillwell, medical illustrator; **13-26,** Courtesy Dr. Henry J Norris, Orlando, FL. From Robboy SJ et al: *Robboy's pathology of the female reproductive tract,* ed 2, London, 2009, Churchill Livingstone; **13-28,** From Lowdermilk DL, Perry SE: *Maternity and women's health care*, ed 8, St Louis, 2004, Mosby; **13-30,** From Emond RT: *Colour atlas of infectious diseases*, ed 4, St Louis, 2003, Mosby; **13-33, 13-44,** From Hacker NF, Moore JG, Gambone JC: *Essentials of obstetrics and gynecology*, ed 4, Philadelphia, 2004, Saunders; **13-34, 13-35, 13-36,** From Edwards SK et al: Surgery in the pregnant patient, *Current problems in surgery* 38(4):213-292, 2001; **13-39, 13-46, 13-47,** From Nichols DH: *Gynecologic and obstetric surgery,* St Louis, 1993, Mosby; **13-48, 13-49, 13-50,** Courtesy Conceptus Inc, San Carlos, CA; **13-53,** From Holcomb GW and Murphy JP: *Pediatric surgery,* ed 5, Philadelphia, 2010, Saunders; **13-54,** From Cortes RA, Farmer DL: Recent advances in fetal surgery, *Seminars in Perinatology* 28(3), 2004; **13-55,** From Adzick NS et al: Successful fetal surgery for spina bifida, *The Lancet* 352(9141):1675-1676, 1998; **13-56, 13-57,** Courtesy Marjorie Pyle, RNC, Lifecircle, Costa Mesa, CA. In Lowdermilk DL, Perry SE: *Maternity and women's health care*, ed 9, St Louis, 2007, Mosby.

CHAPTER 14

14-1, 14-6, 14-7, Modified from Seidel HM et al: *Mosby's guide to physical examination*, ed 6, St Louis, 2006, Mosby; **14-3, 14-15, 14-25, 14-30, 14-32, 14-40, 14-49, 14-50, 14-66, 15-80,** From Nagle GM: *Genitourinary surgery*, St Louis, 1997, Mosby; **14-8, 14-64,** Courtesy Bard Urological, Covington, GA; **14-10, 14-12,** Courtesy Jeffrey Rosenblum, MD; **14-13,** Courtesy CR Bard, Urological Division, Covington, GA. In Nagle GM: *Genitourinary surgery*, St Louis, 1997, Mosby; **14-14, 14-17, 14-31, 14-62,** From Williamson MR, Smith AY: *Fundamentals of uroradiology*, Philadelphia, 2000, Saunders; **14-16, 14-33, 14-60, 14-61,** Courtesy Gyrus-ACMI, Southborough, MA; **14-18,** Courtesy Circon Corp, Santa Barbara, CA. In Nagle GM: *Genitourinary surgery*, St Louis, 1997, Mosby; **14-20, 14-21*B*, 14-78,** From Tighe SM: *Instrumentation for the operating room*, St Louis, 2007, Mosby; **14-24, 14-27, 14-28, 14-72*A*,** Courtesy American Medical Systems, Minnetonka, MN; **14-26, 14-42, 14-43, 14-44, 14-51, 14-52, 14-70, 14-71, 14-72*B*, 14-79, 14-81,** From Droller MJ: *Surgical management of urologic disease*, St Louis, 1992, Mosby; **14-37, 14-38,** Courtesy Ethicon, Inc, Somerville, NJ; **14-41, 14-47,** Courtesy Omni-Tract Surgical, St Paul, MN; **14-54,** Courtesy Intuitive Surgical, Inc.; **14-55, 14-56,** From Wein AJ et al: *Campbell-Walsh urology*, ed 9, Philadelphia, 2007, Saunders; **14-58,** Courtesy Circon Corp, Santa Barbara, CA; **14-63, 14-65,** From Raz S: *Atlas of transvaginal surgery*, ed 2, Philadelphia, 2002, Saunders; **14-73, 14-74, 14-76,** From Gillenwater JY et al: *Adult and pediatric urology*, ed 3, vol 2, St Louis, 1996, Mosby; **14-75,** From Gray M: *Genitourinary disorders,* St Louis, 1992, Mosby; **14-77,** Copyright © Karl Storz Endoscopy America, Inc.

CHAPTER 15

15-1, 15-2, 15-3, 15-5, From Netter Anatomy Illustration Collection, © Elsevier, Inc. All rights reserved; **15-4,** From Wein RO, Weber RS: Parathyroid surgery, *Neuroimaging Clinics of North America* 18(3):554-555, 2008; **15-6,** From Fakhran S et al: Parathyroid imaging, *Neuroimaging Clinics of North America* 18(3):538, 2008; **15-7,** From Kukora JS et al: Thyroid nodule. In Cameron JL, editor: *Current surgical therapy*, ed 7, St Louis, 2001, Mosby; **15-8, 15-9, 15-10, 15-11, 15-12,** From Dhingra JK, Raval T: Minimally invasive surgery of the thyroid, eMedicine.com, June 13, 2008, WebMD; **15-13,** From Healy J, Hodge J: *Surgical anatomy*, ed 2, Philadelphia, 1990, BC Decker.

CHAPTER 16

16-1, 16-2, 16-3, From Isaacs JH: *Textbook of breast disease*, St Louis, 1992, Mosby; **16-4,** From Townsend CM: *Sabiston textbook of surgery*, ed 16, Philadelphia, 2001, Saunders; **16-5,** Courtesy Wende W. Logan, MD, Rochester, NY and the Breast Clinic of Rochester; **16-6,** Image redrawn courtesy Ethicon Endo-Surgery, Inc; **16-7*A*,** From Don Bliss, artist, National Cancer Institute (NCI), www.cancer.gov; **16-7*B*,** From Ignatavicius DD, Workman ML: *Medical-surgical nursing: critical thinking for collaborative care*, ed 5, St Louis, 2006, Mosby; **16-8,** From Townsend CM et al: *Sabiston textbook of surgery: the biological basis of modern surgical practice*, ed 18, Philadelphia, 2008, Saunders; **16-9,** From Ignatavicius DD, Workman ML: *Medical-surgical nursing: patient-centered collaborative care*, vol. 2, ed 6, St Louis, 2010, Mosby; **16-10,** From Ignatavicius DD, Workman ML: *Medical-surgical nursing: critical thinking for collaborative care,* ed 4, Philadelphia, 2002, Saunders; **16-11,** Redrawn from Zollinger RM: *Atlas of surgical operations*, ed 6, NY, 1988, MacMillan.

CHAPTER 17

17-1, 17-8, 17-9, 17-17, 17-30, 17-31, 17-37, Courtesy National Eye Institute, National Institutes of Health; **17-2,** From Seidel HM et al: *Mosby's guide to physical examination*, ed 6, St Louis, 2006, Mosby; **17-3,** From Thompson JM et al: *Mosby's clinical nursing*, ed 5, St Louis, 2002, Mosby; **17-4,** From Monahan FD et al: *Phipps' medical-surgical nursing: health and illness perspectives*, ed 8, St Louis, 2007, Mosby; **17-14,** Courtesy Don Mikes, Vice-President, Global Marketing, Moria, Inc., Doylestown, PA; **17-18,** Courtesy June Nichols, Board Certified Ocularist, Diplomate, American Society of Ocularists; **17-19,** From Swartz MH: *Textbook of physical diagnosis*, ed 6, Philadelphia, 2010, Saunders; **17-22, 17-24, 17-25, 17-26,** From Tenzel RR: *Textbook of ophthalmology*, vol 4. *Orbit and oculoplastics*, London, 1993, Gower; **17-23,** From Ignatavicius DD, Workman ML: *Medical-surgical nursing: critical thinking for collaborative care*, ed 5, St Louis, 2006, Mosby; **17-29,** From Wilson TS: LASIK surgery, *AORN J* 71(5):977-978, 2000; **17-33, 17-34, 17-35,** From Lindquist TD, Lindstrom RL: *Ophthalmic surgery: looseleaf and update service,* St Louis, 1990, Mosby; **17-36*B*,** Courtesy of Jason Malecka, President of IOP; **17-40, 17-41,** From Federman JL et al: *Retina and vitreous*, London, 1994, Mosby; **17-42,** From Ryan SJ et al: *Retina,* vol 3, ed 4, St Louis, 2006, Mosby.

CHAPTER 18

18-1, 18-2, 18-44, 18-46, From Ignatavicius DD, Workman ML: *Medical-surgical nursing: critical thinking for collaborative care*, ed 5, St Louis, 2006, Mosby; **18-3,** From DeWeese DD et al: *Otolaryngology: head and neck surgery,* ed 7, St Louis, 1988, Mosby; **18-5, 18-17*A*** and ***C***, From Saunders WH et al: *Nursing care in eye, ear, nose, and throat disorders*, ed 4, St Louis, 1979, Mosby; **18-7,** From Seidel HM et al: *Mosby's guide to physical examination*, ed 6, St Louis, 2006, Mosby; **18-8,** From Huether SE, McCance KL: *Understanding pathophysiology*, ed 4, St Louis, 2008,

Mosby; **18-9**, From Marino LB: *Cancer nursing,* St Louis, 1981, Mosby; **18-10**, **18-16**, **18-17*B***, **18-21**, From Myers EN: *Operative otolaryngology: head and neck surgery,* vol. 1 & 2, ed 2, St Louis, 2008, Saunders; **18-11**, **18-28**, **18-38**, **18-39**, **18-40**, **18-52**, **18-53**, From Cummings CW et al: *Otolaryngology: head and neck surgery,* ed 3, St Louis, 1993, Mosby; **18-13**, Courtesy Medtronic Xomed; **18-15**, From Tighe SM: *Instrumentation for the operating room*, ed 7, St Louis, 2007, Mosby; **18-18**, Courtesy Richard A. Buckingham, MD, Clinical Professor, Otolaryngology, Abraham Lincoln School of Medicine, University of Illinois, Chicago. In Seidel HM et al: *Mosby's guide to physical examination*, ed 6, St Louis, 2006, Mosby; **18-22**, **18-23**, Courtesy Cochlear, Ltd; **18-24**, **18-25**, **18-26**, Courtesy Entific Medical Systems; **18-27**, **18-35**, **18-50**, From DeWeese DD, Saunders WH: *Textbook of otolaryngology,* ed 6, St Louis, 1982, Mosby; **18-31**, From Schuller DE, Schleuning AJ: *Otolaryngology: head and neck surgery,* ed 8, St Louis, 1994, Mosby; **18-32**, From Thawley SE, Garrett H: Endoscopic sinus surgery; an outpatient procedure that minimizes tissue removal, *AORN J* 47:902, 1988. Copyright © AORN, Inc, Denver, CO; **18-42**, From Lewis SM et al: *Medical-surgical nursing: assessment and management of clinical problems*, ed 7, St Louis, 2007, Mosby; **18-43**, From Luckmann J: *Medical-surgical nursing*, ed 3, Philadelphia, 1987, Saunders; **18-45**, From Shah JP, Patel SG: *Head and neck surgery and oncology,* ed 3, London, 2003, Mosby Ltd.

CHAPTER 19

19-1, **19-2**, **19-4**, **19-5**, **19-6**, **19-8**, **19-9**, From Thibodeau GA, Patton KT: *Anatomy and physiology*, ed 7, St Louis, 2010, Mosby; **19-3**, Redrawn from Lewis RC: *Primary care orthopedics*, NY, 1988, Churchill Livingstone; **19-7*A***, **19-12**, **19-13**, **19-102**, From Thibodeau GA, Patton KT: *Anatomy and physiology*, ed 3, St Louis, 1996, Mosby; **19-11**, **19-19**, **19-44**, **19-77**, **19-81**, Courtesy Zimmer, Inc, Warsaw, IN; **19-14**, Courtesy Tenet Medical, Dallas; **19-15**, Courtesy Innomed, Savannah, GA; **19-16**, **19-66**, Courtesy Acufex Microsurgical, Inc, Mansfield, MA; **19-17**, Courtesy OSI, Union City, CA; **19-18**, **19-28**, **19-31**, **19-40**, **19-42**, **19-51**, **19-62**, **19-83**, **19-85**, From Gregory B: *Orthopaedic surgery*, St Louis, 1994, Mosby; **19-20**, **19-55**, Courtesy Zimmer Traction Handbook, 1989, Zimmer, Inc., Warsaw, IN; **19-22**, From Mourad LA: *Orthopedic disorders*, St Louis, 1991, Mosby; **19-24**, From Ignatavicius DD, Workman ML: *Medical-surgical nursing: patient-centered collaborative care*, ed 6, St Louis, 2010, Mosby; **19-25**, **19-87**, **19-88**, **19-89**, **19-90**, **19-93**, Courtesy ConMed Linvatec, Utica, NY; **19-26**, From Monahan FD et al: Phipps' *Medical-surgical nursing*, ed 8, St Louis, 2007, Mosby; **19-27**, Courtesy EBI, Parsippany, NJ; **19-29**, **19-34**, **19-53**, **19-54**, From Gustilo RB et al: *Fractures and dislocations,* vol 2, St Louis, 1993, Mosby; **19-30**, **19-67**, Courtesy Synthes, West Chester, PA; **19-32**, Courtesy Synthes U.S.A., Paoli, PA; **19-33**, Courtesy Prototech AS, Bergen, Norway; **19-35**, Courtesy LTI Medica and the UpJohn Co. Illustration by Beverly Kessler, 1982, Learning Technology, Inc; **19-36**, **19-46**, **19-57**, From Canale ST, Beaty JH: *Campbell's operative orthopaedics*, ed 11, St Louis, 2008, Mosby; **19-37**, Courtesy Biomet, Inc, Warsaw, IN; **19-39**, Redrawn from Rockwood CA et al: *Fractures in adults,* ed 2, Philadelphia, 1984, Lippincott; **19-41**, Courtesy of The Anspach Effort, Palm Beach Gardens, FL; **19-43**, Redrawn from Neer CS: *J Bone Joint Surg* 52-A:1007, 1970; **19-47**, **19-49**, From Crenshaw AH: *Campbell's operative orthopaedics,* ed 8, St Louis, 1992, Mosby; **19-48**, From Knight RA: *AAOS Instructional Course Lecture* 14:123, 1957; **19-50**, **19-69**, From Muller ME et al: *Manual of internal fixation: techniques recommended by AO-ASIF group*, ed 3, Berlin, 1990, Springer-Verlag; **19-52**, Redrawn from Sprague HH, Howard FM: *Contemporary Orthopedics* 16:18, 1988; **19-56**, Courtesy OsteoMed, Addison, TX; **19-58**, Courtesy Exactech, Inc, Gainesville, FL; **19-59**, From Gustilo RB: *The fracture classification manual,* St Louis, 1991, Mosby; **19-60**, Redrawn from Muller ME et al: *The comprehensive classification of fractures of long bones,* Berlin, 1990, Springer-Verlag; **19-61**, Redrawn from Schatzker J et al: *Clinical Orthopedics* 138:94, 1979; **19-63**, From DePuy ACE Medical Co, El Segundo, CA; **19-64**, **19-72**, **19-73**, **19-78**, Courtesy Stryker, Kalamazoo, MI; **19-65**, Redrawn from Cox JS: *Am J Sports Med* 4:72, 1976; **19-68**, From Canale ST: *Campbell's operative orthopaedics*, ed 9, St Louis, 1998, Mosby; **19-70**, From Richards V: *Surgery for general practice*, St Louis, 1956, Mosby; **19-74**, **19-76**, **19-82**, Courtesy Howmedica, Inc, Rutherford, NJ; **19-79**, Redrawn from Gristina AG, Webb LX: *Proximal humeral and monospherical glenoid replacement: surgical technique*, Rutherford, NJ, 1983, Howmedica, Inc; **19-80**, Courtesy Smith & Nephew, Memphis; **19-84**, Courtesy College of Southern Idaho, Twin Falls; **19-86**, From Tighe SM: *Instrumentation for the operating room*, ed 7, St Louis, 2007, Mosby; **19-91**, **19-92**, From Shahriaree H: *O'Connor's textbook of arthroscopic surgery*, Philadelphia, 1984, Lippincott Williams and Wilkins; **19-94**, Courtesy Johnson & Johnson; **19-98**, Courtesy Smith & Nephew Dyonics, Andover, MA; **19-99**, Courtesy David Greg Anderson, MD; **19-100**, From Kim DH et al: *Surgical anatomy and techniques to the spine*, St Louis, 2006, Saunders; **19-101**, Courtesy NuVasive, Inc, San Diego; **19-103**, From Bradford DS et al: *Moe's textbook of scoliosis and other spinal deformities*, ed 2, Philadelphia, 1987, Saunders; **19-104**, Courtesy Medtronic Sofamor Danek, Memphis; **19-105**, **19-106**, **19-107**, **19-108**, Reprinted with permission from Synthes Spine LP; **19-109**, From Ortiz A: Vertebral body reconstruction: review and update on vertebroplasty and kyphoplasty, *Appl Radiol* 37(12): 10-24, 2008.

CHAPTER 20

20-1, **20-27**, From Thibodeau GA, Patton KT: *Structure and function of the body*, ed 13, St Louis, 2008, Mosby; **20-2**, **20-3**, **20-4**, **20-6**, From Thibodeau GA, Patton KT: *Anatomy and physiology*, ed 3, St Louis, 1996, Mosby; **20-5**, Photograph by Sarah-Jane Smith. Artwork modified from Lumley JSP: *Surface anatomy,* ed 3, Edinburgh, 2002, Churchill Livingstone. In Standring S: *Gray's anatomy,* ed 40, Edinburgh, 2008, Churchill Livingstone; **20-7**, **20-9**, **20-10**, **20-12**, **20-29**, From Conway-Rutkowski BL: *Carini and Owens' neurological and neurosurgical nursing*, ed 8, St Louis, 1982, Mosby; **20-8**, **20-15**, **20-16**, **20-22**, From Anthony CP, Thibodeau GA: *Textbook of anatomy and physiology,* ed 11, St Louis, 1983, Mosby; **20-11**, Photograph by Kevin Fitzpatrick on behalf of GKT School of Medicine, London. In Standring S: *Gray's anatomy,* ed 40, Edinburgh, 2008, Churchill Livingstone; **20-13**, Modified from Thibodeau GA, Patton KT: *Anatomy and physiology*, ed 5, St Louis, 2003, Mosby; **20-14**, From Nolte J: *The human brain: an introduction to its fundamental anatomy*, ed 2, St Louis, 1988, Mosby; **20-17**, **20-31**, **20-32**, **20-34**, **20-46**, **20-47**, **20-48**, **20-49**, **20-50**, **20-52**, **20-54**, **20-57**, From Rengachary SS, Ellenbogen RG: *Principles of neurosurgery,* ed 2, Edinburgh, 2005, Mosby Ltd; **20-18**, **20-19**, **20-20**, From Rengachary SS, Wilkins RH: *Principles of neurosurgery*, London, 1994, Wolfe/Mosby Europe Ltd; **20-21**, From Thibodeau GA, Patton KT: *Anatomy and physiology*, ed 7, St Louis, 2010, Mosby; **20-23**, From Standring S: *Gray's anatomy*, ed 40, Edinburgh, 2008, Churchill Livingstone; **20-24**, **20-25**, From Mettler FA: *Neuroanatomy*, ed 2, St Louis, 1948, Mosby; **20-33**, Provided by Shaun Gallagher, GKT School of Medicine, London; photograph by Sarah-Jane Smith. In Standring S: *Gray's anatomy*, ed 40, Edinburgh, 2008, Churchill Livingstone; **20-35**, Courtesy Dr Justin Lee, Chelsea and Westminster Hospital, London. In Standring S: *Gray's anatomy*, ed 40, Edinburgh, 2008, Churchill Livingstone; **20-36**, Courtesy Integra LifeSciences Corp, Plainsboro, NJ; **20-38**, From Barker E: *Neuroscience nursing,* St Louis, 1994, Mosby; **20-40**, Courtesy Zimmer-Reed, Midlothian, VA; **20-41**, Courtesy Midas Rex Corp, Fort Worth, TX; **20-43**, **20-44**, **20-45**, Courtesy Codman, a Johnson & Johnson Co, Raynham, MA; **20-51*A***, Courtesy Codman & Shurtleff, Inc, Randolph, MA; **20-51*B***, Courtesy Holco Instrument Corp, New York; ***C***, Courtesy Omi Surgical Products, a division of Ohio Medical Instrument Company, Cincinnati; **20-53**, From Sachs E: *Diagnosis and treatment of brain tumors and the care of the neurosurgical patient*, ed 2, St Louis, 1949, Mosby; **20-55**, **20-56**, From Carini E, Owens G: *Neurological and neurosurgical nursing*, ed 6, St Louis, 1974, Mosby.

CHAPTER 21

21-1, From Townsend CM et al, editors: *Sabiston textbook of surgery*, ed 18, Philadelphia, 2008, Saunders; **21-2**, **21-3**, **21-10**, **21-19**, **21-20**, **21-26**, **21-30**, **21-34**, **21-39**, **21-40**, From Fortunato N, McCullough SM: *Plastic and reconstructive surgery*, St Louis, 1998, Mosby; **21-4**, Courtesy Carl Zeiss, Oberkochen, Germany; **21-5**, **21-6**, **21-16**, **21-17**, **21-21**, **21-24**, Courtesy Ramasamy Kalimuthu MD, FACS, Oak Lawn, IL; **21-7**, **21-9**, From Thibodeau GA, Patton KT: *The human body in health and disease*, ed 5, St Louis, 2010, Mosby; **21-8**, **21-12**, From Ignatavicius DD, Workman ML: *Medical-surgical nursing: patient-centered collaborative care*, ed 6, St Louis, 2010, Mosby; **21-15**, Courtesy Inamed Aesthetics, Santa Barbara, CA; **21-22**, From Weinzweig N, Weinzweig J: *The mutilated hand*, St Louis, 2005, Mosby; **21-25**, From Fonseca RJ et al: *Oral and maxillofacial trauma*, ed 3, Philadelphia, 2005, Saunders; **21-27**, **21-33** From Kaminer MS et al: *Atlas of cosmetic surgery*, ed 2, St Louis, 2009, Saunders; **21-35**, From Capella, JF: Body lift, *Clinics in Plastic Surgery* 35(1):28, 2008; **21-36**, From Aly A et al: Brachioplasty in the massive weight loss patient, *Clinics in Plastic Surgery* 35(1):146, 2008; **21-37**, From Cram A, Aly A: Thigh reduction in the massive weight loss patient, *Clinics in Plastic Surgery* 35(1): 170, 2008; **21-41**, From Wilkinson TS: *Atlas of liposuction*, Philadelphia, 2005, Saunders.

CHAPTER 22

22-4, From Schottelius BA, Schottelius DD: *Textbook of physiology,* ed 18, St Louis, 1978, Mosby; **22-5**, From Townsend CM et al: *Sabiston textbook of surgery*, ed 16, Philadelphia, 2001, Saunders; **22-7**, From Johnson J, Kirby CK: *Surgery of the chest*, ed 4, Chicago, 1970, Year Book; **22-8**, Courtesy Teleflex Medical, Research Triangle Park, NC; **22-9**, From Baumgartner FJ: Surgical approaches and techniques in the management of severe hyperhidrosis, *Thoracic Surgery Clinics* 18(2):167-181, 2009; **22-10**, From Kernstine KH et al: Robotic Lobectomy, *Operative Techniques in Thoracic and Cardiovascular Surgery,* 13(3):204.e1-204.e23, 2009; **22-11**, From Damjanov I, Linder J, editors: *Anderson's pathology*, ed 10, St Louis, 1996, Mosby; **22-12**, **22-18**, From McCance KL, Huether SE: *Pathophysiology—the biologic basis for disease in adults and children*, ed 6, St Louis, 2010, Mosby; **22-21**, From Sellke F et al: *Sabiston & Spencer surgery of the chest*, ed 7, Philadelphia, 2005, Saunders.

CHAPTER 23

23-1, **23-4**, From Patton KT, Thibodeau GA: *Anatomy and physiology*, ed 7, St Louis, 2010, Mosby; **23-2**, From Thibodeau GA, Patton KT: *Anatomy and physiology*, ed 5, St Louis, 2003, Mosby; **23-3**, From Kumar et al: *Robbins and Cotran pathologic basis of disease*, ed 8, St Louis, 2010, Saunders; **23-5**, From Dettenmeier PA: *Radiographic assessment for nurses*, St Louis, 1995, Mosby; **23-9**, From Townsend CM et al: *Sabiston textbook of surgery*, ed 17, Philadelphia, 2004, Saunders; **23-10**, From Haimovici H: *Vascular surgery: principles and technique*, ed 4, Oxford, 1995, Blackwell Science; **23-12**, **23-15**, From Hershey FB, Calman CH: *Atlas of vascular surgery*, ed 3, St Louis, 1973, Mosby; **23-13**, **23-14**, From MacVittie BA: *Vascular surgery*, St Louis, 1998, Mosby; **23-19**, **23-21**, **23-22**, From Wilson SE: *Vascular access: principles and practice*, ed 3, St Louis, 1996, Mosby; **23-20**, From Calne R, Pollard SG: *Operative surgery*, London, 1992, Gower; **23-23**, From Ballinger PW: *Merrill's atlas of radiographic positions and radiologic procedures*, ed 8, vol 2, St Louis, 1995, Mosby; **23-24**, **23-25**, From Townsend CM et al: *Sabiston textbook of surgery*, ed 18, Philadelphia, 2010, Saunders.

CHAPTER 24

24-1*A*, **24-6*A***, From Thibodeau GA, Patton KT: *Anatomy and physiology*, ed 5, St Louis, 2003, Mosby; **24-2**, **24-6*B*** and ***C***, From Seifert PC: *Cardiac surgery*, St Louis, 1994, Mosby. Drawings by Peter Stone; **24-4**, From Levy MN, Pappano AJ: *Cardiovascular physiology*, ed 9, St Louis, 2007, Mosby; **24-5**, From Thompson JM et al: *Mosby's clinical nursing*, ed 5, St Louis, 2002, Mosby; **24-8**, **24-11**, From Canobbio M: *Cardiovascular disorders*, St Louis, 1990, Mosby; **24-9*A***, **24-34**, **24-54**, From Braunwald E et al, editors: *Heart disease*, ed 6, Philadelphia, 2001, Saunders; **24-9*B***, **24-33*B* and *C***, **24-41*A***, From Seifert PC: *Cardiac surgery*, St Louis, 1994, Mosby; **24-10**, Courtesy Edward A Lefrak, MD, Annandale, VA; **24-12**, From Kinney M, Packa D: *Andreoli's comprehensive cardiac care*, ed 7, St Louis, 1995, Mosby; **24-13**, From Brooks-Tighe SM: *Instrumentation for the operating room*, ed 4, St Louis, 1994, Mosby; **24-14**, Courtesy Scanlan International, St Paul; **24-15**, Courtesy Rultract, Inc, Cleveland; **24-16**, Courtesy Pilling Co, Fort Washington, PA; **24-17**, **24-51**, **24-68**, From Zipes DP et al: *Braunwald's heart disease: a textbook of cardiovascular medicine*, ed 7, Philadelphia, 2005, Saunders; **24-18**, Courtesy Hewlett-Packard Co, Medical Products Group, Andover, MA; **24-19**, **24-35**, **24-37**, **24-38**, **24-42**, **24-44**, **24-45**, **24-48**, **24-52**, **24-57**, **24-58**, **24-59**, **24-61**, **24-62**, **24-63**, **24-65**, **24-66**, **24-67**, **24-69**, **24-70**, **24-71**, **24-72**, **24-73**, **24-75**, **24-76**, **24-79**, From Waldhausen JA et al: *Surgery of the chest*, ed 6, St Louis, 1996, Mosby; **24-20**, **24-21**, Courtesy Meadox Medicals, a division of Boston Scientific Co; **24-22**, Courtesy WL Gore & Associates, Inc, Flagstaff, AZ; **24-23**, Courtesy of St Jude Medical, Inc, St Paul; **24-24**, Courtesy Sulzer Carbomedics, Inc, Austin, TX; **24-25**, **24-28**, **24-33*A***, Courtesy Baxter Healthcare Corp, Edwards CVS division, Santa Ana, CA; **24-26**, **24-27**, **24-32**, **24-46**, **24-74**, Copyright Medtronic, Inc, Minneapolis; **24-29**, **24-77**, **24-78**, Courtesy ATS Medical, Minneapolis, MN; **24-30**, **24-31**, Courtesy CryoLife, Inc, Marietta, GA; **24-36**, Courtesy Bard Cardiopulmonary GTC, Haverhill, MA; **24-39**, From Buxton B et al: *Ischemic heart disease surgical management*, London, 1999, Mosby; **24-40**, Courtesy Stockert Instrumente, Gmbh, Munich; Courtesy of US distributor: COBE CV, division of Sorin Biomedica, Arvada, CO; **24-47**, **24-56**, Courtesy Heartport, Inc., Redwood City, CA; **24-49**, From Doty DB: *Cardiac surgery: operative technique*, St Louis, 1997, Mosby; **24-50**, From Lytle BW et al: Coronary artery bypass grafting with the right gastroepiploic artery, *J Thorac Cardiovasc Surg* 976:826, 1989; **24-55**, Courtesy Heartport, Inc, Redwood City, CA; **24-61**, From David TE et al: Long-term results of mitral valve repair, *J Thorac Cardiovasc Surg* 115(6): 1279-1286, 1998.

CHAPTER 25

25-3, **25-4**, **25-5**, **25-37**, From Children's Hospital of Philadelphia, Philadelphia, PA; **25-6**, From Swartz MH: *Textbook of physical diagnosis: history and examination*, ed 6, Philadelphia, 2010, Saunders; **25-7**, **25-8**, **25-9**, **25-16**, **25-21**, From Coran AG et al: *Surgery of the neonate*, Boston, 1978, Little, Brown; **25-10**, **25-13**, **25-23**, **25-25**, **25-27**, **25-34**, **25-35**, **25-69**, From Holcomb GW and Murphy JP: *Pediatric surgery*, ed 5, Philadelphia, 2010, Saunders; **25-11**, Modified from Gross RE: *An atlas of children's surgery*, Philadelphia, 1970, Saunders; **25-12**, **25-18**, **25-19**, **25-22**, **25-38**, From Spitz L et al: *A colour atlas of paediatric surgical diagnosis*, London, 1990, Mosby Ltd; **25-14**, Modified from Boley SJ: An endorectal pull-through operation with primary anastomosis for Hirschsprung's disease, *Surgery, Gynecology and Obstetrics* 127(2):253, 1986; **25-15**, From Chessell G et al: *Diagnostic picture tests in clinical medicine*, vol 2, St Louis, 1984, Mosby; **25-17**, From DeVries PA: Posterior sagittal anorectoplasty. In Holmann von Kap S, editor: *Anorektale Fehlbildungen*, Stuttgart, 1984, Gustav Fischer-Verlag; **25-20**, Courtesy Dr David Clark, NeoPIX, Albany, NY; **25-24**, From Townsend CM et al: *Sabiston textbook of surgery*, ed 18, Philadelphia, 2008, Saunders; **25-26**, Courtesy H Gil Rushton, MD, Children's National Medical Center, Washington, DC. In Hockenberry MJ, Wilson D: *Wong's nursing care of infants and children*, ed 8, St Louis, 2007, Mosby; **25-28**, **25-29**, **25-33**, Modified from Droller MJ: *Surgical management of urologic disease*, St Louis, 1992, Mosby; **25-30**, From Devine CJ, Jr: Chordee and hypospadias. In Glenn JF, Boyce WH, editors: *Urologic surgery,* ed 3, Philadelphia, 1983, Lippincott; **25-36**, From Fuhrman BP, Zimmerman J: *Pediatric critical care*, ed 3, Philadelphia, 2006, Mosby; **25-39**, Courtesy Albert Biglan, MD, Children's Hospital of Pittsburgh. In Zitelli BJ, Davis HW: *Atlas of pediatric physical diagnosis,* ed 5, St Louis, 2007, Mosby; **25-40**, From Neurosurgery wound closure, Ethicon, Inc; **25-45**, **25-46**, **25-47**, From Zitelli BJ, Davis HW: *Atlas of pediatric physical diagnosis*, ed 5, St Louis, 2007, Mosby; **25-48**, Courtesy Emory University School of Medicine, Atlanta; **25-49**, **25-50**, **25-51**, **25-52**, Katowitz JA, editor: *Pediatric oculoplastic surgery*, Philadelphia, 2002, Springer; **25-53*A***, Redrawn from Chameides L: *Pediatric advanced life support*, Dallas, 1988, American Heart Association; **25-53*B***, From Barkin RM, Rosen P: *Emergency pediatrics: a guide to ambulatory care*, ed 3, St Louis, 1990, Mosby; **25-54**, **25-56**, **25-58**, **25-60**, **25-64**, From Nichols DG, Cameron DE: *Critical heart disease in infants and children*, ed 2, St Louis, 2006, Mosby; **25-55**, **25-59**, **25-61**, **25-63**, **25-65**, From Hockenberry MJ, Wilson D: *Wong's nursing care of infants and children*, ed 8, St Louis, 2007, Mosby; **25-57**, From Cooley DA, Norman JC: *Techniques in cardiac surgery*, Houston, 1975, Texas Medical Press; **25-62**, **25-66**, **25-67**, **25-68**, From Nichols DG et al: *Critical heart disease in infants and children*, St Louis, 1994, Mosby.

CHAPTER 26

26-1, **26-2**, **26-3**, From Federal Interagency Forum on Aging-Related Statistics, *Older Americans 2008: Key Indicators of Well-Being*, Federal Interagency Forum on Aging-Related Statistics, Washington, DC: U.S. Government Printing Office, available at www.agingstats.gov/agingstatsdotnet/main_site/default.aspx. Accessed March 15, 2008.

CHAPTER 27

27-1, Courtesy New Hanover Health Network EMS Air Link, EMS, Emergency Medical Services, Wilmington, NC; **27-2**, **27-14**, From McQuillan KA et al: *Trauma nursing*, ed 4, St Louis, 2009, Saunders; **27-3**, **27-11**, **27-12**, From Neff JA, Kidd PS: *Trauma nursing: the art and science*, St Louis, 1993, Mosby; **27-6**, From Grande CM: *Textbook of trauma anesthesia and critical care*, St Louis, 1993, Mosby; **27-7**, From Brohi K: www.trauma.org, available at www.trauma.org/index.php/search/image_results/3af7210b6a3eb8cf1bb9b55839a3070d/. Accessed December 2009; **27-8**, From Cosgriff H, Jr, Anderson DL: *The practice of emergency care*, ed 2, Philadelphia, Lippincott; **27-9**, Redrawn from Kintzel KC: *Advanced concepts in clinical nursing*, ed 2, Philadelphia, 1997, Lippincott; **27-10**, Redrawn from Becker DP et al: Diagnosis and treatment of head injury. In Youman JR, editor: *Neurological surgery*, ed 3, Philadelphia, 1990, Saunders; **27-13**, Courtesy Haim Paran, MD; **27-15**, From Townsend CM et al: *Sabiston textbook of surgery*, ed 18, Philadelphia, 2008, Saunders.

CHAPTER 28

28-1, Courtesy Philips Medical Systems. In Bontrager KL, Lampignano JP: *Textbook of radiographic positioning and related anatomy*, ed 7, St Louis, 2010, Mosby; **28-2**, **28-4**, **28-5**, From Bontrager KL, Lampignano JP: *Textbook of radiographic positioning and related anatomy*, ed 7, St Louis, 2010,

Mosby; **28-3,** Courtesy ACIST Medical Systems, A Bracco Company. In Bontrager KL, Lampignano JP: *Textbook of radiographic positioning and related anatomy*, ed 7, St Louis, 2010, Mosby.

CHAPTER 29

29-1, From Rothrock JC: *Perioperative care planning*, St Louis, 1996, Mosby; **29-2,** From Skidmore-Roth L: *Mosby's handbook of herbs and natural supplements*, ed 3, St Louis, 2006, Mosby; **29-3,** From Jonas WB: *Mosby's dictionary of complementary and alternative medicine*, St Louis, 2005, Mosby; **29-4,** Modified from McCance KL, Huether SE: *Pathophysiology: the biologic basis for disease in adults and children*, ed 6, St Louis, 2010, Mosby.

CHAPTER 30

30-1, From AORN Guidance Statement: Safe Patient Handling and Movement in the Perioperative Setting. Copyright 2007 AORN, Inc. Used with permission. All rights reserved; **30-2,** From Nancy Hughes, 2009, American Nurses Association; **30-3, 30-4,** From International Healthcare Worker Safety Center, 2005, University of Virginia.

Pharmacology Index

A
Absorbable gelatin sponge, 859-860, 1227
Acetaminophen, 284
Acetazolamide sodium, 623
Acetylcholine chloride, 621
Activase. *See* Tissue plasminogen activator
Adenosine, 1033, 1143
Adrenalin. *See* Epinephrine
Alfentanil (Alfenta), 125, 1032
Amidate. *See* Etomidate
Amiodarone, 1143
Amobarbital sodium (Amytal), 1226
Ampicillin, 306
Amrinone, 1032
Amvisc. *See* Sodium hyaluronate
Anaprox. *See* Naproxen sodium
Ancef. *See* Cefazolin
Anectine. *See* Succinylcholine
Ardeparin, 743
Aristocort. *See* Triamcinolone acetonide
Aspirin, 284
Ativan. *See* Lorazepam
Atracurium, 125, 1032
Atropine sulfate, 127, 621, 1032, 1143
Avitene. *See* Collagen hemostat

B
Bacitracin, 675, 901, 1033
Balanced salt solution, 622, 650
Benadryl. *See* Diphenhydramine
Benzocaine, 674
Benzocaine/tetracaine/butamben, 674
Betamethasone sodium phosphate and betamethasone acetate suspension, 622
Bivalirudin, 1033
B&O suppository, 490
Brethine. *See* Terbutaline
Bretylium (Bretylol), 1033
Brevital. *See* Methohexital
Brevital sodium. *See* Sodium methohexital
Bupivacaine, 126, 135, 138, 407, 621
Buprenorphine (Buprenex), 285
Butorphanol, 285

C
Calan. *See* Verapamil
Calcilean. *See* Heparin
Calciparine. *See* Heparin
Calcium chloride, 1032, 1143
Carbachol, 621
Carbocaine. *See* Mepivacaine
Cefadyl, 1033
Cefazolin, 622, 1033
Ceftazidime, 622
Celecoxib, 284
Celestone. *See* Betamethasone sodium phosphate and betamethasone acetate suspension
Cephalosporins, 1033
Cervidil. *See* Dinoprostone
Cetacaine. *See* Benzocaine/tetracaine/butamben
Chloroprocaine, 126
Choline magnesium trisalicylate, 284
Cisatracurium, 125, 1207
Clindamycin, 306
Cocaine, 622, 674
Codeine, 285
Collagen hemostat, 859
Cortisporin Otic Suspension. *See* Neomycin and polymyxin B sulfates and hydrocortisone
Coumadin. *See* Warfarin
Cyclopentolate (Cyclogyl), 621
Cytotec. *See* Misoprostol

D
Danaparoid, 743
Dantrolene (Dantrium), 140-141
DDAVP. *See* Desmopressin
Decadron. *See* Dexamethasone
Demerol. *See* Meperidine hydrochloride
DepoDur, 125
Depo-Medrol. *See* Methylprednisolone acetate suspension
Desflurane, 122, 124, 1032
Desirudin, 743
Desmopressin, 1033
Dexamethasone, 622
Dexmedetomidine, 127
Diamox. *See* Acetazolamide sodium
Diazepam, 126, 1033, 1229
Diflunisal, 284
Digoxin, 1033
Dilantin. *See* Phenytoin
Dilaudid. *See* Hydromorphone
Dinoprostone, 469
Diphenhydramine, 1226
Diprivan. *See* Propofol
Disalcid. *See* Salsalate
Dizac. *See* Diazepam
Dobutamine (Dobutrex), 1032, 1143
Dolobid. *See* Diflunisal
Dolophine. *See* Methadone
Dopamine hydrochloride, 1032, 1143
Doxacurium, 1032
Doxycycline, 953
Droperidol, 277
Duranest. *See* Etidocaine

E
Endosol. *See* Balanced salt solution
Enflurane, 124, 1032
Enoxaparin, 743
Ephedrine, 1032
Epinephrine, 138, 368, 621, 675, 1032, 1143
Ertapenem, 306
Estrace cream. *See* Estradiol cream
Estradiol cream, 471
Ethrane. *See* Enflurane
Etidocaine, 621
Etodolac, 284
Etomidate, 126, 1198

F
Faslodex. *See* Fulvestrant
Fenoprofen calcium, 284
Fentanyl, 125, 1032, 1229
Flomax. *See* Tamsulosin
FloSeal. *See* Gelatin matrix
Flumazenil, 1230
Fluorescein, 622
5-Fluorouracil, 622, 645
Fluothane. *See* Halothane
Flurbiprofen, 284
Forane. *See* Isoflurane
Fortaz. *See* Ceftazidime
Fulvestrant, 596
Furosemide, 1033, 1207

G
Garamycin. *See* Gentamicin sulfate
Gelatin matrix, 859
Gelfoam. *See* Absorbable gelatin sponge
Gentamicin sulfate, 306, 622
Glucagon, 1226
Glycerin, 622
Glycopyrrolate, 127, 1032
Glyrol. *See* Glycerin
Gonioscopic Prism Solution. *See* Hydroxyethylcellulose
Goniosol. *See* Hydroxypropyl methylcellulose

H
Halothane, 124, 1032
Healon. *See* Sodium hyaluronate
Helistat. *See* Collagen hemostat
Heparin, 743, 981, 1033, 1226
Herceptin. *See* Trastuzumab
Hexabrix. *See* Ioxaglate
Homatropine hydrobromide, 621
Hyaluronidase, 621
Hydromorphone, 285, 1229
Hydroxyethylcellulose, 621
Hydroxypropyl methylcellulose, 621

I
Ibuprofen, 284
Inocor. *See* Amrinone
Instat. *See* Collagen hemostat
Insulin, 1033
Intropin. *See* Dopamine hydrochloride
Iodixanol, 1230
Iodopovidone, 953
Ioxaglate, 1230
Iprivask. *See* Desirudin
Isoflurane, 124, 1032
Isoproterenol (Isuprel), 1032
Isoptin. *See* Verapamil
Isopto Carbachol. *See* Carbachol
Isopto Homatropine. *See* Homatropine hydrobromide
Isopto Hyoscine. *See* Scopolamine hydrochloride

K
Keflex, 1033
Keflin, 1033
Kefzol. *See* Cefazolin
Kenalog. *See* Triamcinolone acetonide
Ketamine (Ketalar), 126
Ketoprofen, 284
Ketorolac, 284

L
Lanoxin. *See* Digoxin
Lapatinib, 596
Lasix. *See* Furosemide
Levophed. *See* Norepinephrine
Levorphanol (Levo-Dromoran), 285
Lidocaine/lidocaine hydrochloride, 126, 138, 407, 621, 674, 1033, 1143
Linezolid, 54
Lodine. *See* Etodolac
Lorazepam, 1032, 1206, 1229
Lorcet. *See* Hydromorphone
Lovenox. *See* Enoxaparin
Lymphazurin, 605

M
Mafenide acetate, 901
Magnesium salicylate, 284
Magnesium sulfate, 470, 1143
Mandol, 1033
Mannitol, 622, 1033, 1205, 1207
Marcaine. *See* Bupivacaine
Maxitrol ointment or suspension. *See* Neomycin and polymyxin B sulfates and dexamethasone
Meclofenamate sodium (Meclomen), 284
Meperidine hydrochloride, 285, 897
Mepivacaine, 621

Metformin, 1218-1219
Methadone, 285
Methohexital, 1032
Methotrexate, 470
Methylene blue, 471, 490
Methylergonovine maleate (Methergine), 469
Methylprednisolone acetate suspension, 622
Metoclopramide, 280
Metrizamide, 1228, 1230
Metronidazole, 306
Miconazole nitrate cream, 471
Midazolam, 116, 126, 1032, 1093, 1206, 1229
Milrinone, 1032
Minocycline, 953
Miochol-E. *See* Acetylcholine chloride
Miostat. *See* Carbachol
Misoprostol, 471
Mitomycin, 622
Mivacurium (Mivacron), 125
Monistat. *See* Miconazole nitrate cream
Morphine liposomal. *See* DepoDur
Morphine sulfate, 125, 285, 897, 1032, 1229
Motrin. *See* Ibuprofen
Mucomyst. *See N*-acetylcysteine
Mupirocin, 675
Mutamycin. *See* Mitomycin
Mydfrin. *See* Phenylephrine
Mydriacyl. *See* Tropicamide

N

N-acetylcysteine, 1226, 1232
Nalbuphine, 285
Nalfon. *See* Fenoprofen calcium
Naloxone (Narcan), 281, 1033, 1143, 1230
Naproxen (Naprosyn), 284
Naproxen sodium, 284
Naropin. *See* Ropivacaine
Nasal Bactroban. *See* Mupirocin
Nebcin. *See* Tobramycin
Neomycin and polymyxin B sulfates and dexamethasone, 622
Neomycin and polymyxin B sulfates and hydrocortisone, 675
Neosporin ointment. *See* Polymyxin B/neomycin/bacitracin
Neostigmine, 127
Neo-Synephrine. *See* Phenylephrine
Nesacaine. *See* Chloroprocaine
Nifedipine, 1033
Nimbex. *See* Cisatracurium
Nitric oxide, 1033
Nitroglycerin, 1032, 1226
Nitroprusside (Nipride), 1032
Nitrous oxide, 124
Norcuron. *See* Vecuronium
Norepinephrine, 1032
Nubain. *See* Nalbuphine
Numorphan. *See* Oxymorphone

O

Occucoat. *See* Hydroxypropyl methylcellulose
Ondansetron, 278
Ophthaine. *See* Proparacaine hydrochloride
Orudis. *See* Ketoprofen
Osmitrol. *See* Mannitol
Osmoglyn. *See* Glycerin
Oxaprozin, 284
Oxidized regenerated cellulose, 859-860
Oxycodone, 285
Oxymetazoline hydrochloride, 675
Oxymorphone, 285
Oxytocin, 469

P

Pancuronium (Pavulon), 126, 1032
Papaverine hydrochloride, 982, 1033, 1226
Parecoxib sodium, 280, 743
Pentazocine, 285
Pentothal. *See* Thiopental
Percocet. *See* Oxycodone
Percodan. *See* Oxycodone
Phenobarbital, 1207
Phentolamine, 1032
Phenylephrine, 621, 1032
Phenytoin, 1206
Pilocarpine hydrochloride, 621
Pipecuronium, 1032
Pitocin. *See* Oxytocin
Pitressin. *See* Vasopressin
Polymyxin B/bacitracin, 622, 901
Polymyxin B/neomycin/bacitracin, 622
Polysporin ointment. *See* Polymyxin B/bacitracin
Pontocaine. *See* Tetracaine hydrochloride
Precedex. *See* Dexmedetomidine
Primacor. *See* Milrinone
Procainamide (Pronestyl), 1033
Procardia. *See* Nifedipine
Proparacaine hydrochloride, 621
Propofol, 126, 128, 137, 1032, 1207
Propranolol, 1204
Prostaglandin E_1 (Prostin VR), 1032
Prostigmine. *See* Neostigmine
Protamine sulfate, 981, 1033
Provisc. *See* Sodium hyaluronate

Q

Quelicin. *See* Succinylcholine
Quinidine, 1033

R

Regitine. *See* Phentolamine
Remifentanil, 125, 1032
Ritodrine, 470
Robinul. *See* Glycopyrrolate
Rocuronium, 126, 1032
Romazicon. *See* Flumazenil
Ropivacaine, 127, 407
Roxicodone. *See* Oxycodone

S

Salsalate, 284
Scopolamine hydrochloride, 621, 1032
Sensorcaine. *See* Bupivacaine
Sevoflurane, 122, 124, 1032
Silver nitrate, 901, 953
Silver sulfadiazine (Silvadene), 901
Sodium bicarbonate, 1143
Sodium chondroitin/sodium hyaluronate, 621
Sodium hyaluronate, 621
Sodium methohexital, 126
Sodium salicylate, 284
Sofarin. *See* Warfarin
Stadol. *See* Butorphanol
Sublimaze. *See* Fentanyl
Succinylcholine, 125, 128, 277, 1032, 1198
Sufentanil (Sufenta), 125, 1032
Sulfamylon. *See* Mafenide acetate
Sulfathiazole/sulfacetamide/sulfabenzamide cream, 471
Suprane. *See* Desflurane
Surgicel. *See* Oxidized regenerated cellulose

T

Talc, 952
Talwin. *See* Pentazocine
Tamoxifen, 596
Tamsulosin, 642
Taxicef. *See* Ceftazidime
Tazidime. *See* Ceftazidime
Telavancin, 54
Terbutaline, 470
Tetracaine hydrochloride, 127, 621, 674
Tetracycline, 306
Thiopental, 126, 128, 1032, 1207
Thrombin, 859-860
Tigecycline, 56
Timolol maleate (Timoptic), 623
Tissue plasminogen activator, 622
Tobramycin, 306, 1033
Tobramycin/dexamethasone (TobraDex), 622
Tracrium. *See* Atracurium
Trastuzumab, 596
Triamcinolone acetonide, 675
Tridil. *See* Nitroglycerin
Trilisate. *See* Choline magnesium trisalicylate
Triple Sulfa. *See* Sulfathiazole/sulfacetamide/sulfabenzamide cream
Tropicamide, 621
Tubocurarine, 126
Tygacil. *See* Tigecycline
Tylox. *See* Oxycodone

U

Ultane. *See* Sevoflurane
Ultiva. *See* Remifentanil

V

Valium. *See* Diazepam
Vancomycin, 306, 1033
Vasopressin, 471, 490, 1226
Vecuronium, 126, 1032, 1207
Verapamil, 1033
Versed. *See* Midazolam
VisCoat. *See* Sodium chondroitin/sodium hyaluronate
Visipaque. *See* Iodixanol
Vitrax. *See* Sodium hyaluronate

W

Warfarin, 743

X

Xylocaine. *See* Lidocaine/lidocaine hydrochloride

Y

Yutopar. *See* Ritodrine

Z

Zemuron. *See* Rocuronium
Zyvox. *See* Linezolid

Index

A

Abbreviations, 30t
Abdomen
  packing of, 1204–1205
  postoperative assessment of, 270
  traumatic injuries of, 1211–1212
  wound closure techniques, 1212, 1212f
Abdominal aortic aneurysms
  description of, 972, 973f
  endovascular repair of, 985t–986t, 987–989, 989f
  resection of, 985–987, 985t–986t, 988f
  Abdominal cerclage, 472–473
Abdominal compartment syndrome, 1192–1193, 1193f
Abdominal hernia. See also specific hernia
  anatomy of, 399
  repair of, 415–417
Abdominal hysterectomy, total, 455–458
Abdominal incisions, 311–315
Abdominal myomectomy, 458, 458f
Abdominal surgery
  early feeding after, 310b
  in elderly, 1178
  incisions. *See* Abdominal incisions
  pediatric, 1111–1113
Abdominal wall
  anterior, 399
  description of, 312, 313f
Abdominoperineal resection, 348–350, 349f
Abdominoplasty, 926–927
Abducens nerve, 833–834, 836t
Ablation
  endometrial. *See* Endometrial ablation
  transrectal cryosurgical ablation of the prostate gland, 526–527
  transurethral laser, of bladder tumors, 536f, 537
  transurethral needle, 519, 520f
Above-knee amputation, 992, 994f
Above-knee popliteal artery, 990
Abscess
  breast, 603
  liver, 387
  spinal epidural, 842–843
Absorbable collagen, 368t
Absorbable gelatin, 368t
Absorbable sutures, 176t, 177–180
Abuse
  child, 1089, 1090b
  elder, 1162b
Accelerated partial breast irradiation, 590–592
Accessory instruments, 198, 198f
Accessory reproductive glands, 481
Acetabulum
  anatomy of, 724–725
  fractures of, 761–762, 763f
Acetylcholine, 844, 1248f
Acoustic nerve, 834–835, 836t
Acoustic neuroma, 689–690, 826
Acromioclavicular joint
  anatomy of, 722–723, 722f
  separation of, 750, 751f
Activated clotting time, 981
Activated partial prothrombin time, 301t–303t, 1017t, 1190b–1191b
Active electrode monitoring, 246, 246f
Acute arterial insufficiency, 973
Acute ischemic stroke, 863
Acute otitis media, 682
Acute pain
  assessment of, 283b, 287f
  description of, 139
  management of. *See* Pain management
  physiologic effects of, 282
  postoperative, 280–283, 281f–282f, 283b, 284t
  reassessment of, 283b
Acute renal failure, 390t
Acute venous insufficiency, 975
Acute-care nurse practitioners, 16
Adapters, 219–221, 220f
Adenoidectomy, 1125–1127
Adhesiolysis, 315–316
Adhesion(s)
  definition of, 254b
  laparotomy-induced, 315–316
  prevention of, 316
  treatment of, 316
Adhesion-related disorder, 316
Adhesives, for wound closure, 185
Adjustable gastric banding, 336, 337f
Adjustable pressure-limiting valve, 122
Adolescents
  bariatric surgery in, 1100–1101, 1101b
  development-based concerns of, 1092–1093
  obesity in, 1100
Adrenal glands, 478
Adrenalectomy, 563–564
Advanced cardiac life support, 137
Advanced practice nurses, 15–16
Advancement flaps, 906–907
Adverse events, 18–19, 947b
Advocacy, 9b
Aeration, 49b, 79
Aerobes, 49b
Aesthetic surgery, 918–933
Aflatoxin, 362t
Afterload, 1015b
Agency for Healthcare Research and Quality, 25b
Aging population, 1157, 1158b, 1158f–1159f
AHRQ. *See* Agency for Healthcare Research and Quality
Airbags, 1185b
Airborne contamination, 89
Airborne precautions, 63–64
Airway
  artificial, 272, 275f
  difficult, 130, 131b
  laryngeal mask, 128, 130, 132f
  obstruction of, 272, 275f, 962f
  oropharyngeal, 275f
  pediatric, 1085, 1144–1145
  transtracheal, 131b
  trauma-based interventions, 1187
Alanine aminotransferase, 363t
Albumin, 301t–303t, 363t
Albumin/globulin ratio, 363t
Alcohol
  as disinfectant, 82
  hand rubs that contain, 93
Alginates, 264t–265t
Alkaline phosphatase, 301t–303t, 363t
Allergic contact dermatitis, 98, 1278
Allis-Adair forceps, 436
AlloDerm, 262t, 893f
Allografts
  aortic valve, 1026, 1027f, 1028t
  description of, 743–744
Alopecia, pressure, 149–150
Alpha fetoprotein, 363t
Alternating current, 241
Alternative therapies. *See* Complementary and alternative therapies
Alvarado foot holder, 732, 732f
Amanita phalloides, 362t
Amaurosis fugax, 973–975
American Association of Blood Banks, 41
American Association of Nurse Anesthetists, 114b
American Association of Tissue Banks, 743
American College of Radiology, 1278
American National Standards Institute, 233
American Nurses Association, 3
American Society of Anesthesiologists
  physical status classification, 115, 116t, 268, 948b, 1168
  Practice Guidelines for Management of the Difficult Airway, 131b
  Standards for Basic Anesthetic Monitoring, 118
  Standards for Postanesthesia Care, 268–269
American Society of Perianesthesia Nurses, 267
American Urological Association, 513, 514b
Ammonia, 301t–303t
Amnesiacs, 1032t–1033t, 1206t–1207t
Amniotic fluid embolism, 476b
Ampulla of Vater, 357, 359
Amputations, 992–994
  above-knee, 992, 994f
  indications for, 992
  operative procedure for, 992–994, 994f
  procedural considerations, 992
  replantation of body parts, 912–913
Amylase, 301t–303t, 364t
Anaerobes, 49b
Anal canal, 299
Anal transposition, for low imperforate anus, 1107–1108, 1107f
Analgesia
  conscious, 118, 137–138
  continuous epidural, 139
  epidural
    continuous, 139
    patient-controlled, 310
    postoperative pain management using, 281
  interventional radiology, 1227–1228, 1229t–1230t
  patient-controlled, 280–281, 286
  spinal, 281
Analgesics, 1032t–1033t
  nonopioid, 284t, 291b
  opioid. *See* Opioids
Anaphylactic reaction, 605b
Anaphylactic shock, 605b
Anatomic medullary locking hip system, 784–787, 785f–787f
Ancillary instruments, 198, 198f
Andrews bed, 732, 733f
Andrews table, 855
Anesthesia
  ambulatory surgery, 116b
  awareness during, 113–114, 114b
  bronchoscopy, 949–950
  cardiac surgery, 1030
  caudal, 134–135, 134f
  choice of, 115–116
  conscious sedation/analgesia, 118, 137–138
  endometrial ablation, 450
  endoscopic minimally invasive surgery, 226
  epidural, 134–135, 134f
  equipment used in, 129f
  examination under, 430
  family education about, 115t
  general. *See* General anesthesia
  geriatric surgery, 1163b, 1171–1173
  history of, 111, 112b
  hypothermia secondary to, 139
  induction phase of, 124–128, 142
  intraoperative awareness, 113–114, 114b
  laparoscopy, 303–305
  laryngeal surgery, 676
  local. *See* Local anesthesia/anesthetics
  malignant hyperthermia caused by, 128, 139–141, 140b–141b
  monitored anesthesia care, 113–114, 118, 137, 686
  neurosurgery, 851–852
  nursing considerations, 141–142
  ophthalmic surgery. *See* Ophthalmic surgery, anesthesia for
  otorhinolaryngologic surgery, 672–676, 674t–675t
  pain management, 138–139
  patient safety during, 113
  pediatric surgery, 1093–1094, 1094t
  pelvic examination under, 430
  perioperative monitoring, 118–121
  plastic and reconstructive surgery, 893–894
  postoperative nausea and vomiting, 117, 117b
  premedications, 116–117
  preoperative preparation, 114–117, 115t

Page numbers followed by f, t, or b indicate figures, tables, or boxes, respectively.

Anesthesia *(Continued)*
regional. *See* Regional anesthesia
risks associated with, 114–115
spinal, 133–134
temperature control during, 139, 140b
thoracic surgery, 944
types of, 117–118
word origin of, 111
Anesthesia care team, 113
Anesthesia gases, 121–123
Anesthesia machines, 121–123
computerized monitoring in, 120
illustration of, 121f
oxygen flush valve, 122
semiclosed-circle system, 122–123
volumeters on, 123
Anesthesia providers, 111–113
Anesthesiologist, 111–113
Anesthesiologist's assistant, 111–113
Aneurysms
abdominal aortic
description of, 972, 973f
endovascular repair of, 985t–986t, 987–989, 989f
resection of, 985–987, 985t–986t, 988f
aortic arch, 1069–1070, 1071f
arterial, 971–972
causes of, 1066
definition of, 871
description of, 829–830
dissecting, 971–972
false, 971–972
fusiform, 1068
intracranial, 871–872, 871f
pathogenesis of, 971–972
ruptured, 863b
saccular, 1068
surgery for, 871–872, 871f
thoracic aortic. *See* Thoracic aortic aneurysms
true, 971–972
Angina pectoris, 1009, 1009b
Angiography, 846, 976–977, 1013, 1014f, 1222b
Ankle
anatomy of, 727, 728f
arthroscopy of, 808–809
fractures of, 776–778, 778f
surgery of, 776–780
total arthroplasty of, 798, 800f
Ankle block, 135
Ankle distractor, 732, 733f
Annuloplasty
mitral, 1060–1061, 1061f
tricuspid valve, 1063–1064
Annuloplasty rings, 1030f
Anorectoplasty, posterior sagittal, 1108, 1109f
Antegrade cardioplegia, 1049
Anterior abdominal wall, 399
Anterior cerebral artery, 828, 829f
Anterior cervical decompression and fusion, 876–877, 876f
Anterior cruciate ligament repair, 774–775, 804–806, 805f–806f
Anterior segment
anatomy of, 611–612
vitrectomy of, 645
Anterior spinal artery, 838–840
Anterior spinal fusion with Isola instrumentation, 813–814
Anterior thoracic surgery, 877
Anterolateral thoracotomy, 1052t–1053t
Anthrax, 65t–66t
Antibiotics
appendicitis treated with, 340b
drug-resistant bacteria caused by misuse of, 55–56
in irrigation solutions, 742
prophylactic use of
before cardiac surgery, 1030–1031
before gastrointestinal surgery, 305, 306t
before neurosurgery, 852
before total joint arthroplasty, 782
types of, 1032t–1033t
Anticholinergics, 124t–127t, 1032t–1033t
Anticoagulants/anticoagulation therapy, 742t, 984b, 1032t–1033t, 1226
Anticonvulsants, 1206t–1207t
Antidysrhythmics, 1046t
Antihypertensive drugs, 275
Antimetabolites, 469t–471t
Antimicrobial prophylaxis, 257, 258b
Antireflux procedure, 324–325
Antisepsis, 255b–257b
Antiseptics, 81
Anus, imperforate. *See* Imperforate anus repair
Anxiety, 1249
Aortic anastomoses, 1055–1056
Aortic aneurysms
abdominal. *See* Abdominal aortic aneurysms
aortic arch, 1069–1070, 1071f
thoracic. *See* Thoracic aortic aneurysms
Aortic cannulation, 1037f
Aortic dissection, 1013, 1014f, 1068–1069, 1069f, 1069t
Aortic insufficiency, 1065
Aortic stenosis, 1065
Aortic valve
allografts, 1026, 1027f
anatomy of, 1006, 1007f
congenital anomalies of, 1065
enlargement of, 1068f
replacement of, 1066, 1067f
surgery of, 1065–1066, 1067f
Aortic-caval cannulation, 1047–1048
Aortography, 1014f, 1016t
Apert's syndrome, 1135, 1135f
Apgar score, 12b
Apligraf (skin substitute), 262t
Appendectomy
antibiotic therapy vs., for appendicitis, 340b
laparoscopic, 340–341
open, 339–340
Aqueduct of Sylvius, 827
Aqueous glutaraldehyde sterilization, 80
Aqueous humor, 611–612
Aqueous shunts, 647b
Arachnoid, 820, 820f
Areola, 588
Argon fluoride, 232
Argon laser, 231–232
Argon-enhanced electrosurgery, 246
Arm, 723f
Armboards, 166, 166f, 366, 406–407, 428–430, 733, 855, 894
Aromatase inhibitors, 596
Aromatherapy, 1247–1248, 1249t
Arterial blood gases, 301t–303t, 941t, 1017t, 1187, 1188t
Arterial conduits, coronary artery bypass grafts with, 1054–1057
Arterial disease
aneurysms. *See* Aneurysms
arterial insufficiency. *See* Arterial insufficiency
Arterial embolectomy, 992, 993f
Arterial insufficiency
acute, 973
cerebrovascular disease, 973–975
chronic, 973
peripheral vascular disease, 975–977
stroke, 973–975
Arterial reconstructive procedures, 985t–986t
Arterial tube grafts, 1024, 1024f
Arteries
anatomy of, 969, 970f–972f
of brain, 973–975, 974f
Arteriography, 976–977
Arteriosclerosis, 1066
Arteriovenous fistula, 996–998, 997f–998f
Arteriovenous malformations
craniotomy for, 872
definition of, 872
description of, 830, 861
endovascular embolization of, 862
surgery for, 872
Arteriovenous shunts, 997
Arthroplasty, 781–800
Arthroscopy, 800–809
Artificial airway, 272, 275f
Artificial disc replacement, 814–815
Artificial urinary sphincter, 546f–547f
As low as reasonably achievable principle, 1220, 1277
Ascending aortic cannulation, 1047
Ascending aortic dissection, 1013, 1014f
Ascending colon, 297–298, 298f
Ascending thoracic aortic aneurysms, 1069, 1070f
Asepsis/aseptic principles and techniques, 57, 85–88
definition of, 57
genitourinary surgery, 487
geriatric surgery, 1173–1174
liver surgery, 369
origins of, 85
pancreatic surgery, 369
skin antisepsis, 101–104, 103f
splenic surgery, 369
surgical attire, 90–93, 91f
gloves. *See* Gloves; Gloving
gowns, 86–87
masks, 91–93, 92f
traffic control, 88–90
Aspartate aminotransferase, 363t
Aspiration
of foreign bodies, 1125, 1126f
pulmonary, 278–280, 280t
Assessments
data collection for, 5
definition of, 5
in nursing process, 5–7
postanesthesia care unit, 267–270, 270f, 270b, 272f
Assisted circulation, 1072–1076
Assisted gowning, 98, 98f
Assisted hatching, 468t
Assisted reproductive therapies, 466–467, 468t
Assisted-gloving technique, 99, 101f
Assistive hearing devices, 690–692
cochlear implantation, 690–691, 690b, 691f
hearing aids. *See* Hearing aids
Association for Radiologic and Imaging Nursing, 1216
Association of Perioperative Registered Nurses
description of, 1, 888
documentation recommendations by, 23, 30b
founding of, 18
perioperative nursing standards, 3–4, 4b
Perioperative Patient Focused Model, 2–3, 4f, 10–11
Perioperative Standards and Recommended Practices, 625
Quality and Performance Improvement Standards for Perioperative Nursing, 5
Recommended Practices for Documentation of Perioperative Nursing Care, 138
Recommended Practices for Sponge, Sharp, and Instrument Counts, 34–36, 36b
safety emphasis of, 18
safety promotion by, 23
Standards of Perioperative Administrative Practice, 3–4
Standards of Perioperative Clinical Practice, 4
Standards of Professional Practice, 4–5
Asthma, 962f
Astrocytomas, 825–826
Atherosclerosis, 969, 973b, 1066
Atria, 1002, 1003f–1004f
Atrial fibrillation
description of, 567–568, 1077–1078
Maze procedure for, 1078, 1078f
Atrial natriuretic peptide, 1010
Atrial septal defect, 1146–1147, 1146f–1147f
Atrioventricular node, 1006f
Atrioventricular valve, 1006, 1007f
Attire, surgical, 90–93, 91f
gloves. *See* Gloves
masks, 91–93, 92f
Audiogram, 668
Augmentation mammoplasty, 928, 929f
Autoexposure, 217b
Autogenous vein grafting, 982
Autografts, 743–744
Autologous blood products, 42, 1197
Automatic gain control, 217b
Automatic staplers, 308–309
Automatic washer-sterilizer, 69
Autonomic nervous system, 843–844
Autotransfusion, 42, 1197
Avulsion fracture, 746
Awareness, intraoperative, 113–114, 114b
Axial pattern flaps, 906–907
Axillary artery cannulation, 1048–1049, 1049b
Axillary node dissection, 605–606, 606f
Axillofemoral graft, 997
Axons, 818, 819f
Ayurveda, 1241

B

Babcock clamp, 195
Bacille Calmette-Guérin, 537
Bacillus anthracis, 65t–66t
Bacillus atrophaeus, 79–81
Back injuries, 1258
Back pain, 809, 1165, 1223b
Bacteria
clostridia, 51
drug-resistant, 55–56
enterococci, 50
gram-negative, 50f
gram-positive, 48, 50f
Mycobacterium tuberculosis, 51–52
staphylococci. *See* Staphylococci
streptococci, 51
surgical site infections caused by, 48
Baker cyst, 775
Balanced anesthesia, 127
Balloon angioplasty, 1222b
Balloon endometrial ablation, 450
Balloon kyphoplasty, 815b
Balloon pumping, 1072, 1073f
Bankart procedure, 753, 753f
Barbed suture, 180
Barbiturates, 1206t–1207t
general anesthesia uses of, 128
Bar-code technologies
medication administration use of, 39
retained foreign object prevention using, 36
Bariatric surgery, 336–337
body contouring after, 927–928, 927f–928f
pediatric, 1100–1101, 1101b
Roux-en-Y gastric bypass, 337, 338f–340f, 1101
Bariatric trauma, 1200–1201, 1201b
Barrett's esophagus, 323
Bartholin's glands
anatomy of, 419
cyst in, 446, 447f
Basal cell carcinoma, 897, 900f
Basal ganglia, 824, 824f
Basilar skull fractures, 819
Basophil, 301t–303t
Basophilic adenomas, 826
Bassini repair, of hernia, 408
Beating heart surgery, 1055–1056

Bed sores. *See* Pressure ulcers
Beds. *See* Operating room beds
Behavioral observational pain scale, 1095b
Bell's palsy, 834
Below-knee revascularization, 990b
Belt lipectomy, 927f, 928
Benign adenomas, 577
Benign cystic teratomas, 462
Benign prostatic hyperplasia, 481, 511, 1179
Benner, Patricia, 5b
Bentall-DeBono procedure, 1068, 1070f
Benzene, 362t
Benzodiazepines, 1206t–1207t, 1229t–1230t
Beryllium, 362t
Bicarbonate, 301t–303t
Bier block, 136
Bile
  composition of, 357–358, 372b
  gallbladder storage of, 359
  hepatocyte production of, 357, 359
  stasis of, 372b
Bile canaliculi, 357
Biliary atresia, 1111–1112, 1112f
Biliary drainage and stenting, 1222b
Biliary system
  anatomy of, 357–358, 359f
  arterial supply of, 373f
  endoscopic retrograde cholangiopancreatography of, 361, 364f
Biliary tract surgery
  asepsis, 369
  blood products, 369–370
  cholecystectomy. *See* Cholecystectomy
  cholecystoduodenostomy. *See* Cholecystoduodenostomy
  cholecystojejunostomy, 380
  cholecystostomy, 377–378
  choledochojejunostomy, 380, 381f
  common bile duct exploration, 378–379
  discharge planning and instructions, 370–371, 370t
  drainage materials, 369
  draping of patient, 368
  evaluation, 370
  family education, 370–371
  hemostatic agents, 368t
  implementation, 364–371
  instrumentation, 368–369
  nursing considerations, 361–371
  nursing diagnoses, 362
  outcome identification, 362
  pain management, 371
  patient education, 370–371
  patient positioning for, 366
  plan of care, 365b–366b
  planning, 362–364
  sequential compression devices for, 367–368
  thermoregulation during, 367
  transduodenal sphincteroplasty, 380–381, 382f
Biliopancreatic diversion, 337, 340f
Bilirubin, 363t
Billroth I gastrectomy, 330–332, 332f
Billroth II gastrectomy, 332, 333f
Biobrane (skin substitute), 262t
Bioburden, 49b
Biofields, 1244, 1245t–1246t
Biofilm, 49b
Biohazard label, 61f
Biologic variation, 1222b
Biological indicators, 49b, 75, 75t
Biologically based therapies, 1241–1242, 1245f
Biomedicine, 1240
Bioprostheses, 1024–1025, 1026f
Biopsy. *See also* Core needle biopsy; Excisional biopsy; Fine-needle aspiration biopsy
  breast, 602–603
  cervical, 445, 446f
  endometrial, 446f
  excisional, 602
  incisional, 602
  lung, 964–965
  open breast, 602–603
  prostatic, 514
  sentinel lymph node, 603–605
  testicular, 510
  transperineal, 514
  transrectal, ultrasonically guided, 514
Bioterrorism, 48, 64–66, 65t–66t
Bipolar coagulation unit, 891–892
BI-RADS scores, 592, 593b
Bispectral index system, 114
Biting-tip forceps, 950–951
Black cohosh, 1253t–1255t
Bladder
  anatomy of, 479, 482f
  augmentation of, 544–545, 545f
  blood supply of, 479
  capacity of, 478
  distention of, 479, 483f
  substitution of, 547–549
  traumatic injury of, 1212–1213
  trigone, 479, 482f
  visualization of, 487
Bladder cancer, 537
Bladder surgery, 535–551
  exstrophy repair, 1119–1120
  urinary diversions. *See* Urinary diversions
  vesical fistula repair, 537–540
  vesicourethral suspension, 540
Bladder tumors
  transurethral laser ablation of, 536f, 537
  transurethral resection of, 536–537, 537f
Blanching, 449
Blast trauma, 1186, 1186t
Blepharoplasty
  dermatochalasis of upper eyelid treated with, 634–635
  description of, 920–921, 921f
  involutional entropion of lower eyelid treated with, 633
  transconjunctival, 635
Blood alcohol level, 1189
Blood exposure, in workplace, 1271f–1272f
Blood flow, 969–970
Blood loss
  estimation of, 1199t
  liver transplantation, 391
  measurement of, 39–40, 40b
  surgical sponge weighing used to estimate, 39–40, 40b
Blood pressure, 1012–1013, 1145b
Blood products
  autologous, 42
  blood volume maintenance using, 40–42
  fresh frozen plasma, 40
  history of, 40b
  packed red blood cells, 40
  preoperative verification of, 369
  procedures before administering, 41
  storage of, 41
  thoracic surgery use of, 944
  unused, 41
  whole, 40
Blood transfusion
  autotransfusion, 42
  history of, 40b
  procedures before, 41
  rapid, 41
  reactions, 41
Blood type, 40–41, 1189
Blood volume, 40–42, 1085–1086
Bloodborne pathogens. See also specific pathogens
  exposure control plan for, 1265–1266
  legislation regarding, 1264b
  needle-stick transmission of, 193
  safety provisions, 1263–1265
Blooming, 217b
Blow-out fracture, 915, 915f, 1209
Blunt suture needles, 181, 181b, 1265, 1266b
Blunt trauma, 1184–1185
Blunt-tipped trocars, 209f–210f
B-mode ultrasonography, 978
Body exhaust system, 737f
Body fluid exposure, in workplace, 1271f–1272f
Body mass index, 157–158, 336b
Body substance isolation, 57–58, 62f, 1275
Body surface area, 900, 902b
Body temperature. *See also* Hypothermia; Thermoregulation
  control of, during anesthesia, 139, 140b
  in elderly, 1173b
  monitoring of, 139
  pediatric, 1144
  postoperative complications of, 276–277
Bone(s)
  anatomy of, 719, 720f–721f
  cancellous. *See* Cancellous bone
  classification of, 719, 722f
  cortical, 719
  healing of, 744, 744f
  remodeling of, 745
Bone anchor, transvaginal sling with, 541–542, 542f
Bone banking, 743
Bone cement. *See* Polymethylmethacrylate
Bone grafts, 743–744
Bone tunnel plug, 805, 805f
Bone wax, 857
Bone-anchored hearing aids, 691–692, 691f–692f
Bone-growth stimulator, 744, 745f
Bony orbit, 610
Bony pelvis, 422–423
Bookwalter self-retaining retractor, 367f
Boost, 217b
Boot-type stirrups, 166, 166f
Botox, 544b
Botulism, 65t–66t
Bovine heart valves, 1024–1025, 1026f, 1028t, 1029b
Bowel resection, 1105
Bowel technique, for gastrointestinal surgery, 309
Bowie-Dick test, 76
Bowman's membrane, 612, 612f
Brachial plexus
  anatomy of, 150f
  neuropathy of, 150, 150f
  patient positioning-related injury of, 150f, 151
  peripheral nerve blocks of, 135
Brachioplasty, 928f
Brachytherapy, 524–526, 526f
Braden scale, for pressure ulcers, 147, 147b, 148t
Brain
  anatomy of, 818–835, 973–975, 974f
  arteries of, 973–975, 974f
  cerebellum, 825
  cerebrum, 821–824, 823f
  commissures of, 818
  diencephalon, 824
  frontal lobe of, 822–823, 823f
  meninges of, 819–820, 820f, 826
  oxygen requirements of, 828–829
  pathologic lesions of, 825–827, 825t
  scalp, 818–819, 820f
  veins of, 831f
  ventricular system of, 825f, 827–828
Brain death, 1215
Brain lesions, 829–830
  aneurysms, 829–830
  hematomas, 830, 832f
  vascular malformations, 830
Brain surgery
  aneurysms, 871–872, 871f
  approaches to, 864–866
  arteriovenous malformations, 872
  burr holes, 864–865
  craniectomy, 865
  cranioplasty, 865–866
  craniotomy, 864–865, 867–870
  aneurysm clipping, 872
  arteriovenous malformations treated with, 872
  definition of, 864, 867
  incisions for, 864
  parasellar tumors treated with, 872–873
  pituitary tumors treated with, 872–873
  procedural considerations for, 867
  pterional, 864, 868–870, 868f–870f
  scalp flap for, 864–865
  suprasellar tumors treated with, 872–873
  tumor resection using, 867–868
  epidural hematoma, 865
  subdural hematoma, 865
Brain surgery *(Continued)*
  transsphenoid hypophysectomy, 875
  transsphenoidal approach, 865
  ventriculoperitoneal shunt placement, 828, 866–867, 867f
Brainstem, 824–825, 839f
Branchial cleft cyst excision, 1127
BRCA1, 593, 594b
BRCA2, 593, 594b
Breast(s)
  anatomy of, 588–597, 589f–590f
  benign lesions of, 588–589, 590t
  blood supply of, 588, 589f
  fibrocystic changes in, 588, 590t
  lymphatic drainage of, 588, 590f
  magnetic resonance imaging of, 592–593
  patient positioning effects on, 156–157
  physiologic changes that affect, 588
  positron emission tomography of, 593
  prone positioning-related compression of, 156–157
  ptosis of, 933, 933f
  ultrasound of, 592
Breast cancer, 589–592
  aromatase inhibitors for, 596
  BRCA1 and *BRCA2*, 593
  clinical breast examination, 592
  complementary and integrative therapies for, 597t
  ductal carcinoma in situ, 595f
  fine-needle aspiration biopsy of, 593, 594f
  HER-2 agents for, 596
  hormone-dependent tumors, 594–596, 597f
  invasive, 591t
  lobular carcinoma in situ, 595f
  mammography of, 592, 592f–593f
  mastectomy for. *See* Mastectomy
  molecular imaging of, 593
  port insertion for long-term treatment of, 596b
  risk/risk factors for, 588–589, 591t
  screening for, 592–593, 592f, 592t
  staging of, 594, 595f
  surgical management of, 604f
  survivorship programs for, 602b
  TNM staging of, 594
  triple-negative, 596–597
  types of, 589, 591t
Breast Imaging Reporting and Data System, 592
Breast reconstruction, 907–911
Breast surgery, 928–933
  abscess drainage, 603
  augmentation mammoplasty, 918, 928, 929f
  axillary node dissection, 605–606, 606f
  biopsy
    open, 602–603
    sentinel lymph node, 603–605

Breast surgery *(Continued)*
breast cancer treated with, 604f
capsulotomy, 929
discharge planning and instructions for, 600–601, 600t–601t
draping for, 599
family education about, 600–601, 600t–601t
gynecomastia excision, 933, 934f
history of, 590b
implants, 928–929
lumpectomy, 603, 604f
lymphedema associated with, 602b
mastectomy. *See* Mastectomy
mastopexy, 933, 933f
nursing considerations for, 597–600
assessment, 597
evaluation, 599–600
implementation, 598–599
nursing diagnoses, 597, 598b
outcome identification, 597
planning, 597–598, 598b
patient education about, 600, 600t–601t
patient positioning for, 599
reconstruction. *See* Breast reconstruction
reduction mammoplasty, 929–933, 930t–931t, 932f, 932b
skin preparation for, 599
Breast-conserving therapy, 592–593
Brescia-Cimino fistula, 996, 997f
Bridge fistulas, 997
Bristow procedure, 753–754
Bronchial arteries, 937
Bronchitis, 962f
Bronchoscope
description of, 131b
flexible, 951
rigid, 949–951
Bronchoscopy, 707
anesthesia for, 949–950
direct, 950
discharge planning and instructions, 947
flexible, 949, 951
lung volume reduction, 961–963, 964b
standard, with rigid bronchoscope, 949–951
Bronchospasm, 272, 1235b
Brow lift, endoscopic, 918–919
Bruit, 977
B-type natriuretic peptide, 1010
Bulbourethral glands, 481
Bulbous urethral cuff, 546, 546f
Bullet trauma, 1185, 1186f, 1197
Bullying, workplace, 1279
Bundle of His, 1006
Bunionectomy, 778–779, 779f–780f
Burns, 899–902
thermal, 37–38
Burr holes, 864–866
Burrs, 678
Burst fracture, 1208–1209

C

Calcitonin, 566
Calcium channel blockers, 1218
Caldwell-Luc with radical antrostomy, 698–699, 698f
Calyces, 478, 481f
Camera control unit, 217
Cancellous bone
description of, 719
grafts, 744
internal fixation screws for, 748–749
Cancer
breast. *See* Breast cancer
cervical
cesium applicators for, 445–446, 446f
description of, 425, 427t, 428f
pelvic exenteration for, 459
endometrial. *See* Endometrial cancer
oral cavity, 699, 700f
ovarian, 425, 427t, 428f
penile. *See* Penile carcinoma
prostate. *See* Prostate cancer
tongue, 700f
vaginal, 427, 427t
vulvar, 425–427, 428f
Candy cane stirrups, 166, 166f
Cannulae, 1037f, 1040f
Cannulated screw fixation, of nondisplaced femoral neck fractures, 765, 765f–766f
Cannulation
aortic, 1037f
aortic-caval, 1047–1048
ascending aortic, 1047
axillary artery, 1048–1049, 1049b
femoral vein–femoral artery, 1048, 1048f
median sternotomy, 1156
neck, 1156
Capacitance pad, 244, 244f
Capacitive coupling, 246, 246f
Capillary telangiectasias, 830
Capitulum, 723
Capnography, 121, 1227–1228
Capsule endoscopy, 300–303
Capsulorrhaphy, 1130f
Capsulorrhexis, 644f
Capsulotomy, 929
Car seats, 1142b
Carbolic acid, 83
Carbon dioxide
description of, 122
pneumoperitoneum, 375
serum levels of, 301t–303t
solubility of, 226
Carbon dioxide embolus, 226, 226b
Carbon dioxide insufflator, 220–221
Carbon dioxide laser
backstops for, 235
corneal damage caused by, 233, 233f
description of, 229–231
eye protection for, 234
gynecologic and obstetric surgery uses of, 431
laryngeal surgery, 706
pressure ulcer treatment using, 903
Carbon tetrachloride, 362t
Carboxyhemoglobin, 120–121
Carcinoembryonic antigen, 301t–303t
Cardiac catheterization, 1014, 1015f, 1016t
Cardiac index, 1015b, 1016t
Cardiac muscle, 1005f
Cardiac output, 1015b, 1016t
Cardiac resynchronization therapy, 1079
Cardiac surgery, 1047–1081. *See also Heart; specific procedures*
admission for, 1030, 1031t
anatomic considerations, 1002–1008, 1003f–1008f
anesthesia for, 1030
antibiotic prophylaxis before, 1030–1031
assessments before
diagnostic tests, 1013–1015, 1013b, 1013f–1014f
history-taking, 1009–1011
laboratory tests, 1015–1018, 1017t
physical examination, 1011–1013
cardiopulmonary bypass. *See* Cardiopulmonary bypass
closure after, 1042–1043
complications of, 1044t–1045t
description of, 1002
discharge planning and instructions, 1045–1047
draping for, 1034
in elderly, 1180
equipment for, 1021, 1021f–1023f
extracorporeal circulation, 1047–1051
facilities for, 1021
family education about, 1045–1047
heart failure, 1058
history of, 1003b
incisions, 1035–1039
instrumentation for, 1021, 1021f–1023f
major adverse cardiac events after, 1010
medications used in, 1030–1033, 1032t–1033t
minimally invasive instrumentation for, 1021, 1022f
patient teaching for, 1046t
monitoring before, 1030, 1031t
monitoring of, 1033–1034
myocardial protection during, 1039–1042
nursing considerations for, 1008–1047
outcome identification, 1018–1020
planning, 1019b–1020b, 1020–1021
operating room for, 1021
patient education about, 1045–1047, 1046t
patient positioning for, 1034
preinduction care, 1029–1030
prepping for, 1034
prosthetic materials used in
description of, 1023–1024, 1024f
heart valves. *See* Prosthetic heart valves
quality of life after, 1046–1047
safety considerations for, 1021
supplies for, 1023
sutures for, 1022–1023
transfer report after, 1043f
trends in, 1002
Cardiac trauma, 1209–1211, 1210f
Cardinal ligament, 420f, 422, 422f
Cardiomyoplasty, 1072
Cardioplegia
antegrade, 1049
delivery of, 1041, 1041f, 1049–1050
description of, 1040–1041
minimally invasive endovascular antegrade-retrograde, 1050, 1050f
retrograde, 1049
Cardiopulmonary arrest, 1088b
Cardiopulmonary bypass, 1036–1039
aneurysm repair, 1068–1069
femoral vein–femoral artery, 1036–1037, 1040f
for lung transplantation, 967–968
major adverse cardiac events and, 1010
with mild hypothermia, 1054
minimally invasive, 1056–1057
off-pump, 1057
pumps, 1038, 1040f
termination of, 1042, 1050
types of, 1053t
weaning from, 1042
Cardiopulmonary death, 1215
Cardiovascular disease
angina pectoris, 1009, 1009b
biomarkers of, 1010
in elderly, 1180
risk factors for, 1010b
Cardiovascular system
age-related changes in, 1163–1164, 1165b
diagnostic tests, 1013–1015, 1013f–1014f, 1013b
magnetic resonance imaging of, 1013, 1014f
pediatric, 1085–1086
postoperative complications of, 272–275
in young vs. old patients, 1012t
Care maps, 12
Caring, 9b
C-arm fluoroscopy, 542, 734, 850
Carotid artery
angioplasty and stenting of, 862
Carotid artery shunt, 994–996, 995f–996f
Carotid endarterectomy, 994–995
with carotid artery shunt, 994–996, 995f–996f
definition of, 994
left, 995f–996f
long-term results of, 969b
monitoring during, 983
operative procedure, 995, 995f–996f
patient education about, 985t–986t
procedural considerations for, 994
Carotid stenting, 969b
Carpal tunnel release, 760
Carpals
anatomy of, 723–724, 724f
fracture of, 761, 762f
Carrier, 49b
Cartilage, 719
Caruncle, urethral, 500
Casts, 735, 737f
Cataract/cataract extraction, 629t, 641–645
in elderly, 1177b
extracapsular, 641–642
pediatric, 1141, 1141b
types of, 1141b
Catheters
central venous, 980, 1034b, 1096–1097
epidural, 978–980
interventional radiology, 1225, 1225f
pulmonary artery, 980
ureteral, 488–493, 491f–492f
urethral, 488–493, 491f–492f
Caudal anesthesia, 134–135
Cavitation, 69
Cavitron ultrasonic surgical aspirator, 389f
Cayenne, 1253t–1255t
Ceiling lift, 1261f
Cellular depolarization, 135
Centers for Medicare & Medicaid Services, 14, 19–20
conditions nonreimbursable by, 145, 250
Deficit Reduction Act, 250
functions of, 19–20
HIPAA administration by, 19–20
pressure ulcers, 145
Centipoise, 1222b
Central line–associated bloodstream infections, 1096, 1097b
Central nervous system
components of, 818
local anesthetic toxicity, 894
tumors of, 825t
Central retinal artery occlusion, 156b
Central venous catheters, 980, 1034b, 1096–1097
Cerebellum, 825
Cerebral aneurysms, 862
Cerebral arteries, 828, 829f
Cerebral blood flow, 1214
Cerebral circulation, 829
Cerebral cortex, 821
Cerebral hemispheres, 821–822, 823f–824f
Cerebral veins, 828–829
Cerebroplegia, 1042
Cerebrospinal fluid, 827–828
drainage of, 698, 853
leak of, 698, 853
rhinorrhea, 819
Cerebrospinal fluid spaces, 820, 822f
Cerebrovascular disease, 973–975
Cerebrum
anatomy of, 821–824, 823f
blood supply, 828–830
Certification in perioperative nursing, 15
Certified registered nurse anesthetist, 111
Cervical cancer
cesium applicators for, 445–446, 446f
description of, 425, 427t, 428f
pelvic exenteration for, 459
Cervical cerclage, 468–473
abdominal approach, 472–473
indications for, 468–472
laparoscopic, 473
McDonald, 472, 473f
Shirodkar, 472, 472f
vaginal approach, 472
Cervical polyps, 444–445, 445f
Cervical vertebrae
anatomy of, 722, 836
anterior cervical decompression and fusion, 876–877, 876f
traumatic injury of, 1208
x-rays of, 845, 846f

Cervicothoracic sympathectomy, 882
Cervix
  anatomy of, 419, 422
  cerclage of. *See* Cervical cerclage
  conization and biopsy of, 445, 446f
  incompetence of, 468–472
Cesarean section, 474–477, 476f–477f
Cesium applicator insertion, 445–446, 446f
Chakras, 1247f
Chalazion, 633
Charge-coupled device, 217b, 218
Chemical burns, 38
Chemical exposure, 1273–1274
Chemical indicators, 74–75
Chemical pleurodesis, 952t–953t
Chemical sterilization, 78–81
  aqueous glutaraldehyde, 80
  biological indicators for, 81
  ethylene oxide for, 78–80, 79t
  low-temperature hydrogen peroxide gas plasma, 80–81, 81f
  peracetic acid, 80
Chemobrain, 601b
Chemoembolization, 1222b
Chemotherapy
  cytotoxic, 320b
  hyperthermic intraperitoneal, 320
  liver, 1226
Chest drainage systems, 944–946, 946f, 959f, 1042
Chest examination, 616
Chest injuries, 945f
Chest radiograph, 1013, 1013f
Chest trauma, 1209–1211
Chest tubes, 945b, 946
Child abuse and neglect, 1089, 1090b
Child life specialist, 1088t
Children. *See* Pediatric surgery
Chiropractics, 1242–1243
Chlorhexidine gluconate, 102b, 103, 894
Chloride, 301t–303t, 1190b–1191b
Chlorine compounds, 82–83
Cholangiogram, intraoperative, 372–374
Cholangitis, 372b
Cholecystectomy
  incidence of, 357
  indications for, 371
  intraoperative cholangiogram, 372–374
  laparoscopic, 374–376
  open, 357, 367f, 371–372, 373f
Cholecystitis, 372b
Cholecystoduodenostomy
  cholecystojejunostomy and, 380
  choledochojejunostomy and, 380
  operative procedure for, 380
Cholecystojejunostomy, 380
Cholecystostomy, 377–378
Choledochojejunostomy, 380, 381f
Choledochoscope, 378–379
Cholelithiasis, 372b
Cholesteatoma, 685, 685f
Cholesterol, 358
Cholinergics, 124t–127t
Chordal flip procedure, 1061–1062, 1062f
Chordee, 1115–1116
Choriocarcinoma, 826
Choroid plexus, 827
Chroma, 217b
Chromatization, 177
Chrominance, 217b
Chromophobe tumors, 826
Chronic arterial insufficiency, 973
Chronic autoimmune thyroiditis, 571b
Chronic pain, 138–139
Chronic pelvic pain, 456b
Chronic venous insufficiency, 975
Chvostek's sign, 572–573
Cicatricial entropion, 633
Cicatrix, 251
Cimino fistula, 997
Cinearteriogram, 1014–1015
Circle of Willis, 828, 829f, 974f
Circulating nurse, 15
Circumcision, 499–500, 500f, 1115, 1116f
Clamping instruments, 210–211, 210f
Clamps, 194–197, 195f, 200, 557f, 1021f
Claudication, 975, 975b
Clavicle
  anatomy of, 722, 722f
  fracture of, 751–752
Clayton technique, 780
Clean contaminated wound, 257, 369
Clean wounds, 254–257
Cleaning of environment, 107–108
Clear corneal cataract procedure, 643–644, 644f
Cleft lip repair, 1131–1132, 1132f
Cleft palate repair, 1132, 1133f
Clinical breast examination, 592
Clinical decision making, 9b
Clinical documentation, 23–25
  communication through, 23
  components of, 23, 30b
  intraoperative record, 23, 27f–29f
  requirements in, 23–25, 30b
Clinical pathways, 12
Clip(s)
  Frazier, 187–188
  hemostatic, 186–188, 187f, 858, 859f
  titanium, 186
Clip applier, 211, 211f
Clitoris, 419, 421f
Closed fractures, 745, 746f
Closed reduction of fractures, 746–747
  nasal fracture, 693, 693f, 915
  operative procedure for, 747
  procedural considerations for, 747
  zygomatic fractures, 915–916
Closed thoracostomy, 966, 966f
Closed-gloving technique, 99, 100f
Clostridia, 51
  C. botulinum, 65t–66t
  C. difficile, 51
Clubfoot, 1131
C-mount, 217b
Coagulation studies, 301t–303t, 1190b–1191b
Cochlea, 658–659
Cochlear implantation, 690–691, 690b, 691f
Code for Nurses, 18
Cohorting, 49b
Coils, 1227
Cold injuries, 1214–1215
Cold light, 205–206
Colectomy
  laparoscopic, 342–343, 342b
  open, 342b
Colectomy, transverse, 346f, 347
Collagen, 498
Collagen dressings, 264t–265t
Collagen sutures, 176t–177t, 177–178
Colles' fracture, 759–760
Colloid cysts, 826
Colocystoplasty, right, 549
Colon
  anatomy of, 297–298, 298f
  ascending, 297–298, 298f
  blood supply of, 297–298, 298f
  descending, 297–298, 298f
  sigmoid, 346f, 347–348
  surgical procedures of
    abdominoperineal resection, 348–350, 349f
    colectomy. *See* Colectomy
    colostomy. *See* Colostomy
    ileoanal endorectal pull-through, 350–352, 351f–353f
    resection, 346f
    right hemicolectomy and ileocolostomy, 345–347
    sigmoid colon resection, 346f, 347–348
    transverse colectomy, 346f, 347
  transverse, 297–298, 298f
  wall of, 298
Colonoscope, flexible, 205f
Colonoscopy, 321–322
  definition of, 321–322
  preprocedural instructions for, 311b
Color bars, 217b
Color reproduction, 217b
Colostomy, 343, 1105–1107, 1106f
  operative procedure, 343, 344f
Colpomicroscopy, 425
Colposcopy, 425
Columella, 659, 687
Common bile duct
  anatomy of, 357, 359f
  description of, 296
  open exploration of, 378–379
Common peroneal nerve, 153, 154f–155f
Communication
  clinical documentation as form of, 23–25, 27f–29f, 30b
  hand-off, 26b, 30, 31b
  safety and, 23
Compartment syndrome
  abdominal, 1192–1193, 1193f
  definition of, 1192
  patient positioning and, 167b, 171
  prevention of, 167b
  signs and symptoms of, 1192, 1193t
  soft tissue injuries and, 1214
Complement assay, 301t
Complementary and alternative therapies, 1219–1220
  alternative medical systems, 1240–1241
  ambulatory surgery, 1256b
  aromatherapy, 1247–1248, 1249t
  background on, 1240
  biofields, 1244, 1245t–1246t
  biologically based therapies, 1241–1242, 1245f
  body-based methods, 1242–1243, 1249t
  categories of, 1240–1243
  cultural characteristics of, 1244b
  diet, 1242
  energy therapies, 1243–1256
  evaluation of, 1241b
  guided imagery, 1247, 1248f
  herbs, 1242, 1245f, 1250–1252, 1252b
  history of, 1240, 1244b
  hypnotherapy, 1246–1247
  integrative health therapies, 1252–1256
  legislative and administrative recommendations for, 1242b
  manipulative methods, 1242–1243
  mind-body interventions, 1241
  music, 1248–1250
  patient education about, 1251t
  psychoneuroimmunology, 1250
  therapeutic touch, 1244–1246, 1246t, 1247b
Complete blood count, 301t–303t, 941t, 1017t
Composite dressings, 264t–265t
Composite grafts, 906
Composite video output, 217b
Comprehensive Geriatric Assessment, 1162
Compression fracture, 745–746, 746f
Compression garments, 892–893
Computed tomography, 668, 845, 1013, 1191–1192, 1192t
Computer-assisted surgery, 223
Condensation, 68
Conduction system
  description of, 1006, 1006f
  disturbances of
    implantable cardioverter-defibrillator for, 1080f, 1081
    myocardial pacing electrodes for, 1080–1081
    pacemaker for, 1078–1079, 1079f
    surgery for, 1077–1081
    transvenous pacing electrodes for, 1079–1080, 1079f
Conductive hearing loss, 666t, 684
Condylomata acuminata
  of penis, 499
  of vagina, 433, 433f
Confusion, 1166–1167
Congenital diaphragmatic hernia, 473, 474f, 1112–1113, 1113f
Congenital heart disease, 1145–1156
Conjoined tendon, 407
Conjunctiva
  anatomy of, 610, 612f
  surgery of, 637
Conscious sedation/analgesia, 118, 137–138
Constipation, 289
Contact dermatitis
  allergic, 98, 1278
  irritant, 98, 1278
Contact precautions, 56, 64
Contaminated wound, 257, 369, 1196
Contamination
  airborne, 89
  definition of, 49b
Continuous bladder irrigation, 491–492
Continuous epidural analgesia, 139
Continuous passive motion, 737f
Continuous positive airway pressure, 702
Continuous suture, 183, 185f
Continuous wave Doppler, 977
Continuous-flow resectoscope, 515–516, 516f
Contractility, 1015b
Contrast media, 1228–1236
  seafood allergy and, 1219b
Cooper ligament
  anatomy of, 397–398
  hernia repair, 407–408, 409f–410f
Coping, 1203
Coracoclavicular suture fixation, 750
Core needle biopsy
  of breast, 602
  of prostate gland, 514
Cornea
  anatomy of, 612, 612f–613f
  layers of, 612, 612f
  refractive power of, 613f
Corneal surgery, 637–640
  pediatric, 1141
Coronary anastomoses, 1056f–1057f
Coronary arteries, 1002–1003, 1005f
Coronary artery bypass grafts
  aortic valve replacement and, 1066
  with arterial and venous conduits, 1054–1057
  off-pump, 1051
  practice guidelines for women undergoing, 1009b
  with reversed saphenous vein, 1057f
Coronary artery disease
  description of, 1002–1003
  inflammation's role in, 1010
  risk factors for, 1010, 1010b
Coronary circulation, 1002–1003, 1005f, 1039–1040
Corpus callosum, 821, 823f
Corpus cavernosum, 482, 482f
Corpus luteum, 421–422
Corpus spongiosum, 482, 482f
Corpus striatum, 824
Cortical bone, 719
Cortical tumors, 827
Cortisol, 301t–303t
Cotrel-Dubousset system, 812–813, 813f
Cotton mesh gauze, 264t–265t
Cotton sutures, 180
Cottonoid strips, 859f
Coughing, 371
Council on Surgical and Perioperative Safety, 25b

Couplers, 219–221, 220f
Cowper's glands, 481
COX-2 inhibitors. *See* Cyclooxygenase type 2 inhibitors
Cranial fossae, 819, 822f
Cranial nerve(s), 664, 830–835, 835f
Craniectomy, 1129
Craniofacial disjunction, 1209
Craniofacial surgery, 1135–1137, 1135f
Craniopharyngiomas, 827
Cranioplasty, 865–866
Craniosynostosis, 819, 1129
Craniotome, 850
Craniotomy, 864–865, 867–870
  aneurysm clipping, 872
  arteriovenous malformations treated with, 872
  definition of, 864, 867
  draping for, 856
  head support in prone position for, 169
  incisions for, 864
  parasellar tumors treated with, 872–873
  pituitary tumors treated with, 872–873
  procedural considerations for, 867
  pterional, 864, 868–870, 868f–870f
  scalp flap for, 864–865
  suprasellar tumors treated with, 872–873
  tumor resection using, 867–868
Cranium. *See also* Head; Skull
  deformities of, 819
  stereotactic surgery of, 864
C-reactive protein, 301t–303t, 1010
Creatinine, 1016t
Creutzfeldt-Jakob disease, 57
  instruments exposed to, 57, 58b, 60t–61t
Cricoid pressure, 130f, 1198f
Cristae, 658–659
Critical incident–stress debriefing, 1204
Critical items, 60t–61t, 82
Critical volume hypothesis, 123
Crossmatching, 40–41, 1189
Crouzon's disease, 1135, 1135f–1136f
Cruciate ligaments
  anatomy of, 727, 727f
  repair of, 773–775, 774f, 804–806, 805f–806f
Cryosurgery, 248–249, 526–527
Cryotherapy, 626
Crystalloid solutions, 40
CSPS. *See* Council on Surgical and Perioperative Safety
Curettage
  dilation and, 443–444
    instrumentation set for, 199
    patient and family education about, 432t
Cutdown technique, 319
Cutting instruments, 194, 194f
Cutting taper needle, 183t
Cyclooxygenase type 2 inhibitors, 280
Cycloplegics, 621t–623t
Cyst(s)
  Baker, 775
  Bartholin's gland, 446, 447f
  colloid, 826
  dermoid, 462, 463f, 826
  epidermoid, 826
  ovarian, 462, 463f–464f
Cystectomy
  ovarian, 452–453
  radical, with pelvic lymphadenectomy, 547, 548f
  thyroglossal duct, 583–584, 585f
Cystic artery, 373f
Cystocele repair, 435–436, 435f–436f
Cystoduodenostomy, 381
Cystogastrostomy, 381
Cystojejunostomy, 381, 383f
Cystoscope, flexible, 497, 497f
Cystoscopy, 494b, 495–498
  pediatric, 1115
Cystostomy
  suprapubic, 535–536, 535f
  trocar, 537, 538f
Cystourethroscope, 497
Cytotoxic chemotherapy, 320b

D

Dacron, 1023, 1024f
Dacryocystectomy, 632f
Dacryocystitis, 632, 632f
Dacryocystorhinostomy, 632–633, 632f–633f
Damage control surgery, 1204–1205
Data collection, 5
Dead space, 254b
Debridement, 258, 262b, 902
Deceleration injury, 1209
Decision-making, clinical, 9b
Decompressive laparotomy, 1193
Decontamination
  definition of, 82
  description of, 61
  methods of, 68
Decortication, 965, 965f
Decubitus ulcers. *See* Pressure ulcers
Deep breathing, 371
Deep hypothermia with circulatory arrest, 1068–1069
Deep incisional surgical site infection, 49b, 254b
Deep lamellar endothelial keratoplasty, 639
Deep tissue injury, 147, 149
Deep vein thrombosis
  acute venous insufficiency caused by, 975
  anticoagulation therapy for, 742t
  in elderly, 1172b
  postoperative, 289
  prevention of, 8b, 289, 739b, 855, 1172b, 1197–1198
  sequential compression stockings for prevention of, 855
  in trauma patients, 1197–1198
Deflux, 1122
Dehiscence, of wound, 254b, 257f, 312
Dehydration, 1173–1174, 1174t
Delayed primary closure, 251, 252f
Delayed union, 744
Delegation, 9–10, 10b
Delirium
  in elderly, 1166–1167, 1175b
  emergence, 277, 277f
Dendrites, 818, 819f
Denonvilliers' fascia, 298–299
Depolarizing muscle relaxants, 124t–127t, 128
Dermagraft, 262t
Dermatochalasis, 634–635
Dermatomes, 838, 842f, 890, 891f
Dermis, 250, 251f
Dermoid cysts, 462, 463f, 826
Derotational osteotomy, 1130–1131
Descemet's membrane, 612, 612f
Descending colon, 297–298, 298f
Descending thoracic aortic aneurysms, 1069–1072, 1072f
Deterministic effect, 1222b
Developmental hip dysplasia, 1130–1131, 1130f
Diabetic foot, 903–904
Diabetic retinopathy, 642f, 648–649, 649f
Diagnostic peritoneal lavage, 1192
Diamond jaw needle holder, 195
Diaphragmatic hernia, congenital, 324, 473, 474f, 1112–1113, 1113f
Diarthrotic joints, 719
DICOM, 217b
Diencephalon, 824
Dietary Supplement Health and Education Act, 1250
Diffusion capacity of carbon monoxide, 941t
Digital processing, 219
Digital rectal examination, 511
Digital replantation, 912
Digital subtraction angiography, 846, 977f, 1221
Dilation, urethral, 500–501
Dilation and curettage, 443–444
  instrumentation set for, 199
  laparoscopy with, 450–451
  patient and family education about, 432t
Diode laser, 232
Direct bronchoscopy, 950
Direct coupling, 244–245, 245f
Direct current, 241
Discharge planning and instructions
  biliary surgery, 370–371, 370t
  breast surgery, 600–602, 600t–601t
  cardiac surgery, 1045–1047
  contrast media, 1234t
  gastrointestinal surgery, 310–311
  genitourinary surgery, 493
  geriatric surgery, 1175–1177
  gynecologic and obstetric surgery, 430–431
  liver surgery, 370–371, 370t
  neurosurgery, 860–861, 860t–861t
  ophthalmic surgery, 628
  orthopedic surgery, 743
  otorhinolaryngologic surgery, 680
  pancreatic surgery, 370–371, 370t
Discharge planning and instructions *(Continued)*
  pediatric surgery, 1095–1096, 1096b
  plastic and reconstructive surgery, 896–897
  postoperative, 268b, 292
  splenic surgery, 370–371, 370t
  thoracic surgery, 947
  thyroid surgery, 577
  vascular surgery, 984–985
Disinfectants
  alcohol, 82
  categorization of, 82
  chlorine compounds, 82–83
  definition of, 81
  glutaraldehyde, 83
  high-level, 82
  hydrogen peroxide, 83
  intermediate-level, 82
  iodine, 83
  iodophors, 83
  low-level, 82
  ortho-phthalaldehyde, 83
  phenolics, 83
  quaternary ammonium compounds, 83–84
  types of, 82
Disinfection, 81–84
  endoscopic minimally invasive surgery instrumentation, 214
  operating room, 108
Diskectomy, endoscopic, 879
Dislocations, 745–750
  hip, 762
  patellar, 773, 773f
  radial head, 759
  shoulder, 753–754
  sternoclavicular, 750
Dismembered pyeloplasty, 555–556
Dispersive electrode monitoring, 243–244, 309
Dissecting aneurysm, 971–972
Dissecting instruments, 210, 210f
Dissecting sponges, 187b
Dissectors
  description of, 194, 194f
  endoscopic minimally invasive surgery, 210, 210f
Distal femoral fractures, 769–770, 769f
Distal humeral fractures, 756–758, 756f–758f
Diuretics, 1046t, 1205
Diverticular disease, 1178
Diverticulum, esophageal, 324
Doctor of Nursing Practice, 16
Dong quai, 1253t–1255t
Donor embryo, 468t
Donor oocyte, 468t
Do-not-resuscitate orders, 1180
Doppler probe, 120
Doppler scanning, 977
Dose fractionation, 1222b
Double-balloon enteroscopy, 321
Double-gloving, 99b, 1265
Double-J stents, 491
Double-lung transplantation, 967
Double-pigtail stents, 491, 491f
Dragging, 449
Drain(s), 265, 266f, 309, 369, 430, 944–946
Drainage
  biliary tract surgery, 369
  chest, 944–946, 946f, 959f, 1042
  empyema, 965–966
  glaucoma, 646–647, 647f
  liver surgery, 369
Drapes/draping
  central venous catheters, 1034b
  configurations of, 105–106, 106f
  fenestrated sheets, 105, 106f
  hand, 913
  laparotomy sheets, 105, 106f
  liposuction, 924–925
  neurosurgery, 855–856
  orthopedic surgery, 733–734
  plastic and reconstructive surgery, 894–895
  polyvinyl chloride sheeting, 105–106, 106f
  procedure for, 106–107, 107f
  reusable, 104–105
  single-use, 104–105, 895
  sterile field created with, 104–107
  thoracic surgery, 943
  vascular surgery, 980
Dressings, 263
  changing of, 1174
  gynecologic and obstetric surgery, 430
  historical perspective on, 263b
  home care for, 259t
  Montgomery straps for, 263, 265f
  neurosurgery, 859
  ophthalmic, 627–628, 627f
  plastic and reconstructive surgery, 892–893
  primary, 263
  purposes of, 263
  secondary, 263
  securing of, 263
  selection of, 263, 264t–265t
"Drip" towels, 38
Droplet precautions, 64
Dry heat sterilization, 81
Duct of Wirsung, 359–360
Ductal carcinoma in situ, 595f
Ductal ectasia, 590t
Duodenal bulb, 295–296
Duodenal switch, 337, 340f
Duodenum
  anatomy of, 295–296, 296f–297f
  blood supply of, 296, 297f
  transduodenal sphincteroplasty, 380–381, 382f
  ulcer of, 330
Duplex ultrasonography, 978
Dura mater, 820, 820f, 836
Durasphere, 498
Dust covers, 74
Dyes, 120–121
Dynamic air removal, 49b
Dysfunctional bleeding, 456b
Dysrhythmias, 275

E

Ear, 657–659
  protruding, 1134, 1134f
  reconstruction of, 1133–1134
  surgery of. *See* Otologic surgery
Echinacea, 1011t, 1253t–1255t
Echocardiography, 1013–1014, 1015f
ECRI Institute, 25b, 205–206

Ectopic parathyroid glands, 566–567
Ectopic pregnancy
  definition of, 451–452
  medical management of, 452b
  ruptured, 451f
  salpingectomy for, 451–452, 452f
  salpingostomy for, 451–452, 453f
  signs and symptoms of, 451–452
Ectropion, 634, 634f–635f
Edge-to-edge technique, 1062
Ejaculatory ducts
  description of, 481
  transurethral incision of, 518
Ejection fraction, 1015b, 1016t
Elbow
  arthroscopy of, 808
  total arthroplasty of, 797–798, 799f
Elderly. *See also* Geriatric surgery
  abuse of, 1162b
  age-related changes in, 1163–1167, 1165b
  assessments in, 1162–1169
  body temperature in, 1173b, 1174
  cardiovascular system in, 1163–1164, 1165b
  deep vein thrombosis prevention in, 1172b
  delirium in, 1166–1167, 1175b
  dental health in, 1168
  depression in, 1162
  digestive system in, 1164, 1165b
  functional status assessments, 1162
  hernias in, 1178–1179
  integumentary system in, 1163, 1166t
  interdisciplinary approach, 1162
  medications for, 1164t
  musculoskeletal system in, 1165, 1165b
  nervous system in, 1165–1166, 1165b
  nutritional status impairments in, 1162, 1168
  pain assessments in, 1166–1167, 1167b, 1176b
  population increases, 1157, 1158f–1159f, 1158b
  psychologic changes in, 1166–1167
  respiratory system in, 1163, 1165b
  sensory changes and deficits in, 1166, 1171
  trauma in, 1200
  urinary system in, 1164–1165, 1165b
Electrical burns
  laparoscopic instruments as cause of, 308b
  prevention of, 37–38, 38b
  risk for, 37–38
Electrical hazards, 239
Electrical stimulation, 744–745, 745f
Electrocardiogram, 616, 1013, 1031t, 1167–1168, 1192
Electrocautery, 241
Electrocoagulation, 1127f
Electroencephalogram, 847
Electrolytes, 1016t
  blood, 1190b–1191b
  risk for imbalance, 39–42
  serum, 301t–303t, 1190b–1191b
Electromagnetic spectrum, 118t, 226–227, 227f
Electronic shutter, 217b
Electrosurgery, 241–246
  hemostasis using, 309
  neurosurgery use of, 857
Electrosurgical units, 37–38
  bipolar, 625–626, 857, 857f
  dispersive electrode monitoring, 243–244, 309
  grounded, 243
  history of, 241b
  isolated, 243
  physics of, 241
  tissue response monitoring system, 244
Elmslie-Trillat procedure, 773, 773f
Embolectomy, arterial, 992, 993f
Embolic agents, 1226–1227
Embolism
  carbon dioxide, 226, 226b
  venous air, 856b
Embolization, 1222b
Embryonal cell carcinoma, 826
Emergence delirium, 277, 277f
Emergency thoracotomy, 1201–1202, 1201f, 1211
Emphysema, 962f
Empyema drainage, 965–966
En bloc resection, 562f
Endarterectomy, carotid. *See* Carotid endarterectomy
EndoCinch, 322–323
Endocouplers, 219–221, 220f
End-of-life care, 1203–1204
Endolymphatic sac
  decompression or shunt, 688, 688f
Endometrial ablation, 449–450
  patient and family education about, 432t
Endometrial biopsy, 446f
Endometrial cancer
  cesium applicators for, 445–446, 446f
  description of, 425, 427f, 427t
Endometriosis, 450f, 456b
Endoscopes, 204–205
  care of, 212–215
  cleaning and processing of, 83–84
  flexible, 204, 207f, 234, 321
  handling of, 212–215
  lenses, 207f
  light sources, 205–206, 207f
  neurosurgery uses of, 849–850
  operative, 204, 207f
  rigid, 204, 206f
  safety considerations, 237
  semirigid, 204
Endoscopic retrograde cholangiopancreatography, 361, 364f
Endoscopic ultrasound, 300
Endoscopy/endoscopic surgery
  anesthesia for, 226
  brow lift, 918–919
  capsule, 300–303
  cerebrospinal fluid leak repair, 698
  complications of, 226
  definition of, 947
  diskectomy, 879
Endoscopy/endoscopic surgery *(Continued)*
  electrosurgery considerations, 244–246
  capacitive coupling, 246, 246f
  direct coupling, 244–245, 245f
  insulation failure, 245, 245f
  fiberoptic cables, 205–206, 207f
  gastrointestinal surgery. *See* Gastrointestinal surgery, endoscopic procedures
  genitourinary, 497
  gynecologic and obstetric applications, 431b
  instrumentation for, 206–217, 369
  instrumentation used in, 198
  insufflation, 224–226, 224f–225f
  irrigation during, 247–248
  light sources, 205–206, 207f
  mitral valve surgery, 1063, 1065f
  mucosal resection, for Barrett's esophagus, 323
  natural orifice transluminal, 319, 578
  neuroendoscopy, 861–862
  open surgery vs., 116t
  otorhinolaryngologic, 705–707
  overview of, 204–217
  pectus excavatum correction, 1099–1100, 1099b, 1100f
  pelvic, 205b
  percutaneous endoscopic gastrostomy, 328–330
  radical, 318
  rapid response teams, 226b
  robotics, 222–223, 223f
  smoke evacuation, 237–239
  sutures for, 211, 212f–213f
  suturing, 184
  thoracic surgery, 947–955
  thoracic sympathectomy, 953–955, 954b
  thyroid resection, 580b
  triple, 707
  upper, 321, 321b
  video technology, 217–224
Endotracheal tube, 1093, 1094t
  general anesthesia uses of, 128, 129f, 131b
  intubation complications, 1198–1199
  laser beam igniting of, 236, 236f
Endovascular procedures
  abdominal aortic aneurysm repair, 985t–986t, 987–989, 989f
  descending thoracic aortic aneurysm repair, 1071
  description of, 862–863, 863b
  minimally invasive surgery antegrade-retrograde cardioplegia, 1050, 1050f
Endovenous laser ablation, of varicose veins, 999, 1000b
End-tidal carbon dioxide, 121, 128–129
End-to-end anastomosis, 334f–335f, 348, 348f
Energy therapies, 1243–1256
Enterocele, 435, 438, 439f
Enterococci, 50
  vancomycin-resistant, 56
Enterovaginal fistula repair, 440f
Entropion, 633, 634f
Enucleation, 628–631, 630f
Envelope-style wrapping, 71, 72f
Environment
  cleaning of, 107–108
  infection control considerations, 66–67, 107–108
  protective, 64
  Standard Precautions for, 63
Environmental noise, 113, 113b
Enzymatic debridement, 258
Eosinophilic adenomas, 826
Ependymoma, 826
Ephedra, 1011t, 1253t–1255t
Epicondylar humeral fracture, 756–758
Epidermis, 250, 251f
Epidermoid cysts, 826
Epididymectomy, 509–510
Epididymis, 481
Epidural analgesia
  continuous, 139
  patient-controlled, 310
  postoperative pain management using, 281
Epidural anesthesia, 134–135, 134f
Epidural catheters, 978–980
Epidural hematoma, 830, 865, 1206f
Epidural space, 819–820
Epigastric hernia, 416
Epi-LASIK, 639
Epilepsy, 853b
Epinephrine, 478
EPINet, 1267, 1268f–1270f
Epiphyseal plate, 720
Epiphyseal separation, 746
Epiploic appendices, 298
Epispadias repair, 1118–1120
Epistaxis, 693–694, 694b
Erbium:YAG laser, 231
Ergonomics, 1258, 1259f, 1260
Esophageal atresia repair, 1101–1102, 1102f–1103f
Esophageal dilation, 327
Esophagectomy, 323
  instrumentation for, 323
  procedural considerations for, 323
  transhiatal, 323–324
  transthoracic, 324
Esophagogastroduodenoscopy, 311b, 321, 374
Esophagomyotomy, 326
Esophagoscopes, 707f
Esophagoscopy, 707, 707f
Esophagus
  anatomy of, 295, 296f
  blood supply to, 295
  cancer of, 323
  diverticulum of, 324
  surgical procedures of, 323–327
  antireflux procedure, 324–325
  diverticulum excision, 324
  esophageal dilation, 327
  esophagectomy. *See* Esophagectomy
  esophagomyotomy, 326
  hiatal hernia repair, 324–325
  laparoscopic Nissen fundoplication, 325–326, 325f
  video-assisted thoracotomy surgery, 324
Esotropia, 1138b
Essure implant, 466, 466f–467f
Estimated amount of blood loss, 39–40, 40b
Estradiol, 424t
Estrogen receptors, 596, 597f
Ethmoid sinus, 696f
Ethyl alcohol, 82
Ethylene oxide sterilization, 78–80, 79t, 215
Eustachian tube, 657
Evaluation, 12
Evidence-based practice, 12–14
  definition of, 12–14
  Iowa Model of, 13f
Evisceration
  of orbit, 631
  of wound, 254b, 257f
Evoked potentials, 847, 853, 1015
Examination under anesthesia, 430, 1141
Excimer laser, 232
Excisional biopsy
  of breast, 602
  of conjunctiva, 637
  of eyelids, 636
Excisional debridement, 902
Exenteration, 631
Exotropia, 1138b
Expiration, 937–938
Exposure Prevention Information Network, 192b
External ear
  anatomy of, 657, 658f
  reconstruction of, 1133–1134
External fixation of fractures
  Colles' fracture, 759–760
  description of, 747, 748f
  pelvic fracture, 781
External os, 419
Extracapsular cataract extraction, 641–642
Extracorporeal circulation, 1037–1038, 1047–1051
Extracorporeal membrane oxygenation, 1153–1156, 1155f
Extracorporeal shock-wave lithotripsy, 555
Extracorporeal sutures, 211, 213f
Extradural tumors, 841–842
Extraocular muscles, 611, 612f, 615
Extravasation of contrast media, 1233–1236
Eye(s). *See also* Ophthalmic surgery
  anatomy of, 610–613. See also specific anatomy
  assessment of, 614–616
  blood supply to, 613
  external examination of, 615
  laboratory studies of, 615–616
  laser protection, 233–234, 233f–234f, 235b
  muscles of, 611, 612f
  nerve supply to, 613
  ophthalmoscopic examination of, 616f
  patient positioning-related injuries of, 156, 156b
  personal protective equipment for, 1265
  radiation exposure effects on, 1223t
  refractive apparatus of, 612–613
  traumatic injuries of, 1209

Eye (surgical needle), 180–181, 182f
Eyedrops
Eyelid surgery
  anatomy, 610, 612f
  chalazion removal, 633
  dermatochalasis, 634–635
  description of, 623–624, 633–637
  ectropion repair, 634, 634f–635f
  entropion repair, 633, 634f
  excisional biopsy, 636
  frontalis suspension, 636, 637f
  levator aponeurosis repair, 635–636, 636f
  ptosis, 635–636, 1138–1141, 1138f–1139f
  traumatic injuries, 636–637
Eyewear
  laser protection, 233–234, 233f
  protective, 61, 63

F

Facedown positioning, 651b
Facelift. *See* Rhytidectomy
FACES pain scale, 282f, 1094
Facial nerve, 834, 836t
  anatomy of, 664, 700–702
  branches of, 702f
  decompression of, 689
  monitoring of, 676, 676f
Facial telangiectasia, 922b–924b
Facial trauma, 1209
Facultative bacteria, 49b
Fall(s)
  injuries caused by, 1185
  pediatric, 1090b
  prevention of, during transport, 160
  workplace, 1261–1263
Fallopian tubes
  anatomy of, 419–421, 421f
  cancer of, 427, 427t
  ligation of, 464–466
    definition of, 464
    laparoscopic, 465, 465f–466f
    mini-laparotomy approach, 465–466
    operative procedure, 464–466
    transcervical approach, 466, 466f
  microscopic reconstructive surgery of, 463–464
  salpingo-oophorectomy of, 463
False aneurysm, 971–972
False vocal cords, 663
Falx cerebelli, 820, 820f
Family education
  anesthesia, 115t
  breast surgery, 600–602, 600t–601t
  genitourinary surgery, 493
  geriatric surgery, 1175–1177
  gynecologic and obstetric surgery, 430–431, 432t
  hernia repair, 404t, 405–406
  neurosurgery, 860–861
  ophthalmic surgery, 628
  orthopedic surgery, 743
  otorhinolaryngologic surgery, 680, 681t–682t
  pediatric surgery, 1095–1096
  plastic and reconstructive surgery, 896–897
  thoracic surgery, 947
Family education *(Continued)*
  thyroid surgery, 577
  trauma surgery, 1203
  vascular surgery, 984–985, 985t–986t
  wound care, 258, 259t, 292
Fasanella-Servat procedure, 1138–1139, 1139f–1140f
Fascia lata graft, 542f
Fascia renalis, 478
Fasciculations, 128
Fecal urobilinogen, 363t
$FEF_{25-75\%}$, 941t
Female reproductive system
  assessment of, 423–427, 424t
  bony pelvis, 422–423
  cervix. *See* Cervix
  external genital organs, 419, 420f–421f
  fallopian tubes. *See* Fallopian tubes
  lymphatic supply of, 423
  nerve supply of, 423
  ovaries, 421–422
  pelvic cavity, 419–422
  uterus, 419, 422f
  vagina. *See* Vagina
  vascular supply of, 423
  vulva, 419, 421f
Femoral arteriotomy, 993f
Femoral artery, 990
Femoral fractures
  condylar, 768–770
  distal, 769–770, 769f
  intercondylar, 770–772
  neck
    cannulated screw fixation for, 765, 765f–766f
    description of, 763
    internal fixation of, 765, 765f–766f
  shaft, 767–768, 767f
  supracondylar, 770–772
  traumatic, 1213–1214
Femoral head replacement, 765–767, 766f
Femoral hernia
  anatomy of, 398–399, 398f
  incidence of, 396
  repair of, 410, 413, 413f–414f
Femoral nerve
  block of, 135
  neuropathy of, 153–154, 155f
Femoral sheath, 399
Femoral vein–femoral artery cannulation, 1048, 1048f
Femoral vein–femoral artery cardiopulmonary bypass, 1036–1037, 1040f
Femoral-popliteal bypass, 990
  in situ, 991
Femoral-tibial bypass, 990
Femorofemoral bypass, 991–992, 991f–992f
Femur
  anatomy of, 724–726, 725f
  fractures of. *See* Femoral fractures
Fetal surgery, 473–474, 474f–475f
Feverfew, 1253t–1255t
FEV_1/FVC, 941t
Fiberoptic cables, 205–206, 207f
Fiberoptic instruments, 892
Fiberoptic laryngoscope blade, 129f
Fibroadenoma, 590t
Fibrocystic breast disease, 588, 590t
Fibula, 726–727, 726f–727f
Film badges, 1278
Fimbriae, 419–421
Fine-needle aspiration biopsy
  of breast cancer, 593, 594f
  of thyroid nodules, 572
Fingers, 157
Fire, surgical
  description of, 104b
  laser-related, 235–237, 236f, 236b
  risk reduction for, 673b
Fire risk assessment, 32b–33b
Fisherman's knot, 211
Fissure of Rolando, 821–822, 823f
Fistula
  arteriovenous, 996–998, 997f–998f
  enterovaginal, 440f
  rectovaginal, 438–440, 441f
  ureterovaginal, 438
  urethrovaginal, 438, 440f
  vesicointestinal, 537–538, 538f
  vesicosigmoid, 539–540
  vesicovaginal, 438, 440f, 537–539
Flammable liquids, 37–38
Flaps, 906–907
  myocutaneous, 908–909, 910f
Flash lamp pulsed dye laser, 232
Flash steam sterilization, 78, 78t
Flash sterilization, 891b
Flat bones, 719, 722f
Flat sponges, 187b
Flesh-eating bacteria, 51
Flexible bronchoscope, 951
Flexible cystoscope, 497, 497f
Flexible endoscopes, 204, 207f, 234, 321
Floppy iris syndrome, 641–642
Fluence, 228
Fluid imbalance, risk for, 39–42
Fluid losses, 1199t
Fluid volume overload, 946
Fluorodeoxyglucose positron emission tomography, 361
Fluoroscopy, 734, 1220–1222
Foam dressings, 264t–265t
Focal point, 228
Focused assessment with sonography in trauma, 1192, 1192t
Foley catheter, 374–375, 491–492, 492f, 517f
FoleyGoalie, 491–492, 492f
Follicle-stimulating hormone, 424t
Fontan procedure, 1151
Fontanelles, 819
Foot
  anatomy of, 727, 728f
  bones of, 727, 729f
  clubfoot, 1131
Foot surgery, 776–780
Foot-candle, 217b
Foramen magnum, 819, 839f
Foramen of Monro, 827
Forced expiratory volume in 1 second, 941t
Forced vital capacity, 941t
Forced-air warming units, 139, 276, 367
Forceps
  biting-tip, 950–951
  bronchoscopy use of, 950–951
  description of, 195, 195f–196f, 198, 200
  ear, 680f
  endoscopic minimally invasive surgery use of, 210–211
  ophthalmic surgery, 624f–625f
Foreign objects, retained, 34–36, 34b, 36b, 190b, 202, 1125, 1125f–1126f, 1126b
Formaldehyde, 37, 57
Formalin, 37
Fourth ventricle, 824–825
Fowler's position, 162b–163b, 168f, 855
Fraction of inspired oxygen sensor, 122
Fracture(s), 745–750
  acetabular, 761–762, 763f
  ankle, 776–778, 778f
  avulsion, 746
  basilar skull, 819
  blow-out, 915, 915f, 1209
  burst, 1208–1209
  carpal, 761, 762f
  clavicular, 751–752
  closed, 745, 746f
  closed reduction of, 746–747, 747f
  Colles', 759–760
  compression, 745–746, 746f
  definition of, 745
  external fixation of. *See* External fixation of fractures
  femoral. *See* Femoral fractures
  humeral. *See* Humeral fractures
  incomplete closed, 745
  internal fixation of, 748–750
    open reduction and, 749–750, 750f
    pins, 749, 749f
    plating, 748f, 749
    rod, 749, 749f
    screws for, 748, 748f
  lateral malleolar, 778f
  Le Fort, 916, 1209, 1209f
  longitudinal, 745–746, 746f
  mandibular, 917, 1209
  maxillary, 915–916, 916f
  Monteggia, 759
  nasal, 693, 693f, 915
  oblique, 745–746, 746f
  olecranon, 758, 758f
  open, 745
  orbital floor, 915
  osteoporotic, 745
  patellar, 772–773
  pathologic, 745–746, 746f
  pelvic, 780–781, 781t, 1212–1214
  radial head, 759
  rib, 1209–1210
  scaphoid, 761, 762f
  skull, 819, 1205–1208, 1208f
  spinal column, 1208–1209
  tibial plateau, 768–770, 771f–772f, 772
  transverse, 745–746, 746f
  trimalar, 916
  trimalleolar, 778
  types of, 745–746, 746f
  zygomatic, 915–916
Fracture bed position, 162b–163b, 165, 165f, 732–733, 733f
Francisella tularensis, 65t–66t
Frazier clips, 187–188
Free flaps, 906–907
Free skin graft, for urethroplasty, 1117, 1119f
Free transverse rectus abdominis myocutaneous flap, 910
Free-flowing carbon dioxide laser, 230
Free-lock compression plate and lag screw fixation, of intertrochanteric fracture, 763–765, 764f
Fresh frozen plasma, 40
Friction, 144
Frontal lobe, 822–823, 823f
Frontal sinus trephination and obliteration, 697–698, 698f
Frontalis suspension, for ptosis, 636, 637f
Frozen section, 37
Full-thickness burns, 900, 902f
Full-thickness skin grafts, 904–906
Functional cysts, 462
Functional endoscopic sinus surgery, 695–699, 695b, 696f–697f
Functional recovery index, 14b
Fusiform aneurysm, 1068

G

Gadolinium-enhanced magnetic resonance imaging, 846, 847f
Gallbladder
  anatomy of, 359, 360f
  bile storage in, 359
  cholecystectomy. *See* Cholecystectomy
Gallstones, 372b
Gamete intrafallopian transfer, 468t
Gamma knife therapy, 835b
Ganglion excision, 760–761
Gangrene, 254b
Garlic, 1011t, 1253t–1255t
Gastrectomy
  partial, 330–332, 332f–333f
  subtotal, 333f
  total, 332–333, 334f–335f
Gastric reflux, 226
Gastric ulcer, 330
Gastroduodenal artery, 296, 297f, 360f
Gastroenterology, 295
Gastroepiploic artery, 1054, 1055f
Gastroesophageal reflux disease
  causes of, 1098
  definition of, 322
  endoscopic procedures for, 322–323
  laparoscopic Nissen fundoplication for, 325–326, 325f
  signs and symptoms of, 322
Gastrohepatic ligament, 329f
Gastrointestinal anastomosis staplers, 199f
Gastrointestinal bleeding, 1178
Gastrointestinal surgery. *See also specific procedure*
  abdominal incisions, 311–315
  age-related changes in, 1164, 1165b
  anatomy, 295–299, 296f–298f
  antibiotic prophylaxis before, 305, 306t
  bariatric. *See* Bariatric surgery
  bowel technique for, 309

Gastrointestinal surgery *(Continued)*
colon. *See* Colon, surgical procedures of
dietary resumption after, 310
discharge planning and instructions, 304, 310–311
endoscopic procedures, 320–323
esophagus. *See* Esophagus, surgical procedures of
family education, 310–311
hemostasis, 309
indications for, 295
instrumentation for, 307
intraoperative intraperitoneal chemotherapy, 320, 320b
laboratory studies, 300, 301t–303t
laparoscopy. *See* Laparoscopy
laparotomy. *See* Laparotomy
nursing considerations, 299–311
assessment, 299–303, 300b
evaluation, 309
implementation, 303–309
nursing diagnoses, 303, 304b–305b
outcome identification, 303
planning, 303
nursing interventions, 306b
ostomy
ileostomy, 341–342
site-marking for, 299b
stoma, 322
wound ostomy continence nurse for, 299, 310–311
pain management after, 310
patient education, 310–311
pediatric, 1101–1108
peristalsis delays after, 310
plan of care for, 304b–305b
postanesthesia care unit transport after, 309
postoperative considerations
description of, 310
ileus, 310, 310b
sequential compression devices used in, 307
small bowel. *See* Small bowel/intestine, surgical procedures of
specimen collection and handling, 309
sponges for, 309
stomach. *See* Stomach, surgical procedures of
suture materials used in, 309
Gastrointestinal tract
anatomy, 295–299, 296f–297f
description of, 299
Gastrojejunostomy, 330, 331f
Gastroschisis, 1110–1111, 1111f
Gastrostomy, 1102–1104, 1103f–1104f
Gender reassignment, 918
General anesthesia, 117–118, 123–133
airway management in difficult, 130, 131b
laryngeal mask airway, 128, 130, 132f
anticholinergics for, 124t–127t
barbiturates for, 128
bronchoscopy, 944
cholinergics for, 124t–127t
General anesthesia *(Continued)*
depolarizing muscle relaxants for, 124t–127t
drugs used in, 124t–127t
emergence phase of, 124–127, 131–133
endogenous endorphins, 123
endotracheal tube for, 128, 129f, 131b
equipment used in, 129f
gases used in, 124t–127t
induction phase of, 124–128
inhalation technique, 127
intravenous technique
analgesics used in, 124t–127t
description of, 127
intubation for, 128–129, 129f
levels of, 123–124
maintenance of, 124–127, 130–131
mechanism of action, 123
Meyer-Overton theory of, 123
muscle relaxants, 124t–127t, 128
nondepolarizing muscle relaxants for, 124t–127t
ophthalmic surgery, 620
opioid analgesics for, 124t–127t
phases of, 124–127
pressure ulcer risks, 146
protein receptor theory of, 123
pulmonary aspiration risks, 130b
sequence of, 128–133
total intravenous anesthesia, 127–128
types of, 127–128
untoward events of, 133
vascular system changes during, 155
Genitalia
female, 419, 420f–421f
patient positioning effects on, 157
Genitourinary surgery
advances in, 478
age-related changes in, 1164–1165, 1165b
anatomy of, 478–482
ancillary equipment, 488
aseptic techniques, 487
bladder. *See* Bladder surgery
discharge planning and instructions, 493
in elderly, 1179
endoscopic equipment, 488
endoscopy, 497
family education, 493
irrigating fluids, 487–488
nursing considerations, 482–493
assessments, 482–484, 484t
evaluation, 493
implementation, 486–493
nursing diagnoses, 484, 485b
outcome identification, 484
planning, 485–486
patient education, 493, 494b
patient positioning for, 486–487
patient safety, 486
pediatric, 1115–1125
penis, 499–500, 500f
photography, 493
rapid response teams, 486b
ureters, 551–564
urethra, *499–506*. *See also specific procedure*
urethral and ureteral catheters, 488–493, 491f–492f
Genitourinary system
female, 483f
laboratory studies, 484, 484t
male, 481–482, 483f
traumatic injuries of, 1212–1213, 1213f, 1213t
Geobacillus stearothermophilus, 75, 75t
Geriatric care, 1160b
Geriatric surgery. *See also* Elderly
abdominal surgery, 1178
anesthesia
assessments before, 1163b
induction of, 1171–1173
aseptic techniques for, 1173–1174
cardiac surgery, 1180
cataracts, 1177b
considerations for, 1160b
decision-making considerations, 1161
dehydration concerns, 1173–1174, 1174t
diagnostic tests before, 1167–1168
discharge planning and instructions for, 1175–1177
ethical issues, 1180
family education about, 1175–1177
genitourinary surgery, 1179
hernia repair, 1178–1179
laboratory tests before, 1167–1168
nursing considerations, 1162–1171
assessments, 1162–1169
evaluation, 1174–1175
implementation, 1169–1174
nursing diagnoses, 1169, 1170b–1171b
outcome identification, 1169
planning, 1169, 1170b–1171b
older population, 1157, 1158f–1159f, 1158b
operative risk determinations, 1168–1169, 1169b
ophthalmic surgery, 1179
orthopedic surgery, 1179–1180
overview of, 1157
patient education about, 1175–1177
patient positioning for, 1172–1173
preliminary evaluations, 1158–1162
preoperative preparation, 1171
procedures, 1177–1180
safety considerations, 1173–1174
skin preparation for, 1173–1174
vascular surgery, 1180
Germ cell tumors, 826
Germicides, 56, 81
Germinoma, 826
Gerota's capsule, 559
Gerota's fascia, 478
Gerstmann-Stäussler-Scheinker syndrome, 57
Ginger, 1011t, 1253t–1255t, 1255b
Ginkgo, 1011t, 1253t–1255t
Ginseng, 1011t, 1253t–1255t
Glasgow Coma Scale, 846t, 1142, 1144t, 1205
Glaucoma
aqueous shunts for, 647b
classification of, 1141t
drainage devices for, 646–647, 647f
iridectomy for, 645, 645f
pediatric, 1141, 1141t
trabeculectomy for, 645–646, 646f, 1141
vision effects, 642f
Gleason score, 513
Glenohumeral joint, 722–723
Glial cells, 818
Glioblastoma multiforme, 825–826
Glisson's capsule, 357
Globe
anatomy of, 611–612, 612f
enucleation of, 628–631, 630f
surgery of, 628–631
Globulin, 363t
Glomerular filtration rate, 1231–1232, 1232b
Glossopharyngeal nerve, 835
Gloves
benefits of, 98
bloodborne pathogen exposure, 61
latex allergies and sensitivities, 98
powder as lubricant, 98
selection of, 93
soiled, removal of, 99–101, 102f
Standard Precautions, 63
surgical site infection risks associated with perforation of, 182b
Gloving, 98–99
assisted technique, 99, 101f
closed technique, 99, 100f
double-gloving, 99b, 1265
open technique, 99, 101f
γ-Glutamicrotranspeptidase, 363t
γ-Glutamyltransferase, 363t
Glutaraldehyde, 57, 83–84, 215, 489t–490t
Goiter, 577–578
Goldenseal, 1253t–1255t
Gore-Tex patch, 417
Gown, 63, 86–87, 95–98
soiled, removal of, 99–101, 102f
Gowning, 96–98, 96f–98f
Grafts
prosthetic vascular, 982
skin. *See* Skin grafts
Gram stain, 49b
Gram-negative bacteria, 50f
Gram-positive bacteria, 48
Graspers
description of, 195
endoscopic minimally invasive surgery use of, 210–211, 210f
Graves' disease, 577–578
Gravity convection sterilizer, 81
Gravity displacement steam sterilizer, 76, 76f
Gray matter, 837
Greater curvature of stomach, 295
Greater trochanter, 724–725, 725f–726f
Greater tuberosity, 723
Groin lymphadenectomy, 433–434, 434f
Grounded electrosurgical units, 243
Group A streptococci, 51
Growth factors, 262
Guided imagery, 1247, 1248f
Guidewires, 1225, 1225f
Gynecologic cancer, 425–427
Gynecologic surgery. *See also Female reproductive system; Obstetric surgery; specific procedure*
anatomy, 419–423
assessments, 423–427, 426b
diagnostic studies before, 424–425
discharge planning and instructions, 430–431
drains, 430
dressings, 430
ectopic pregnancy, 451–452, 451f, 452b, 453f
examination under anesthesia, 430
family education, 430–431, 432t
instrumentation, 428
intimate partner violence, 424, 425b
laparoscopic, 450–451
lasers in, 431
lithotomy position for, 428–430
medication history, 424
medications used in, 469t–471t
minimally invasive, 431b, 448–455
nursing considerations, 423–431
assessments, 423–427, 426b
evaluation, 430
implementation, 428–430
nursing diagnoses, 427, 429b
outcome identification, 428
planning, 428
packing, 430
patient education, 430–431, 432t
patient positioning, 428–430
plan of care, 429b
prepping for, 430
vagina. *See* Vaginal surgery
Gynecomastia, 933, 934f
Gyri, 821–822

H

Haight anastomosis, 1102f
Hair
preoperative removal of, 855, 980b
traumatic loss of, 1090b
Hall Surgairtome, 200, 850, 852f
Hammer toe deformity, 779
Hand
anatomy of, 723–724, 724f
carpal tunnel release, 760
ganglion excision, 760–761
surgery of, 760–761
toe-to-hand transfer, 913–914, 914f
Hand drape, 913
Hand hygiene
devices for, 1276b
indications for, 255b–257b
infection prevention benefits of, 63b
methods of, 93, 255b
origins of, 1275b
scrubbing, 94–95, 95f
Standard Precautions guidelines for, 62–63
surgical, 93–95
World Health Organization guidelines for, 23b

Hand rubs, 93
Hand scrub, 94–95, 95f
Hand-assisted laparoscopic surgery, 307
Hand-honed reverse cutting needle, 183t
Hand-offs/handovers, 25–30, 26b, 31b
  postanesthesia care unit, 31b, 34b, 267, 269b, 577
  report content, 269b
Handwashing, 62–63, 63b, 255b–257b
Hashimoto's disease, 571b, 577–578
Hasson technique, 319
Haustra, 298
Hawthorn, 1253t–1255t
Hazardous drug exposure, 1274
Head. *See also* Cranium; Skull
  pin fixation of, 169
  support of, in prone position, 169–170
  traumatic injuries of, 1205–1209, 1205f–1206f, 1206t–1207t, 1208f
Head cover, 91
Headache, postdural puncture, 133–135
Head-elevated laryngoscopy position, 157–158
Healing Touch, 1246t
Health Insurance Portability and Accountability Act. *See* HIPAA
Health literacy, 1176b
Healthcare Information and Management Systems Society, 25b
Healthcare-associated infections
  description of, 49b, 59t, 1276
  surgical site infections and, 250
  varicella zoster virus, 1276
HealthGrades, 25b
Hearing, 657, 1166
Hearing aids
  bone-anchored, 691–692, 691f–692f
  description of, 670–671
  implantable, 691–692, 691f–692f
  semi-implantable, 692
Hearing impairment, 665b
Hearing loss
  assistive hearing devices for. *See* Assistive hearing devices
  in children, 690b
  description of, 664–665
  types of, 666t
Heart
  anatomy of, 1002, 1003f–1008f
  atrium of, 1002, 1003f–1004f
  blood supply, 1003f–1004f
  conduction system of, 1006, 1006f
  muscle of. *See* Cardiac muscle
  nerve impulses to, 1006
  remodeling of, 1006
  surfaces of, 1005f
  total artificial, 1076
  transplantation of, 1076–1077, 1076f–1077f
  traumatic injuries of, 1209–1211, 1210f
  ventricles of, 1002, 1003f–1004f
Heart failure, 1058
Heart valves
  anatomy of, 1006, 1007f–1008f
  prosthetic. *See* Prosthetic heart valves
  surgery of. *See* Valvular surgery
  traumatic rupture of, 1210
Heart-lung transplantation, 1076–1077
Heller procedure, 326
Hematocrit, 301t–303t, 941t, 1017t
Hematoma, 830, 832f, 1206f
Hematopoietic neoplasms, 826
Hematopoietic stem cell transplantation, 64
Hematuria catheter, 492
Hemicolectomy, 343
  left, 346f
  right, 345–347, 346f
Hemi-Fontan procedure, 1152, 1154f
Hemilaryngectomy, 712t
Heminephrectomy, 559
Hemithorax, 937f–938f
Hemithyroidectomy, 577
Hemodynamics, 1015b, 1016t
Hemoglobin, 941t, 1017t, 1190b–1191b
Hemoglobin concentration, 301t–303t
Hemorrhoidectomy, 352–354
Hemostasis, 185–188
  agents for, 368t, 858–859, 858t
  electrosurgery for, 309
  ligating clips, 186–188, 187f, 858, 859f
  ligation methods, 186
  neurosurgery, 856–859, 857f
  sponges for, 185, 187b, 858
Hemostats, 195, 195f
Hemovac drain, 266f
Henderson, Virginia, 5b
HEPA filters, 107
Heparin-induced thrombocytopenia, 1226
Hepatic artery, 357, 359f
Hepatic cords, 357
Hepatic portoenterostomy, 1111–1112, 1112f
Hepatic resection, 387–388, 388f–389f
Hepatic sinusoids, 357
Hepatic transplantation. *See* Liver transplantation
Hepatitis, 52
  definition of, 52
  infectious, 52
Hepatitis A virus, 52
Hepatitis B virus
  description of, 52
  needle-stick transmission of, 193
  transmission of, 52
  workplace transmission of, 1276
Hepatitis C virus
  needle-stick transmission of, 193
  prevention of, 52
  transmission of, 52
Hepatitis D virus, 52
Hepatitis E virus, 52
Hepatitis G virus, 52
Hepatobiliary disease, 361
Herbal medicines, 1011t
Herbs, 1242, 1245f, 1250–1252, 1252b
Hernia
  abdominal
    anatomy of, 399
    repair of, 415–417
  anatomy of, 396, 398f
  classification of, 396
  congenital diaphragmatic, 473, 474f, 1112–1113, 1113f
  definition of, 396
  diagnosis of, 400
  in elderly, 1178–1179
  epigastric, 416
  femoral
    anatomy of, 398–399, 398f
    incidence of, 396
    repair of, 410, 413, 413f–414f
  gender predilection, 396
  incarcerated, 396, 403–405
  incisional, 398f, 415–416
  inguinal. *See* Inguinal hernia
  interparietal, 416
  Littre's, 414–415
  Maydl, 414–415
  pain associated with, 400
  physical examination for, 400
  plan of care, 402b
  Richter, 414–415, 416f
  scrotal, 1179
  sites of, 396
  sliding, 403–405, 414, 414f–415f
  smoking and, 396
  spigelian, 416
  umbilical. *See* Umbilical hernia
  ventral, 415–416
Hernia repair
  Bassini technique, 408
  Cooper ligament, 407–408, 409f–410f
  device for, 411–412
  discharge planning, 405–406
  family education after, 404t, 405–406
  femoral, 410, 413, 413f–414f
  Gore-Tex patch, 417
  history of, 397b
  home care after, 404t
  incidence of, 396
  inguinal, 406–415, 417, 1108–1110
  laparoscopic, 410–413
  McVay, 407–408, 409f–410f
  mesh-plug technique, 409–410, 411f
  nursing considerations, 400–406
  patient education after, 404t, 405–406
  patient positioning for, 403
  patient-centered care, 401b
  preperitoneal, 413, 414f
  prioritizing of, 397b
  Shouldice technique, 408–409
  synthetic mesh and patch, 416–417, 417f
  vest-over-pants, 415-416
Herniated nucleus pulposus, 880f
Hesselbach triangle, 399, 399f
Hiatal hernia, 324–325
Hiatal herniorrhaphy, 324
Hierarchy of Controls, 1266b
High-definition television, 217b
High-definition video, 218
High-intensity focused ultrasound, 513b
High-level disinfectants, 82
High-osmolality contrast media, 1222b, 1230–1231
HIMSS. *See* Healthcare Information and Management Systems Society
Hinged spinal frame, 170, 170f
Hip
  anatomy of, 724–726, 725f
  developmental dysplasia of, 1130–1131, 1130f
  dislocation of, 762
  surgery of, 761–768
    acetabular fractures, 761–762, 763f
    femoral head replacement, 765–767, 766f
    fracture repair. *See* Hip fractures
Hip fractures, 762–768
  classification of, 762–763, 763f
  in elderly, 1179
  femoral neck
    cannulated screw fixation for, 765, 765f–766f
    description of, 763
    internal fixation of, 765, 765f–766f
  intertrochanteric
    description of, 763–765
    free-lock compression plate and lag screw fixation of, 763–765, 764f
  subtrochanteric, 762–763, 763f
Hip grafts, 856
Hip spica casts, 736, 737f
HIPAA
  Centers for Medicare & Medicaid Services administration of, 19–20
  videoconferencing considerations, 224
Hippocampus, 824
Hippocrates, 58b, 174
Hirschsprung's disease, 1105–1106, 1106f
HIV, 52–53
  needle-stick transmission of, 193
  postexposure prophylaxis after occupational exposure to, 53t, 1267
  Universal Precautions to prevent exposure to, 57–58
H1N1, 89b–90b
Holding area, 142
Holmium:YAG laser, 231
Home care
  dressings, 259t
  hernia repair, 404t
  nephrectomy, 495t
  oxygen therapy, 948t–949t
  thyroidectomy, 578t
  wound care, 259t
Homeopathic medicine, 1241
Horner syndrome, 136
Horseshoe headrest, 169
Horton-Devine urethroplasty, 502
Hospital-based surgery, 20b
Huang qi, 1253t–255t
Human immunodeficiency virus. *See* HIV
Humeral fractures
  distal, 756–758, 756f–758f
  epicondylar, 756–758
  head, 754, 754f
  intercondylar, 756–758
  shaft, 754–756, 755f
  supracondylar, 756–758
Humerus
  anatomy of, 723, 723f
  distal, 723
Hydrocelectomy, 506–508, 508f, 1120–1121, 1121f
Hydrocephalus, 828, 866
Hydrocolloid dressings, 264t–265t
Hydrodissection, 247–248, 248f
Hydrogel, 264t–265t
Hydrogen peroxide
  as disinfectant, 83
  gas plasma sterilizer, 80–81, 81f
Hydrosurgery, 261
Hydrotherapy, 261
Hyperbaric oxygenation, 258–259
Hyperbaric spinal anesthesia, 133
Hyperhidrosis, 953, 954b
Hyperparathyroidism, primary, 572
Hypertension, 275
Hyperthermia
  malignant, 128, 139–141, 140b–141b, 276–277, 1093–1094
  postoperative, 276–277
Hyperthermic intraperitoneal chemotherapy, 320
Hyperthyroidism, 571b, 573–574, 1178
Hypertropia, 1138b
Hypnotherapy, 1246–1247
Hypnotics, 1206t–1207t
Hypobaric spinal anesthesia, 133
Hypocalcemia, 577, 583
Hypochlorites, 82–83
Hypoglossal nerve, 835
Hyponatremia, 449
Hypopharynx, 661
Hypophysectomy, transsphenoid, 875
Hypoplastic left heart syndrome, 1151–1153
Hypospadias, 1115–1118
Hypotension, 1235b
  definition of, 273
  intraoperative, 226
  postoperative, 273–275
  after subarachnoid block, 133
Hypothalamus, 824
Hypothermia. *See also* Body temperature; Thermoregulation
  anesthesia-related, 139
  in cardiac surgery, 1040
  cerebral blood flow affected by, 1214
  classification of, 1214
  definition of, 1214
  high-risk groups for, 276
  intraoperative, 146
  laparoscopic surgery, 307
  operating room temperature and, 145–146
  postoperative, 276
  surgery-related, 6b
  trauma-related, 1214
Hypothyroidism, 571b
Hypotropia, 1138b
Hypovolemia, 275, 388b
Hypovolemic shock, 1200t
Hysterectomy
  alternatives to, 456b
  modified radical, 459f
  patient and family education about, 432t
  radical, 459, 459f–460f
  simple, 459f
  total abdominal, 455–458

Hysterectomy *(Continued)*
vaginal
laparoscopic-assisted, 453–454
robotic-assisted, 454–455, 454b
standard procedure, 446–448, 447b, 448f
Wertheim radical, 459, 459f–460f
Hysteroscopy, 448–449

I

Ileal conduit, 549–550
Ileal reservoir, 550–551
Ileoanal endorectal pull-through, 350–352, 351f–353f
Ileoascending bladder substitution, 549
Ileocecal bladder substitution, 549
Ileocecal valve, 297
Ileocolostomy, 345–347
Ileocystoplasty, for bladder augmentation, 545f
Ileostomy, 341–342. *See also* Ostomy
Image-guided surgery, 852–853, 852f, 864
Imagery, 738t–739t
Immunity, 49b
Immunizations, 1276–1277
Impedance, 241
Imperforate anus repair, 1107, 1107f
anal transposition, 1107–1108, 1107f
high, 1108, 1109f
low, 1107–1108, 1107f
posterior sagittal anorectoplasty, 1108, 1109f
Impingement syndrome, 752
Implant(s)
arthroplasty, 781
breast, 908, 908f–909f, 928–929
orthopedic surgery
equipment for, 740–741
FDA requirements for, 740–741
penile. *See* Penile implants
plastic and reconstructive surgery, 893, 893f, 893b
total joint arthroplasty, 781
total knee arthroplasty, 789, 789f
tracking medical devices, 893b
Implantable cardioverter-defibrillator, 1080f, 1081
Implementation, 9, 9b
In situ femoral-popliteal bypass, 991
In vitro fertilization embryo transfer, 468t
Incision(s)
abdominal. *See* Abdominal incisions
cardiac surgery, 1035–1039
femoral, 1051
laparotomy, 316, 317f
lower oblique inguinal, 312–313
McBurney, 312, 312f, 339
median sternotomy, 1035–1036, 1036f
midabdominal transverse, 314
midline, 312, 312f
neck dissection, 716f
oblique, 312–314, 312f
Incision(s) *(Continued)*
paramedian, 312, 312f
Pfannenstiel, 314, 315f
postauricular, 682
site of, 311–312, 312f
subcostal, 312f, 313–314, 314f
supraumbilical, 376f
thoracic, 1052t–1053t
thoracoabdominal, 314–315, 316f, 1052t–1053t
thoracotomy, 944f
transverse, 312f, 314–315, 315f–316f
umbilical, 319
vertical midline, 312
Incisional biopsy, 602
Incisional hernia, 398f, 415–416
Incomplete closed fractures, 745
Incontinence. *See* Urinary incontinence
Incorrect counts, 36
Incus, 657, 658f
Indiana pouch, 551
Indigo carmine, 489t–490t
Infection
barriers to, 48
causes of, 48–85
definition of, 49b
enterococci, 50
healthcare-associated. *See* Healthcare-associated infections
multidrug-resistant, 53–57
history of, 53–54
resistance mechanisms, 54–56
Staphylococcus aureus. *See* Methicillin-resistant *Staphylococcus aureus*
tuberculosis. *See* Multidrug-resistant tuberculosis
vancomycin intermediate-resistant *Staphylococcus aureus*, 56
Mycobacterium tuberculosis, 51–52
prosthetic vascular graft, 982
Pseudomonas aeruginosa, 50–51
staphylococci. *See* Staphylococci
streptococci, 51
surgical site. *See* Surgical site infections
terminology associated with, 49b
trauma and, 1196
vancomycin-resistant enterococci, 56
viruses that cause, 52–53
Infection control, 57–85
asepsis. *See* Asepsis/aseptic principles and techniques
bioterrorism and, 64–66
engineering practices for, 66–67
environmental cleaning for, 107–108
hand hygiene. *See* Hand hygiene
historical influences on, 58b
Universal Precautions. *See* Universal Precautions
Infection prevention, 67–85
disinfection. *See* Disinfection
importance of, 59b
pasteurization, 84
sterilization. *See* Sterilization
Infectious agent, 49b
Infectious diseases, 66b, 1276–1277
Infectious hepatitis, 52
Inferior sagittal sinus, 828–829
Inferior thyroid artery, 566–567, 570f
Infertility
assessment of, 426b
assisted reproductive therapies for, 466–467, 468t
criteria for, 467
prevalence of, 466
surgery for
fallopian tube microscopic reconstructive surgery, 463–464
oophorectomy, 462–463, 464f
oophorocystectomy, 462–463
salpingo-oophorectomy, 463
Inflatable penile implant, 505–506, 505f, 507f–508f
Influenza
H1N1, 89b–90b
vaccine for, 1276
workplace exposure to, 1276
Informatics, 16
Informed consent, 402b, 1089
Infundibulopelvic ligament, 420f
Inguinal hernia
anatomy of, 396–398, 398f
in children, 1108–1110
direct, 398f, 399, 410, 413
in females, 413
incidence of, 396
indirect, 398f, 399, 410, 413
Littre's, 414–415
Maydl, 414–415
repair of, 406–415, 417, 1108–1110
Richter, 414–415, 416f
Inguinal ligament, 396–397
Inhalation gases, 124t–127t
Injectable anesthetics, 894
Inotropic agents, 1032t–1033t
Inpatient unit, 34b
Insemination, 468t
Inspiration, 937–938
Institute for Safe Medication Practices, 25b, 39
Institute of Medicine, 18, 25b
Institutional standards of care, 12
Instrument(s), 193–202
arthroscopy, 803f
bronchoscopy, 950
cardiac surgery, 1021, 1021f–1023f
Creutzfeldt-Jakob disease exposure, 57, 60t–61t
cystoscopy, 496–497, 497f
forceps. *See* Forceps
gastrointestinal surgery, 307
handwashing of, 69
historical perspective on, 193
inspection of, 196–197
interventional radiology, 1225, 1225f
intraoperative cleaning of, 68
laparoscopy, 307
laparotomy, 199, 315
laser surgery, 235
neurosurgery, 850–851, 852f
pediatric surgery, 1093
plastic and reconstructive surgery. *See* Plastic and reconstructive surgery
thoracic surgery, 943
ultrasonic cleaning of, 69
vascular surgery, 983
Instrument counts, 201–202
incorrect, 36
needles, 189
record for, 35f
safety checklist quality tool for, 192f
sheet for, 191f
Instrument sets, 199
Insufflation, 224–226
carbon dioxide flow, 224, 317–318
monitoring of, 224–225
pneumoperitoneum creation, 319
tubing used for, 224, 225f
Veress needle for
insertion of, 224, 224f
safety considerations, 318b
Insufflators
with carbon dioxide warming, 225–226, 225f
description of, 224
Insula, 824
Integra (skin substitute), 262t
Integrative health therapies, 1252–1256
Integumentary system, 1163
Intercondylar femoral fractures, 770–772
Intercondylar groove, 725
Intercondylar humeral fracture, 756–758
Intercostal nerve, 936
Intermaxillary fixation, 917
Intermediate-level disinfectants, 82
Intermittent claudication, 975b
Internal mammary artery, 1051, 1054f, 1055
Internal os, 419
Internal urethrotomy, 500–501
International normalized ratio, 363t
Interparietal hernia, 416
Interrupted suture, 183, 185f
InterStim sacral nerve stimulator, 542–543, 543f–544f
Interstitial laser coagulation of the prostate, 518–519, 519f
Interstitial radiotherapy with brachytherapy, 524–526, 526f
Interventional radiology
ambulatory, 1238b
analgesia for, 1227–1228, 1229t–1230t
catheters for, 1225, 1225f
contrast media. *See* Contrast media
definition of, 1216
description of, 872
dose monitoring, 1224b
equipment for, 1224, 1225f
instrumentation and supplies for, 1225, 1225f
medications
history-taking, 1218
sedation and analgesia, 1225–1226
nurse duties, 1218b
nursing care in, 1218–1238
assessment, 1218–1220
evaluation, 1236–1238
implementation, 1224–1236
nursing diagnoses, 1220, 1221b
outcome identification, 1220
planning, 1220–1224, 1221b
outpatients, 1238
patient education about, 1220
Interventional radiology *(Continued)*
patient positioning for, 1236
personnel radiation monitoring, 1224
pregnancy contraindications, 1220
procedures, 1236, 1237b, 1238f
radiation exposure
monitoring of, 1220
protection methods, 1221–1223, 1223f
shielding against, 1222–1223, 1223f
sedation for, 1227–1228, 1229t–1230t
Seldinger technique, 1236, 1238f
terminology associated with, 1223t
units of measure, 1220, 1222t
universal protocol, 1236
Interventional uroradiology, 493–495
Intervertebral disk, 721–722, 814, 836
Intervertebral disk disease, 843, 843f–844f
Intervertebral foramina, 838
Intimate partner violence, 424, 425b
Intraabdominal pressure, 1192–1193
Intra-aortic balloon pump, 1072, 1073f
Intraarterial thrombolysis, 863
Intracapsular cataract extraction, 641
Intracavitary implant, 446f
Intracerebral hemorrhage, 830, 832f
Intracervical insemination, 468t
Intracranial aneurysms, 871–872, 871f
Intracranial pressure, 1205
Intracranial stenosis, 862–863
Intracranial tumors, 825, 825t
Intracytoplasmic sperm injection, 468t
Intraductal ectasia, 590t
Intradural spinal cord tumor, 878
Intradural tumors, 840–842
Intramedullary nailing fixation, of tibial shaft fractures, 775–776, 776f–777f
Intraocular lens, 642–643
Intraocular pressure, 156b
Intraoperative awareness, 113–114, 114b
Intraoperative cholangiogram, 372–374
Intraoperative hypotension, 226
Intraoperative intraperitoneal chemotherapy, 320, 320b
Intraoperative period
hand-off communication in, 31b
hypothermia, 146
Intraoperative record, 23, 27f–29f
Intraoperative ultrasonography, 388
Intraosseous infusion, 1144f
Intraperitoneal chemotherapy, 320, 320b
Intrapleural pressure, 938
Intrathecal pump therapy, 881–882

Intrathoracic thyroidectomy, 582
Intrauterine insemination, 468t
Intravenous access, in children, 1142–1144
Intravenous analgesics, 124t–127t
Intravenous anesthesia
  nursing assessment and actions for, 1227b
  pediatric, 1093
  regional, 136–137
Intubation
  complications of, 1198–1199
  general anesthesia, 128–129, 129f
  rapid-sequence, 1198, 1198b
Intussusception, 1104–1105, 1105f
Involutional entropion, 633
Iodinated contrast media, 1219b
Iodine, 83
Iodophors, 83
Ionic, 1222b
Iowa Model of Evidence-Based Practice, 13f
Iridectomy, 645, 645f
Irregular bones, 719, 722f
Irrigating fluids
  antibiotics in, 742
  description of, 487–488, 489t–490t
Irrigation
  continuous bladder, 491–492
  endoscopic minimally invasive surgery, 247–248
Irritant contact dermatitis, 98, 1278
Ischemic optic neuropathy, 156b
Island flaps, 906–907, 1120f
Islets, 360
ISMP. *See* Institute for Safe Medication Practices
Isobaric spinal anesthesia, 133
Isola instrumentation, 813–814
Isolated electrosurgical units, 243
Isopropyl alcohol, 82
Isosulfan blue dye, 605

J

J pouch, for ileoanal endorectal pull-through, 351, 351f
Jackknife position, 162b–163b, 170–171, 171f
Jackson Pratt drain, 266f
Jackson table, 855
Jejunum, 295–297, 296f
Jet ventilation, 236–237
Johanson urethroplasty, 501–502
Johnson, Dorothy, 5b
Joints. *See also specific joint*
  definition of, 719
  diarthrotic, 719
  synarthrotic, 719
Joule, 228

K

Kasai procedure, 1111–1112, 1112f
Kava kava, 1253t–1255t
Kehr's sign, 1211
Keller procedure, 779
Keloid, 254b
Keratin, 250
Keratoplasty, 638–639
  deep lamellar endothelial, 639
  lamellar, 639
  penetrating, 638–639
Keratorefractive surgery, 639–640
Kerosene, 362t
Kidney(s)
  anatomy of, 478, 479f–481f
  blood supply of, 478
  contrast media-nephrotoxicity, 1231–1232
  lymphatic system of, 478
  traumatic injury of, 1212, 1213f, 1213t
  urine excretion by, 478
Kidney clamps, 557f
Kidney stones, 552
Kidney surgery, 553–559
  adrenalectomy, 563–564
  approaches to, 552
Kidney transplantation, 559–563
King, Imogene, 5b
Knee
  anatomy of, 726–727, 726f–727f
  bones of, 726–727
  capsule of, 727
  cruciate ligaments of
    anatomy of, 727, 727f
    repair of, 773–775, 774f
  menisci, 727, 727f
  popliteal cyst excision, 775
  synovial membrane of, 727, 728f
Knee arthroscopy, 812
  anterior cruciate ligament repair, 804–806, 805f–806f
  description of, 801, 801b
  diagnostic uses, 802
  meniscal tear resection and repair with, 802–804, 804f
  operative uses of, 802–806
  patient positioning for, 801, 802f
  procedural considerations for, 801–802, 802f
Knee-chest position, 162b–163b, 171
Knee-crutch stirrups, 166, 166f
Kneeling position, 162b–163b, 171, 171f
Knot typing, 184, 211
Kocher clamp, 195
Kraske position, 170–171, 171f
Krypton fluoride, 232
KTP laser, 231
Kupffer cells, 357
Kyphoplasty, 815–816, 815b

L

Labia majora, 419, 421f
Labia minora, 419, 421f
Labyrinthectomy, 688
Lacerations, corneal, 637
Lacrimal apparatus
  anatomy of, 610, 611f
  surgery of, 631–633
Lacrimal fossa surgery, 631
Lactate dehydrogenase, 363t
Lambert-Beer law, 120
Lamellar keratoplasty, 639
Laminar airflow, 737
Laminar blood flow, 969–970
Laminectomy, 809, 877–878, 878f
Laminotomy, 878–879
Lancet, 183t
Laparoscope
  insulation failure, 245, 245f
  operative, 207f
Laparoscopically assisted, defined, 318
Laparoscopy, 317–320. *See also* Minimally invasive surgery
  abdominal trauma evaluations, 1212
  adjustable gastric banding, 336, 337f
  adrenalectomy, 564
  advantages of, 319, 319b
  anesthesia for, 303–305
  appendectomy, 340–341
  cervical cerclage, 473
  cholecystectomy, 374–376
    benefits of, 357
    complications of, 374b
    operative technique for, 375–376, 375f–376f
    pneumoperitoneum, 375
    procedural considerations, 374–375
    recovery from, 370
    robotic-assisted, 376, 377b
    same-day vs. overnight stay, 370b
    trocar placement for, 375f
  colectomy, 342–343, 342b
  common bile duct exploration, 379f
  complications of, 318
    hypothermia, 307
    insulation failure, 245, 245f
  contraindications, 318–319
  definition of, 317
  diagnostic, 1212
  dilation and curettage with, 450–451
  disadvantages of, 319b
  disposable system, 248f
  draping for, 307
  endometriosis, 450f
  equipment placement, 308
  extracorporeal surgery during, 209
  gastrointestinal tract, 307
  gynecologic and obstetric surgery, 450–451
  hand-assisted, 307
  hepatic surgery, 388–389
  hernia repair, 410–413
    description of, 405
    open technique vs., 416b
  history of, 317
  instrumentation for
    accessories, 307
    description of, 307
    illustration of, 187f
    insulation considerations, 245, 245f, 308b
  insufflation for. *See* Insufflation
  kidney transplantation from living donor, 560–561
  lymph node dissection, 530
  nephrectomy, 557–559, 559f
  Nissen fundoplication, 325–326, 325f, 1098–1099, 1099f
  open, 209
  operative procedure, 319–320
  ovarian cystectomy, 452–453
  pancreatic cyst–gastrostomy, 383f
  patient positioning for, 305–306, 367
  pneumoperitoneum for, 224, 319
  port placement for, 317–318
  procedural considerations, 319
  pyloromyotomy, 1097–1098, 1098f
Laparoscopy *(Continued)*
  radical prostatectomy, 532–533
    operative procedure, 533
    procedural considerations, 533
    robotic-assisted, 534, 534f–535f
  robotic systems, 308
  Roux-en-Y gastric bypass, 337, 338f–340f, 1101
  single port, 318–319
  splenectomy, 393–394
  terminology associated with, 318b
  tubal occlusion, 465, 465f–466f
  vaginal hysterectomy, 453–454
Laparotomy, 315–317
LAP-BAND, 336, 337f
Large intestine
  anal canal, 299
  anatomy of, 297–299
  cecum, 297, 298f
  colon, 297–298, 298f
  rectum, 298–299, 298f
Laryngeal cartilages, 661–663
Laryngeal edema, 1235b
Laryngeal mask airway, 128, 129f, 130, 132f
Laryngeal surgery
  adjunctive procedures, 707, 707f
  carbon dioxide laser, 706
  description of, 704, 705f
Laryngectomy
  hemilaryngectomy, 712t
  partial, 711, 712t
  supraglottic, 712t
  total, 711–713, 712t, 713f–714f
  vertical, 712t
Laryngofissure, 708–711
Laryngoscope, 129f, 131b
Laryngoscopy, 705–706, 705f
Laryngospasm, 272
Larynx
  anatomy of, 661–663
  carcinoma of, 712t
  ligaments of, 663
  muscles of, 663, 663f
LASEK. *See* Laser epithelial keratomileusis
Laser(s), 226–231
  gynecologic and obstetric surgery uses of, 431
  diode, 232
  documentation of, 240, 240f
  endotracheal tube ignited by, 236, 236f
  erbium:YAG, 231
  excimer, 124t–127t, 232
  flash lamp pulsed dye, 232
  gynecologic and obstetric surgery uses of, 431
  history of, 227b
  holmium:YAG, 231
  KTP, 231
  mirrors for, 236
  Nd:YAG, 231, 431, 449, 641, 944
  otorhinolaryngologic surgery uses of, 678
  plastic and reconstructive surgery uses of, 922, 922b–924b
  safety considerations, 232–241
  subclassification of, 233
  system components, 229–230, 230f
Laser(s) *(Continued)*
  tissue interactions, 228–229, 228f
  tunable dye, 232
  warning signs for, 234, 235f
Laser beam
  carbon dioxide, 230
  collimated, 227
  fire caused by, 235
  power of, 227–228
  reflection of, 228
  spot size of, 228
  transmission of, 228
Laser epithelial keratomileusis, 640
Laser head, 229
Laser light
  absorption of, 228
  carbon dioxide, 229
  characteristics of, 227–229
  color of, 124t–127t
  scattering of, 228
  wavelength of, 124t–127t
Laser lithotripsy, 555
Laser safety officer, 240
Laser surgery
  condylomata of penis treated with, 499
  diabetic retinopathy treated with, 649
  instrumentation considerations, 235
  jet ventilation used for, 236–237
  nonintubation technique for, 236–237
  ophthalmic, 626
  orthopedic applications, 737
  plastic surgery, 892
  team members, 240–241
  transmyocardial revascularization, 1057
  transurethral laser ablation of bladder tumors, 536f, 537
  varicose veins, 999, 1000b
Laser-assisted in-situ keratomileusis, 639–640, 640f
LASIK. *See* Laser-assisted in-situ keratomileusis
Latent heat of vaporization, 68
Latent tuberculosis, 51–52
Lateral canthal sling procedure, 634, 635f
Lateral kidney position, 162b–163b, 172f, 173
Lateral malleolar fracture, 778f
Lateral position, 162b–163b
Lateral rectus resection, for strabismus, 1137–1138
Lateral thoracotomy, 1052t–1053t
Latex allergies and sensitivities, 98, 369b, 1278–1279, 1280b
Laundry, 62
Le Fort fractures, 916, 1209, 1209f
Lead, 362t
Lead aprons, 1222–1223, 1223b
Leeuwenhoek, Anton von, 58b
Left atrial suction retractors, 1021, 1023f
Left hemicolectomy, 346f
Left main coronary artery, 1002–1003
Left ventricle, 1002, 1003f–1004f
Left ventricular aneurysmectomy, 1057–1058, 1059f

Left ventricular assist devices, 1072, 1074f
Leininger Sunrise Model, 1243f
Lens surgery, 641–645
  anatomy, 613, 613f
  anterior segment vitrectomy, 645
  cataract/cataract surgery. *See* Cataract/cataract extraction
Lesser curvature of stomach, 295
Lesser trochanter, 725, 725f–726f
Leucine aminopeptidase, 363t
Levator ani muscles, 423
Levator aponeurosis repair, for ptosis, 635–636, 636f
Leydig cells, 481
Licorice, 1253t–1255t
Lifting equation, 1260–1261
Ligament(s), *719*. *See also specific ligament*
Ligament of Treitz, 296, 296f, 331f
Ligamenta flava, 721–722
Ligating clips, 186–188, 187f
Ligature
  definition of, 174, 186
  loop, 211, 212f
  securing of, 186
  Surgitie ligating loop, 212f
  Surgiwip suture ligature, 213f
  transfixion, 186
Light
  electromagnetic spectrum, 226–227, 227f
  laser. *See* Laser light
  monochromatic, 227
  principles of, 226–227, 228f
  wavelength of, 118t, 226–227
Light gain, 217b
Limbic system, 824
Linea alba, 399
Linea semilunaris, 399
Linens
  soiled, 108
  Standard Precautions for, 63
Lipase, serum, 364t
Liposuction, 922–926
Liquid nitrogen, 248–249
Lister, Joseph, 58b
Litholapaxy, 497
Lithotomy position, 165–167
  finger injuries associated with, 157
  gynecologic and obstetric surgery, 428–430
  lower extremity neuropathies secondary to, 153
  risks and interventions for, 162b–163b
Lithotripsy
  extracorporeal shock-wave, 555
  laser, 555
Littre's hernia, 414–415
Liver
  abscess of, 387
  anatomy of, 357, 359f
  arterial supply of, 373f
  bile production by, 357, 359
  blood supply of, 373f
  blood-clotting functions of, 358
  function tests for, 361, 363t
  functions of, 357–359
  imaging studies of, 361
  lobules of, 357, 359f–360f
  microsomal enzyme system, 358–359
  surgical procedures of
Liver *(Continued)*
  abscess drainage, 387
  asepsis, 369
  blood products, 369–370
  discharge planning and instructions, 370–371, 370t
  drainage materials, 369
  draping of patient, 368
  evaluation, 370
  family education, 370–371
  hemostatic agents, 368t
  implementation, 364–371
  instrumentation, 368–369
  laparoscopic, 388–389
  nursing considerations, 361–371
  nursing diagnoses, 362
  outcome identification, 362
  pain management, 371
  patient education, 370–371
  plan of care, 365b–366b
  planning, 362–364
  radioimmunoguided, 389–390
  resection, 387–388, 388f–389f
  robotic-assisted laparoscopic, 388–389
  sequential compression devices for, 367–368
  thermoregulation during, 367
  transplantation. *See* Liver transplantation
  toxic agents, 362t
  traumatic injury of, 1211, 1212t
Liver transplantation, 390–392
Lobectomy, 960
  robotic, 955f
  video-assisted thoracic surgery, 955f
Lobular carcinoma in situ, 595f
Local anesthesia/anesthetics
  central nervous system toxicity from, 894
  complications of, 134–135
  description of, 118, 124t–127t, 138
  endoscopic procedures under, 320–321
  epidural anesthesia using, 134–135
  infusion systems, 896t–897t
  ophthalmic surgery, 620–624, 623f
  otorhinolaryngologic surgery, 666–667, 672, 674t–675t
  pain management using, 281–282
  rapid response teams for, 895b
  toxicity caused by, 135–136
"Log-roll" technique, 168–170
Long bones, 719–720, 722f
Longitudinal fracture, 745–746, 746f
Loop colostomy, 343
Loop fistula, 998f
Loop ligatures, 211, 212f
Loupes, 892, 892f
Low back pain, 1223b
Lower extremity
  amputation of, 994f
  compartments of, 1192f
  neuropathies of, 153–155, 154f–155f
Lower eyelid blepharoplasty, 921, 921f
Lower leg surgery, 768–776
  femoral condyle fractures, 768–770
  tibial plateau fractures, 768–770, 771f–772f, 772
Lower oblique inguinal incision, 312–313
Low-level disinfectants, 82
Low-osmolality contrast media, 1222b, 1230
Lowsley retractors, 522, 523f
Low-temperature hydrogen peroxide gas plasma sterilizer, 80–81, 81f
Lumbar puncture, 828, 847
Lumbar vertebrae, 722
Luminance, 217b
Lumpectomy, 603, 604f
Lung(s). *See also* Respiratory system
  age-related changes in, 1163
  biopsy of, 964–965
  collapse of, 944, 945f
  function of, 936–938
  lobes of, 936–937, 939f
  nerves of, 937
  transplantation of, 967–968, 1077
Lung cancer
  illustration of, 957f
  TNM staging of, 956, 957b–958b, 959f
Lung surgery, 956–968
  segmental resection, 960, 961f
  wedge resection, 961, 962f
Lung volume reduction surgery, 961–964
Luque segmental spinal rod procedure, 812
Luteinizing hormone, 424t
Lymph node dissection
  axillary nodes, 605–606, 606f
  laparoscopic, 530
Lymphadenectomy
  groin, 433–434, 434f
  pelvic
    nerve-sparing radical retropubic prostatectomy with, 527–529, 528f–529f
    radical cystectomy with, 547, 548f
  radical, 511
Lymphatic system
  of breast, 588, 590f
  of female reproductive system, 423
  of kidneys, 478
  of neck, 664, 665f
  of pelvis, 423, 423f
Lymphedema, 602b
Lymphocytes, 301t
Lymphomas, 826

M

Maceration, 144
Macular hole, 648
Macular pucker, 648–649
Magnetic resonance angiography, 846, 1013, 1014f
Magnetic resonance imaging
  of breast, 592–593
  of cardiovascular system, 1013, 1014f
  description of, 668
  gadolinium-enhanced, 846, 847f
  of spine, 846, 847f
  stereotactic, 846
  vascular imaging uses of, 978
Magnification, surgical, 862b
Major adverse cardiac events, 1010, 1045–1046
Male reproductive system, 481–482, 483f
Male sling, 543–544
Malecot catheter, 492–493, 492f
Malignant hyperthermia, 128, 139–141, 140b–141b, 276–277, 1093–1094
Malleus, 657, 658f
Malunion, 744
Mammography, 592, 592f–593f
Mandibular fractures, 917, 1209
Marshall-Marchetti-Krantz procedure, 441, 540
Martius flap, 539f
Masks
  application of, 92–93, 92f
  handling of, 92f
  laryngeal mask airway, 128, 129f, 130, 132f
  soiled, removal of, 99–101
  Standard Precautions for, 63
  surgical, 91–93, 92f
Mastectomy
  breast reconstruction after. *See* Breast reconstruction
  modified radical, 604f, 606–608
  simple, 604f, 606, 607f
  subcutaneous, 606
Mastoidectomy, 685–686, 686f
Mastoiditis, 657
Mastopexy, 933, 933f
Maxillary fractures, 915–916, 916f
Maxillary sinus, 696f
Maxillofacial surgery, 914–917
  nasal fractures, 693, 693f, 915
Maximum life span potential, 1157
Maximum permissible exposure, 233
Maydl hernia, 414–415
Mayo scissors, 194, 194f
Mayo stand, 106–107, 107f, 199, 200f
Maze procedure, 1078, 1078f
McBurney incision, 312, 312f, 339
McDonald cervical cerclage, 472, 473f
McVay repair, 407–408, 409f–410f
Mean arterial pressure, 978–980
Mean corpuscular hemoglobin, 301t–303t
Mean corpuscular hemoglobin concentration, 301t–303t
Mean corpuscular volume, 301t–303t
Meatoplasty and glanuloplasty incorporated procedure, 1116, 1117f
Meatotomy, urethral, 500
Mechanical circulatory support, 1072–1076
Mechanical clot extraction, 863
Mechanical convection sterilizer, 81
Mechanical debridement, 258
Mechanism of injury evaluations, 1184–1186, 1184t, 1185f
Meckel's diverticulectomy, 338–339
Median nerve, 150, 151f
Median sternotomy
  aortic-caval cannulation, 1047–1048
Median sternotomy *(Continued)*
  brachial plexus injury during, 151
  cannulation, 1156
  chest closure in, 1042
  incisions, 1035–1036, 1036f, 1052t–1053t
  lung volume reduction surgery, 961–963
  Maze procedure, 1078
  minimally invasive incisions vs., 1058f
Mediastinal lesion excision, 967
Mediastinoscopy, 952
Mediastinum
  anatomy of, 936, 1004f
  thoracoscopic view of, 954f
Medical device reporting, 216
Medical errors, 487b
Medical imaging, 734b
Medical record, 976b
Medical Research Council Scale for Muscle Strength Grading, 844, 846t
Medication administration
  bar-code, 39
  policies and procedures for, 38–39
  safety considerations, 38–39, 39b
Medication reconciliation, 579b, 667b
Medication safety, 981b
Medullary fixation, of humeral shaft fracture, 754–756, 755f
Medulloblastoma, 826
Melanoma, 897, 898b–899b, 900f
Membranous labyrinth, 657–658
Meniere's disease, 688, 835
Meninges
  anatomy of, 819–820, 820f
  tumors of, 826
Meningiomas, 826, 842
Meningocele, 840, 1128–1129, 1128f
Meniscus
  anatomy of, 727, 727f
  arthroscopic resection and repair of, 802–804, 804f
Menopause, 426b
Mesencephalon, 824–825
Mesh-plug repair, of hernia, 409–410, 411f
Mesosalpinx, 422
Metacarpals
  anatomy of, 723–724, 724f
  arthroplasty of, 799, 800f
Metal halide bulbs, 206
Metastases
  brain tumors, 827
  spinal cord tumors, 840
Metatarsals
  anatomy of, 727, 729f
  arthroplasty of, 799–800
  fracture of, 779–780
  head resection, 780
Methicillin-resistant *Staphylococcus aureus*, 56
  discovery of, 53–54
  incidence of, 56, 102b
  infections caused by, 56, 99b
  sites of, 56
  transmission of, 56
  treatment of, 54t
Metzenbaum scissors, 194, 194f, 520f
Meyer-Overton theory, 123
Microbial resistance, 54–55

Microdiskectomy, 809–810, 810f, 879, 879b
Microfibrillar collagen, 368t
Microlaryngoscopy, 706
Microneurosurgery, 861
Microscope, operating, 626–627, 627f, 677–678, 892
Microscopic epididymal sperm aspiration, 509
Microsomal enzyme system, 358–359
Microsurgery
  instruments for, 69–71
  reconstructive procedures, 911–914
    description of, 911–912
    replantation of amputated body part, 912–913
    toe-to-hand transfer, 913–914, 914f
Microwave ablation, 247
Midabdominal transverse incision, 314
Midas Rex drill, 850–851, 852f
Midazolam, 116–117
Middle cerebral artery, 828, 829f
Middle ear
  anatomy of, 657
  nitrous oxide effects on, 673b
Miles' resection, 348
Mind-body medicine, 1241
Minimally invasive surgery. *See also* Laparoscopy
  anesthesia for, 226
  cannulation, 1048
  cardiopulmonary bypass, 1056–1057
  complications of, 226
  electrosurgery considerations, 244–246
  endovascular antegrade-retrograde cardioplegia, 1050, 1050f
  femoral cannulation, 1048
  fiberoptic cables, 205–206, 207f
  gynecologic and obstetric, 448–455
  gynecologic and obstetric applications, 431b
  instrumentation for, 206–217, 369
  insufflation, 224–226, 224f–225f
  irrigation during, 247–248
  light sources, 205–206, 207f
  open surgery vs., 116t
  overview of, 204–217
  parathyroidectomy, 586–587
  pediatric, 1097–1100
  rapid response teams, 226b
  robotically assisted procedures, 454–455
  robotics, 222–223, 223f
  smoke evacuation, 237–239
  spine, 809–810, 810f
  sutures for, 211, 212f–213f
  thyroid surgery, 578
  total hip arthroplasty, 787–788
  video technology, 217–224
Minimally invasive video-assisted thyroidectomy
  description of, 578
  incisions, 582, 584f
  indications for, 579
  instrumentation for, 582, 583f
  procedural considerations, 582–583, 583f–584f
Mini-Mental State Evaluation, 1168–1169
Mini-sternotomy, 1052t–1053t
Mini-thoracotomy, 1036, 1052t–1053t
Miotics, 621t–623t
Miscarriage, 443b
Mitochondrial antibodies, 363t
Mitral annuloplasty, 1060–1061, 1061f
Mitral regurgitation
  definition of, 1060
  mitral annuloplasty for, 1060–1061, 1061f
  mitral valvuloplasty for, 1061–1062, 1061f–1062f
Mitral stenosis
  definition of, 1058–1059
  open commissurotomy of mitral valve for, 1060
Mitral valve
  anatomy of, 1006, 1007f
  repairs of, 1058–1063
Mitral valve replacement, 1062–1063, 1064f, 1066
Mitral valvuloplasty, 1061–1062, 1061f–1062f
Mixed hearing loss, 666t
Modified Blalock-Taussig shunt, 1151–1152
Modified Fontan procedure, 1152–1153, 1155f
Modified neck dissection, 715–716, 717f
Modified radical hysterectomy, 459f
Modified radical mastectomy, 604f, 606–608
Modular Austin Moore endoprosthesis, 767
Mohs' surgery, 898–899
Moisture, 144
Molecular breast imaging, 593
Monitored anesthesia care, 113–114, 118, 137, 686
Monochromatic light, 227
Monocryl sutures, 176t–177t
Monocytes, 301t–303t
Mons pubis, 419, 421f
Monteggia fracture, 759
Montgomery straps, 263, 265f
Morbid obesity, 306, 336
Motor vehicle collisions, 1185, 1185f, 1185b, 1209
Multidrug-resistant tuberculosis, 56–57
  high-risk patients for, 56–57
  history of, 53–54
  prevention of, 57
  transmission of, 56–57
Murmur, 1008
Muscle relaxants, 124t–127t, 128, 1032t–1033t
Muscles, 719
Musculoskeletal system
  age-related changes in, 1165, 1165b
  patient positioning effects on, 150
Music therapy, 1248–1250
Mycobacterium tuberculosis, 51–52. *See also* Multidrug-resistant tuberculosis
Mycophenolic acid, 361b
Mydriatics, 621t
Myelography, 847
Myelomeningocele, 473, 475f, 1128–1129, 1128f
Myocardial contusion, 1210
Myocardial pacing electrodes, 1080–1081
Myocardial revascularization, 1053t
Myomectomy, abdominal, 458, 458f
Myringotomy, 682–683, 683f–684f
Myxedema coma, 1178

N

Nares, 659–660
Nasal cavity, 659, 659f
Nasal fracture reduction, 693, 693f, 915
Nasal septum
  anatomy of, 659
  submucous resection of, 692–693, 693f
Nasolacrimal duct, 631–632
Nasopharynx, 660
Nasoseptoplasty, 692–693
National Center for Complementary and Alternative Medicine, 1240, 1256b
National Hospital Quality Alliance, 25b
National patient safety goals, 19
  hand-off communication, 267
  healthcare-associated infections, 255b–257b
  hospital-based surgery, 20b
  office-based surgery, 21b
National Quality Forum, 25b, 976
National Surgical Quality Improvement Program, 25b, 55b
National Television Standards Committee, 218
Natriuretic peptides, 1010
Natural orifice transluminal endoscopic surgery, 319, 578
Naturopathic medicine, 1241
Nausea and vomiting, postoperative, 117, 117b, 277–278, 277b–278b, 278f–279f, 1255b
Navicular bone, 727, 729f
Nd:YAG laser, 231, 431, 449, 641, 944
Neck
  hyperextension of, 574–576
  lymphatic drainage of, 664, 665f
  musculature of, 663–664
  pretracheal fascia of, 664
  traumatic injuries of, 1209
Neck dissection, 584–585
  incisions, 716f
  modified, 715–716, 717f
  radical, 713–715, 714f, 715b
Neck surgery
  cannulation, 1156
  draping for, 677
  open procedures, 707–717
  patient positioning for, 672
  reconstructive procedures, 717
  tracheostomy, 707–708, 708f, 709t–710t
Necrotizing enterocolitis, 1105
Needle. *See* Surgical needles
Needle holders
  description of, 188f, 195, 196f, 198
  endoscopic, 211, 211f
Needlestick injuries
  bloodborne pathogen transmission risks, 193
  blunt-point needles used to prevent, 181b
  Occupational Safety and Health Administration rules, 58–61
  reports, 1268f–1270f
  response to, 1266–1267
  Universal Precautions for, 57–58
Needlestick Safety and Prevention Act, 189–190, 625, 1267
Neer total shoulder arthroplasty, 795–797, 798f
Negative pressure wound therapy, 260–261
Negativity, 145, 147
Neglect, 1089, 1090b
Neobladder, orthotopic ileocolic, 549
Nephrectomy
  heminephrectomy, 559
  home care education for, 495t
  instrumentation for, 556, 557f
  laparoscopic, 557–559, 559f
  open approach to, 556–557, 558f
  radical, 559
Nephroblastoma. *See* Wilms' tumor
Nephrolithotomy, 554
  percutaneous, 554–555, 555f
Nephrostomy, 553b, 554
Nephrotomy, 553b
Nephroureterectomy, 556
Nerve-sparing radical retropubic prostatectomy with pelvic lymphadenectomy, 527–529, 528f–529f
Nervous system
  age-related changes in, 1165–1166, 1165b
  composition of, 818, 819f
  peripheral, 818
  sympathetic, 841f
Neurectomy, vestibular, 688–689
Neuroblastoma, 1114
Neuroendoscopy, 861–862
Neuroleptic malignant syndrome, 140
Neurologic assessment tools, 844, 846t
Neuromuscular blockers, 1206t–1207t. *See also* Muscle relaxants
Neurons, 818, 819f
Neurosurgery
  anatomic considerations, 818
  anesthesia, 851–852
  deficits secondary to, 860
  description of, 818
  diagnostic procedures, 845–847, 846f–847f
  discharge planning and instructions after, 860–861, 860t–861t
  draping for, 855–856
  dressings used in, 859
  electrosurgery, 857
  endovascular procedures, 862–863, 863b
  equipment used in, 848–859
  family education about, 860–861
  hair removal for, 855
Neurosurgery *(Continued)*
  hemostasis for, 856–859
  instrumentation for, 850–851, 852f
  lumbar drains for, 853
  microneurosurgery, 861
  minimally invasive techniques, 861–864
  monitoring during, 853
  nursing considerations, 844–861
  patient education about, 860–861
  patient positioning for, 853–855, 854b
  pediatric, 1127–1129
  preparations for, 844–845
  radiologic interventions used in, 850
  rapid response team for, 845b
  skin preparation for, 855
  skull clamps used in, 854, 854b
  stereotactic
    equipment for, 850, 851f
    image-guided navigation, 852–853, 852f
    procedures, 851f, 864
  sutures used in, 859
  ventricular drains for, 853
  visualization in, 856–859
Neurotransmitters, 1248f
Neutral plasma coagulation, 247
Neutral zone, 1264–1265
Neutrophils, 301t–303t
"Never events,", 2b
New York Heart Association Functional Classification System, 1008b
Nexgen total knee arthroplasty, 789–793, 790f–792f
NHQA. *See* National Hospital Quality Alliance
Nicks-Nuñez operation, 1068f
Nightingale, Florence, 5b, 58b, 267
Nipple
  anatomy of, 588
  discharge from, 588–589
  reconstruction of, 910–911, 912f–913f
Nissen fundoplication, laparoscopic, 325–326, 325f, 1098–1099, 1099f
Nitrous oxide, 673b
Noise, environmental, 113, 113b
Nominal hazard zone, 233
Nonabsorbable sutures, 178t–179t, 179–180
Noncritical items, 60t–61t, 82
Nondepolarizing muscle relaxants, 124t–127t, 128
Noninflatable penile implant, 505
Nonionic radiopaque contrast agents, 489t–490t
Nonsteroidal antiinflammatory drugs, 280
Nontoxic nodular goiter, 577–578
Norepinephrine, 844
Normal-pressure hydrocephalus, 828
North American Nursing Diagnosis Association International, 7, 7b
Norwood procedure, 1152, 1153f

Nose. *See also* Rhinologic surgery
anatomy of, 659–660, 659f–660f
rhinoplasty of, 921–922
NPO fasting, 118t
NQF. *See* National Quality Forum
NSQIP. *See* National Surgical Quality Improvement Program
5-Nucleotidase, 363t
Nurse
historical description of, 5b
responsibilities of, 5b
Nurse anesthesia programs, 111–113
Nurse educator, 1088t
Nursing diagnoses, 7
breast surgery, 597, 598b
cardiac surgery, 1018, 1019b–1020b
definition of, 7
examples of, 7b
gastrointestinal surgery, 303, 304b–305b
genitourinary surgery, 484, 485b
geriatric surgery, 1169, 1170b–1171b
gynecologic and obstetric surgery, 427, 429b
hernia repair, 400, 402b
neurosurgery, 847, 848b
North American Nursing Diagnosis Association International, 7, 7b
ophthalmic surgery, 616, 618b–619b
orthopedic surgery, 729, 730b–731b
otorhinolaryngologic surgery, 668, 669b–670b
pediatric surgery, 1089, 1091b
postanesthesia care unit, 270, 271b, 288
thoracic surgery, 940, 942b
thyroid surgery, 573, 576b
trauma surgery, 1194, 1195b
vascular surgery, 978, 979b
wound infections, 257–258
Nursing informatics, 16
Nursing interventions
description of, 9
documenting of, 10
list of, 9b
suturing as, 184
Nursing process, 5–9.
assessment, 5–7
description of, 1
evaluation, 12
implementation, 9, 9b
nursing diagnosis, 7, 7b
outcome identification, 7–8, 8b
for patient positioning. *See* Patient positioning, nursing process for
planning, 8
steps of, 3f, 5
Nylon sutures, 178t–179b, 180

O

Oasis (skin substitute), 262t
Obesity
in adolescents, 1100
definition of, 336b
morbid, 306, 336
patient positioning considerations, 157–158, 157f, 157b, 306
WHO definition of, 1200–1201
Oblique fracture, 745–746, 746f
Oblique incisions, 312–314, 312f
Obstetric surgery, 467–473. *See also* Gynecologic surgery
cervical cerclage. *See* Cervical cerclage
discharge planning and instructions, 430–431
family education, 430–431, 432t
fetal surgery, 473–474, 474f–475f
medications used in, 469t–471t
patient education, 430–431, 432t
Obstructive sleep apnea, 702, 703b, 704f
Obturator nerve, 154, 155f
Occluding clamps, 195
Occupational injuries, 62
Occupational Safety and Health Administration
Bloodborne Pathogens Standards, 189–190, 1264b
ethylene oxide exposure guidelines, 79–80
glutaraldehyde recommendations, 215
needle-stick injury prevention, 58–61
permissible exposure limits, 1273–1274
Ocular history, 615, 615b
Ocular implants, 628–629
Ocular prostheses, 628–629, 630f
Ocular trauma, 1209
Oculomotor nerve, 833–834, 836t
Office of Alternative Medicine, 1240
Office-based surgery
error prevention in, 19
national patient safety goals for, 19, 21b
Off-pump coronary artery bypass surgery, 1051
Older population, 1157, 1158f–1159f, 1158b
Olecranon fractures, 758, 758f
Olfactory nerve, 830, 836t
Oligodendroglioma, 826
Omphalocele, 1110–1111, 1110f
Oophorectomy, 462–463, 464f
Oophorocystectomy, 462–463
Open breast biopsy, 602–603
Open cholecystectomy, 357, 367f, 371–372, 373f
Open colectomy, 342b
Open commissurotomy, of mitral valve, 1060
Open fractures, 745
Open laparoscopy, 209
Open laparotomy, 308
Open reduction and internal fixation
of clavicular fractures, 751–752
of fractures, 749–750, 750f
of mandibular fractures, 917
Open thyroidectomy, 581–582, 581f
Open-gloving technique, 99, 101f
Operating microscope, 626–627, 627f, 849
Operating room. *See also* Surgical suite
air conditioning in, 67
air pressure in, 67
ambient temperature in, 139, 145
cardiac surgery, 1021
contamination in, 107
design of, 66–67, 67f
floors in, 66–67
fracture beds, 732–733, 733f
heat loss prevention in, 276
heating of, 67
holding area in, 142
hypothermia concerns, 145–146
infection control considerations, 66, 67f
orthopedic surgery, 730
plastic and reconstructive surgery, 888
scrub sinks in, 67, 67f
spills in, 108
teamwork in, 1281b
transport of patient to postanesthesia care unit, 142, 946
ventilation in, 67
Operating room beds, 160–162
lateral transfer of patient from stretcher to, 1259f
neurosurgery, 849
Operating room briefings, 26b
Operating room nursing, 1
Ophthalmic artery, 613
Ophthalmic surgery. *See also* Eye(s)
anatomic considerations, 610–613
anesthesia for, 620–624
general, 620
local, 620–624, 623f
conjunctiva, 637
dacryocystorhinostomy, 632–633, 632f–633f
discharge planning and instructions about, 628
draping for, 624
dressings for, 627–628, 627f
in elderly, 614b, 1179
eyelids. *See* Eyelid surgery
family education about, 628
forceps used in, 624f–625f
glaucoma. *See* Glaucoma
globe, 628–631
historical developments in, 619b
instrumentation for, 624–627, 624f–625f, 627f
lacrimal apparatus, 631–633
laser, 626
medications, 620, 621t–623t
nasolacrimal duct, 631–632
nursing considerations for, 614–628
orbit, 628–631
patient education about, 628
patient positioning for, 624
pediatric, 1137–1141, 1137f–1140f
prepping for, 624
safety considerations, 617–620
sutures used in, 627
vitreoretinal surgery, 647–649
Ophthalmoscope, 616f
Opiate agonists, 1229t–1230t
Opioids
general anesthesia using, 124t–127t
intramuscular injection of, 280–281
intrathecal administration of, 281
pain management using, 280–281
patient education about, 291b
respiratory depression caused by, 281
Opportunists, 49b
Optic nerve, 613, 830–833, 836t
Optic tract, 830
Oral cavity
anatomy of, 660, 661f
cancer of, 699, 700f
Oral cavity surgery, 699–704
draping for, 677
operative procedures, 699
patient education about, 681t–682t
patient positioning for, 672
procedural considerations for, 699
uvulopalatopharyngoplasty, 702–704, 705f
Orbit
anatomy of, 610
blow-out fracture of, 915, 915f, 1209
evisceration of, 631
exenteration of, 631
Orbit surgery, 628–631
Orbital floor fractures, 915
Orbital septum, 610
Orbit-craniofacial surgery, 1135–1137, 1135f
Orchiectomy, 510–511
Orchiopexy, 1121–1122, 1123f–1124f
Orem, Dorothy, 5b
Organ of Corti, 658–659
Organ procurement, 1215
Organ/space surgical site infection, 49b, 254b
Orientation, 217b
Oropharyngeal airway, 275f
Oropharynx, 660–661
Orthognathic surgery, 917
Orthopedic surgery. *See also specific procedure*
airflow control in, 737, 737f
ambulatory, 801b
anatomic considerations, 719–727, 720f–729f
ankle, 776–780
arthroplasty. *See* Total joint arthroplasty
bone banking, 743
discharge planning and instructions, 743
dislocations. *See* Dislocations
draping for, 733–734
in elderly, 1179–1180
equipment and supplies for, 734–740
family education about, 743
fractures. *See* Fracture(s)
history of, 719
immobilization after, 735–737, 737f
implants
equipment for, 740–741
FDA requirements for, 740–741
instruments and accessory items, 740–742
Orthopedic surgery *(Continued)*
implant inventories, 740–741
polymethylmethacrylate, 741–742
powered surgical, 741, 741f
suture material, 741
interventions, 743
medications used in, 742–743, 742t
nursing considerations for, 728–743
operating room considerations, 730
patient education about, 743
patient positioning for, 732–733, 732f–733f
pediatric, 1129–1131
postoperative management, 737–740
immobilization, 735–737, 737f
pain management, 740
preparations for, 733
prone positioning for, 732, 733f
protective measures for, 743
shoulder. *See* Shoulder, surgical procedures of
ortho-Phthalaldehyde, 83
Orthoplasty, 1116–1117, 1118f
Orthotopic ileocolic neobladder, 549
Os coxae, 724
Osmolality, 1222b
Ossicular chain reconstruction, 687
Osteoblasts, 744
Osteomalacia, 745
Osteoporosis, 745, 1179
Osteotomy, 1130–1131
Ostiomeatal complex, 698–699
Ostomy
ileostomy, 341–342
site-marking for, 299b
stoma, 322
wound ostomy continence nurse for, 299, 310–311
Otitis media with effusion, 682
Otoconia, 658–659
Otologic surgery, 680–692
draping for, 676–677
Otoplasty, 1134, 1134f
Otorhinolaryngologic surgery. *See also* Otologic surgery
anatomy involved in, 657
ear, 657–659, 658f
neck, 663–664
nose, 659–660, 659f–660f
throat, 660–664, 661f–663f
anesthesia for, 672–676, 674t–675t
definition of, 657
discharge planning and instructions for, 680
draping for, 676–677
endoscopic procedures, 705–707
equipment for, 678, 680f
facial nerve monitoring, 676, 676f
family education about, 680, 681t–682t
instrumentation for, 678, 680f
lasers for, 678
local anesthesia for, 666–667
medication reconciliation, 667b
nursing considerations for, 664–680

Otorhinolaryngologic surgery *(Continued)*
operative site preparation, 676
pain assessment and management for, 666b
patient education about, 680, 681t–682t
patient positioning for, 671–672
postanesthesia care unit transfer after, 678–679
preoperative room preparation, 671
rapid response teams, 679b
surgical microscope for, 677–678
Outcome identification, 7–8, 8b
Outcome standards, 5
Ovarian cancer, 425, 427t, 428f
Ovarian cystectomy, 452–453
Ovarian cysts, 462, 463f–464f
Ovarian ligament, 420f
Ovaries, 421–422
Oxidized cellulose, 368t
Oxygen cylinders, 122
Oxygen therapy, 948t–949t
Oxygen-dissociation curve, 120
Oxyhemoglobin, 120
Oxytocin, 368t
Ozone sterilizer, 215

P

Pacemaker, 1078–1079, 1079f
Packed red blood cells, 40
Packing, 430, 678–679, 694, 1204–1205
Paget's disease, 745
Pain
acute. *See* Acute pain
assessment of, 283b, 287f
back, 809, 1165, 1223b
chronic, 138–139
chronic pelvic, 456b
in elderly, 1166–1167, 1167b, 1176b
gynecologic, 426b
hernia, 400
indicators of, 1095
misconceptions about, 286t
physiologic effects of, 282
postanesthesia assessment of, 280
postoperative, 280–283, 281f–282f, 283b, 284t
reassessment of, 283b
self-reporting of, 280
spinal lesions as cause of, 843
Pain intensity scales, 282f
Pain management, 138–139, 1176b, 1249–1250
algorithms for, 281f, 287f–288f
cyclooxygenase type 2 inhibitors, 280
after gastrointestinal surgery, 310
importance of, 280
local anesthetics for, 281–282
nonopioid analgesics, 284t, 291b
nonpharmacologic methods, 282
nonsteroidal antiinflammatory drugs, 280
opioids, 280–281, 285t, 291b
orthopedic surgery, 740
otorhinolaryngologic surgery, 666b
patient education about, 291b, 738t–739t
Pain management *(Continued)*
patient-controlled analgesia for. *See* Patient-controlled analgesia
pediatric surgery, 1094–1095
postoperative, 896t–897t
Pain pumps, 405b–406b
Palatopharyngoplasty, 705f
Palpation, 1245b
Pancreas
anatomy of, 359–360, 360f
blood supply of, 359–360, 360f
cancer of, 357, 384b
function tests for, 361, 364t
imaging studies of, 361
islets, 360
secretions of, 359–360
surgical procedures of, 381–387
asepsis, 369
blood products, 369–370
cyst drainage. *See* Pancreatic pseudocysts
discharge planning and instructions, 370–371, 370t
drainage materials, 369
draping of patient, 368
evaluation, 370
family education, 370–371
hemostatic agents, 368t
implementation, 364–371
instrumentation, 368–369
nursing considerations, 361–371
nursing diagnoses, 362
outcome identification, 362
pain management, 371
pancreaticoduodenectomy, 384–385, 385f
patient education, 370–371
plan of care, 365b–366b
planning, 362–364
robotic-assisted laparoscopic, 384
sequential compression devices for, 367–368
thermoregulation during, 367
transplantation, 385–387, 386f, 386b
Pancreas and kidney transplantation, 387f
Pancreatectomy, 1113
Pancreatic pseudocysts
open drainage or excision of, 381–383
Roux-en-Y cystojejunostomy drainage of, 383f
Pancreaticoduodenal artery, 360f
Pancreaticoduodenectomy, 384–385, 385f
Pancreaticojejunostomy, 384
Panretinal photocoagulation, 649
Pantaloon hernia, 399
Papaverine, 489t–490t
para-chloro-*meta*-xylenol, 94
Paralytic ileus, 310, 310b
Paramedian incision, 312, 312f
Pararenal fat, 478
Parasites, 49b
Parasternotomy, 1052t–1053t
Parasympathetic nervous system, 844, 1248f
Parathyroid adenoma, 569f
Parathyroid glands
anatomy of, 566–567, 569f–570f
assessment of, 572–573
dysfunction of, 572, 573b
ectopic, 566–567
Parathyroid hormone, 567, 572, 580b
Parathyroid surgery, 574b
Parathyroidectomy, 585–587
Parathyroid-hormone guided parathyroidectomy, 586–587
Parietal bones, 819
Parietal cell vagotomy, 327
Parietal lobe, 822–823
Parietal pleura, 936
Parotid gland, 660
Parotidectomy, 700–702, 703f–704f
Pars plana vitrectomy, 651, 652f–653f
Partial gastrectomy, 330–332, 332f–333f
Partial laryngectomy, 711, 712t
Partial ossicular replacement prosthesis, 685, 687
Partial penectomy, 502–503, 503f
Partial pressure of carbon dioxide, 301t–303t
Partial prothrombin time, 301t–303t
Partial thromboplastin time, 363t
Passivation, 194
Pasteur, Louis, 58b
Pasteurization, 84, 215
Patella
anatomy of, 719, 727
fractures of, 772–773
realignment of, 773, 773f
recurrent dislocation of, 773, 773f
Patellar tendon graft, for anterior cruciate ligament repair, 805–806
Patellectomy, 772–773
Patent ductus arteriosus, 1100, 1150–1151, 1150f–1151f
Pathogen, 49b
Pathologic fracture, 745–746, 746f
Patient advocate, 1
Patient care equipment, 63
Patient education
anticoagulant therapy, 984b
breast reduction, 930t–931t
breast surgery, 600–602, 600t–601t
cardiac surgery, 1045–1047, 1046t
complementary and alternative therapies, 1251t
genitourinary surgery, 493, 494b
geriatric surgery, 1175–1177
gynecologic and obstetric surgery, 430–431, 432t
hernia repair, 404t, 405–406
interventional radiology, 1220
neurosurgery, 860–861
ophthalmic surgery, 628
orthopedic surgery, 743
otorhinolaryngologic surgery, 680, 681t–682t
oxygen therapy, 948t–949t
pain management medications, 291b, 738t–739t
pediatric surgery, 1095–1096
plastic and reconstructive surgery, 896–897
thoracic surgery, 947
thyroid surgery, 577
trauma surgery, 1203
vascular surgery, 984–985, 985t–986t
wound care, 258, 259t, 292
Patient identification, 939b
Patient positioning
anatomic considerations, 144–160
biliary surgery, 366
bladder surgery, 535
brachial plexus injury, 150f, 151
breast surgery, 599
breasts affected by, 156–157
cardiac surgery, 1034
compartment syndrome and, 167b
cystoscopy, 496
eye injuries during, 156, 156b
finger injuries caused by, 157
Fowler's position, 162b–163b, 168, 168f
fracture bed position, 162b–163b, 165, 165f
genitalia affected by, 157
genitourinary surgery, 486–487
geriatric surgery, 1172–1173
gynecologic and obstetric surgery, 428–430
hernia repair, 403
importance of, 144
interventional radiology, 1236
laparoscopy, 305–306, 367
laparotomy, 305–306
lithotomy. *See* Lithotomy position
liver transplantation, 391
musculoskeletal system effects, 150
nervous system effects, 150–155
neurosurgery, 853–855, 854b
nursing process for, 158–160
obesity considerations, 157–158, 157f, 157b, 306
ophthalmic surgery, 624
orthopedic surgery, 732–733, 732f–733f
otorhinolaryngologic surgery, 671–672
perioperative vision loss associated with, 156b
peripheral neuropathies, 150–155, 150f–155f
physiologic considerations, 144–160
plastic and reconstructive surgery, 894–895
pressure risks associated with, 38
prone position. *See* Prone position
respiratory system effects, 156
reverse Trendelenburg's position, 162b–163b, 164–165, 165f
semi-Fowler position, 162b–163b, 167–168, 168f
skin injuries caused by, 144–150
forces that cause, 144–145
pressure ulcers. *See* Pressure ulcers
spinal anesthesia, 133
supine position, 162–164, 162b–163b, 164f
thoracic surgery, 943, 944f
thyroid surgery, 574–576
trauma surgery, 1196
Trendelenburg's position, 162b–163b, 164, 164f
vascular surgery, 980
Patient positioning *(Continued)*
vascular system effects, 155–156
venous thromboembolism and, 155
Patient safety indicators, 202. *See also* Safety
Patient transport
fall prevention during, 160
from operating room to postanesthesia care unit, 142, 946
Patient-controlled analgesia
for children, 1095
description of, 280–281, 286, 740
after gastrointestinal surgery, 310
postoperative pain treated with, 896t–897t
Patient-controlled epidural analgesia, 310
Patient/physician relationship, 1256b
Patient/prosthesis mismatch, 1065–1066
Pèan forceps, 373f
Pediatric surgery. *See also specific procedure*
abdominal procedures, 1111–1113
adolescents, 1092–1093
airway status, 1085
ambulatory, 1087–1088, 1089b
anatomic considerations, 1085–1086
anesthesia considerations, 1093–1094, 1094t
bariatric, 1100–1101, 1101b
cardiovascular status, 1085–1086
cataract, 1141
child abuse and neglect, 1089, 1090b
congenital heart disease, 1145–1156
corneal, 1141
description of, 1085
developmental stages, 1087t
discharge planning and instructions, 1095–1096, 1096b
family education about, 1095–1096
fluid management, 1086
gastrointestinal, 1101–1108
genitourinary, 1115–1125
glaucoma, 1141
hernias, 1108–1111
informed consent, 1089
instrumentation for, 1093
local anesthesia, 139
metabolism considerations, 1086
minimally invasive, 1097–1100
neurosurgery, 1127–1129
nursing considerations for, 1086–1096
ophthalmic, 1137–1141, 1137f–1140f
orthopedic, 1129–1131
pain management, 1094–1095
patent ductus arteriosus, 1100, 1150–1151, 1150f–1151f
patient education about, 1095–1096
pectus excavatum, 1099–1100, 1099b, 1100f

Pediatric surgery (Continued)
plastic and reconstructive, 1131–1141
postoperative visitations by parents, 1092b
psychologic development considerations, 1086
pulmonary status, 1085
resuscitation medications, 1143t
sutures for, 1093
temperature regulation considerations, 1086
trauma, 1141–1145, 1142b, 1145t
tumor resection, 1113–1115
vascular access for, 1096–1097
vital signs, 1145t
Pedicle flaps, 906–907
Pedicle screw fixation, of spine, 810–811, 811f
Pedunculated cervical myoma, 444–445, 445f
Pelvic brim, 422
Pelvic cavity, 419–422
Pelvic diaphragm, 423
Pelvic exenteration, 459–462, 461f–463f
Pelvic floor, 423
Pelvic lymphadenectomy
nerve-sparing radical retropubic prostatectomy with, 527–529, 528f–529f
radical cystectomy with, 547, 548f
Pelvic osteotomy, 1131
Pelvic peritoneum, 422
Pelvis
anatomy of, 724–726, 724f
blood supply of, 423, 423f
bony, 422–423
external fixator of, 748f
fracture of, 780–781, 781t, 1212–1214
lymphatic supply of, 423, 423f
nerve supply of, 423, 423f
true, 422–423
Pelvis ostium, 398
Pelviscopy, 205b
Penectomy, 502–503
Penetrating keratoplasty, 638–639
Penetrating trauma, 1185–1186, 1186f, 1212
Penile carcinoma
laser ablation of, 499
penectomy for. *See* Penectomy
Penile implants, 503–506
Penis
anatomy of, 482, 482f–483f
arteries of, 506
circumcision of, 499–500, 500f
condylomata ablation, 499
orthoplasty of, 1116–1117, 1118f
Penrose drain, 266f, 325f
Peptic ulcer disease, 1178
Peracetic acid sterilization, 80
Percutaneous coronary interventions, 1015, 1051
Percutaneous endoscopic gastrostomy, 328–330
Percutaneous nephrolithotomy, 554–555, 555f
Percutaneous transhepatic cholangiography, 361
Percutaneous transluminal coronary angioplasty, 989–990, 1015
PerFix plug, 410, 411f
Perfluorocarbon exchange, 653f
Perfluoropropane gas, 655
Performance improvement, 14–15
activities of, 11–12
patient care delivery, 14–15
Peribulbar block, 623, 623f
Pericardiectomy, 1051
Pericardiocentesis, 1210, 1210f
Pericranium, 818
Perinatal loss, 443b
Perineal repair, 438, 440f
Perioperative nurse
patient advocate role of, 1
responsibilities of, 1
Perioperative nursing
definition of, 1
overview of, 1–3
roles, 15–16
settings for, 1
standards of, 3–12, 4b
Perioperative nursing data set, 10–12, 11f
Perioperative Patient Focused Model, 2–3, 4f, 10–11
Perioperative vision loss, 156b
Peripheral arterial disease, 969
Peripheral arterial occlusive disease, 969, 973
Peripheral iridectomy, 645, 645f
Peripheral nerve(s)
anatomy of, 843–844
patient positioning-related injury of, 150
repairs of, 882–883, 883f
stretching of, 150
surgery of, 882–883, 883f
Peripheral nerve blocks, 135–136
Peripheral nervous system, 135, 818, 843
Peripheral neuropathies
brachial plexus, 150, 150f
common peroneal nerve, 153, 154f–155f
femoral nerve, 153–154, 155f
lower extremity, 153–155, 154f–155f
obturator nerve, 154
patient positioning-related, 150–155, 150f–155f
risk factors for, 150
sciatic nerve, 153, 154f
somatosensory evoked potentials for prevention of, 154, 155b
tibial nerve, 154
ulnar nerve, 152
upper extremity, 150–155, 150f–153f
Peripheral vascular disease, 975–977
Peripheral white matter, 837
Periurethral-transurethral injection of bulking agents, 498
Permissible exposure limit, 1273–1274
Personal protective equipment, 61, 62f, 68, 90, 320, 1265
Pertussis, 1276–1277
Pesticides, 362t
Peyer's patches, 296–297
Pezzer's catheter, 492–493, 492f
Pfannenstiel incision, 314, 315f
pH, 301t–303t
Phacoemulsification
in cataract extraction, 641, 644–645
extracapsular method with, 644–645
machines for, 625
Phalanges, 723–724, 724f
Pharyngeal flap, 1132–1133
Pharyngitis, 1126
Pharynx
anatomy of, 660–661
obstruction in, 1125–1126
Phenol and alcohol, 368t
Phenolics, 83
Phenylephrine, 489t–490t
Pheochromocytoma, 563
Phonosurgery, 711
Phosphate, 301t–303t
Phosphorus, 362t
Photoacoustic effect, 228
Photochemical effect, 228
Photodynamic therapy, 323
Photorefractive keratectomy, 639
Photoselective vaporization of the prostate gland, 518
Phototherapeutic keratectomy, 638
Photothermal effect, 228
Physical status classification, 115, 116t, 948b
Pia mater, 820, 820f
Pilonidal cyst and sinus, 354–355, 354f
Pin fixation, of fractures, 749, 749f
Pituitary adenomas, 826–827
Pituitary gland, 824
Pituitary tumors, 872–873
Pixel, 217b
Plague, 65t–66t
Planning, 8
Plasma sterilization, 80–81, 81f, 215
Plasmids, 54
Plastic and reconstructive surgery
aesthetic surgery. *See* Aesthetic surgery
anatomic considerations, 885–886
anesthesia for, 893–894
breast. *See* Breast reconstruction
burn surgery. *See* Burns
candidates for, 887
communication in, 887
discharge planning and instructions for, 896–897
draping for, 894–895
dressings for, 892–893
equipment for, 888–892
family education about, 896–897
growth of, 885, 885b
implant materials for, 893, 893f, 893b
incisions, 886f
instrumentation for, 890
lasers, 922, 922b–924b
maxillofacial. *See* Maxillofacial surgery
microsurgical, 911–914
description of, 911–912
replantation of amputated body part, 912–913
toe-to-hand transfer, 913–914, 914f
nipple, 910–911
nursing considerations for, 886–897
Plastic and reconstructive surgery *(Continued)*
operating room for, 888
origins of, 885b
patient education about, 896–897
patient involvement in, 886b
patient positioning for, 894–895
pediatric, 1131–1141
psychologic complications after, 887b
rapid response teams for, 895b
self-image considerations, 886
skin cancer. *See* Skin cancer
skin preparation for, 894
subspecialties of, 885
sutures for, 892
therapeutic environment for, 886–887
Plate fixation
description of, 748f, 749
Monteggia fractures treated with, 759, 760f
tibial plateau fracture, 770, 772f
tibial shaft fractures, 776
Platelet count, 301t–303t, 1190b–1191b
Pledgetted suture, 983f
Pleural cavity, 936
Pleural space, 936
Pleurodesis, 952t–953t
Plicae circulares, 295–297
Pneumatic antishock garment, 1214
Pneumatic retinopexy, 654, 655f
Pneumatic tourniquet, 136, 734–735, 734f, 735b, 891
Pneumatic-powered instruments, 890–891
Pneumonectomy, 956–960, 959f–960f
Pneumoperitoneum, 224, 319, 375
Point, of surgical needles, 181–182, 183t
Policies and procedures, 12
Poly(ADP-ribose) polymerase enzyme inhibitors, 596–597
Polybutester, 180
Polydioxanone sutures, 176t–177t
Polyester fiber sutures, 178t–179t, 180
Poly-4-hydroxybutyrate suture, 178
Polymethylmethacrylate, 741–742, 781–782, 783f
Polyp(s)
cervical, 444–445, 445f
nasal, 699, 699f
vocal cord, 706f
Polypectomy, nasal, 699, 699f
Polypropylene mesh, 540f
Polypropylene sutures, 180
Polytetrafluoroethylene, 982, 1022–1023
Polyvinyl alcohol, 455
Polyvinyl chloride sheeting, 105–106, 106f
Popliteal cyst excision, 775
Porcine heart valves, 1024–1025, 1026f, 1028t, 1029b
Porta hepatis, 357
Portal vein, 357, 359f
Positron emission tomography, 940
Postanesthesia care unit
admission to, 267–269
assessments, 267–270, 270f, 270b, 272f, 286–288
cardiovascular system assessments, 269–270
complications in
acute pain. *See* Postanesthesia care unit, pain
airway obstruction, 272, 275f
aspiration, 278–280, 280t
body temperature, 276–277
bronchospasm, 272
cardiovascular, 272–275
cognitive function, 277
dysrhythmias, 275
emergence delirium, 277, 277f
hypertension, 275
hyperthermia, 276–277
hypotension, 273–275
hypothermia, 276
hypovolemia, 275
laryngospasm, 272
nausea and vomiting, 117, 117b, 277–278, 277b–278b, 278f–279f
premature ventricular contractions, 275
respiratory, 272–283
thermoregulatory, 276–277
discharge from, 286
evolution of, 268b
after gastrointestinal surgery, 309
hand-off communications/report, 31b, 34b, 267, 269b, 577, 628
history of, 267
noise reduction in, 113
nursing diagnoses, 270, 271b, 288
nursing process, 267–272
pain
acute, 280–283, 281f–282f, 283b, 284t
assessments of, 280, 283b, 287f
parental visitations in, 1092b
postoperative unit transfer from
assessments, 286–288, 289b
early ambulation, 289, 292f
nursing diagnoses, 288, 290b
plan of care, 290b
renal system assessments, 270
surgical site assessments, 270
transport of patient to, from operating room, 142, 946
Postanesthesia care unit record, 270, 273f–274f
Postauricular incision, 682
Postcentral gyrus, 821–822
Postdural puncture headache, 133–135
Postembolization syndrome, 1226
Posterior cerebral artery, 828, 829f
Posterior chamber lenses, 642
Posterior cruciate ligament repair, 806
Posterior fossa, 819
Posterior nasal packing, 694, 695f
Posterior sagittal anorectoplasty, 1108, 1109f
Posterior segment
anatomy of, 611–612
vitrectomy of, 649–651, 650f

Posterior spinal artery, 838–840
Posterior spinal fusion with Harrington rods, 811–812
Posterior vitrectomy, 625–626
Posterior vitreous detachments, 648
Posterolateral thoracotomy, 1052t–1053t
Postexposure prophylaxis
  hepatitis B virus exposure, 52, 1267
  HIV exposure, 53t, 1267
Postoperative ileus, 310, 310b
Postoperative nausea and vomiting, 117, 117b, 277–278, 277b–278b, 278f–279f, 1255b
Postoperative period
  abdominal assessment, 270
  assessments, 267–270, 270f, 270b, 272f
  discharge instructions, 268b
  discharge planning, 292
  family education, 292
  pain
    assessment of, 280–283, 281f–282f, 283b, 284t
    management of, 896t–897t
  patient education, 292
  postanesthesia care unit. *See* Postanesthesia care unit
  rapid response team in, 291b
  rewarming in, 276, 276f
  surgical site, 270
  telephone calls to patients, 21b
Posttraumatic stress disorder, 1204b
Potassium, 301t–303t, 1190b–1191b
Povidone-iodine, 83, 676
Preadmission testing, 114
Prealbumin, 301t–303t
Precentral gyrus, 821–822
Preganglionic neurons, 844
Pregnancy
  abdominal surgery during, 473–477
  cardiac arrest in, 467b
  ectopic. *See* Ectopic pregnancy
  fetal assessments, 1199
  hypovolemic shock in, 1200t
  maternal adaptations during, 1200t
  maternal changes during, 468
  radiology contraindications during, 1220
  trauma/trauma surgery during, 1199–1200, 1200t
Preload, 1015b
Premature ventricular contractions, 275
Premedications, before anesthesia, 116–117
Preoperative preparation, 114–117
  briefings, 403b
  patient evaluation, 114–115
  verification procedures, 31, 617–619, 729b, 978
Preperitoneal distention balloon, 412
Preperitoneal hernia repair, 413, 414f
Presbycusis, 1166
Presbyopia, 1166
Pressure
  description of, 144, 146
  Fowler's position areas for, 168, 168f
  injuries caused by, 38
  supine position areas for, 164f
Pressure alopecia, 149–150
Pressure bags, 1225
Pressure dressings, 892
Pressure ulcers, 145–150
  pathophysiology of, 903f
  risk factors for, 145–147, 902–903
  rotational flap for, 903f
  sites of, 146, 902–903
  stages, 149, 902–903
  treatment of, 902–903, 903f
  Prevacuum steam sterilizer, 77–78, 77f
Primary hyperparathyroidism, 572
Primary intention, 250–251, 252f
Primary pathogens, 49b
Primary suture line, 183, 184f
Primitive neuroectodermal tumor, 826
Prions, 57
Progesterone, 421–422, 424t
Prolactin, 424t
Prolactin cell adenoma, 827
Proliferative retinopathy, 649f
Prone position, 168–169
  arm placement in, 169
  breast compression caused by, 156–157
  genitalia affected by, 157
  head support in, 169–170
  intraocular pressure effects, 156b
  jackknife, 162b–163b, 170–171, 171f
  knee-chest, 162b–163b, 171
  kneeling, 162b–163b, 171, 171f
  lateral, 162b–163b, 172
  lateral chest, 162b–163b, 172
  lateral kidney, 162b–163b, 172f, 173
  "log-roll" technique, 168–169
  neurosurgery in, 855
  orthopedic surgery, 732, 733f
  perioperative vision loss associated with, 156b
  respiratory system affected by, 169–170
  risks and interventions for, 162b–163b
  spinal frame, 170, 170f
  supine position to, 170
Prosencephalon, 821
PROSPECT, 283
Prostate cancer
  American Urological Association stages, 513, 514b
  description of, 511
  diagnosis of, 512b
  grading of, 513
  high-intensity focused ultrasound for, 513b
  management of, 512b
  metastatic, 514b
  risk factors for, 512b
Prostate gland
  anatomy of, 479, 481, 483f
  core needle biopsy of, 514
  interstitial laser coagulation of, 518–519, 519f
  photoselective vaporization of, 518
  transrectal cryosurgical ablation of, 526–527
  transrectal guided ultrasound of, 494b
  transurethral incision of, 517–518
  transurethral resection of, 487, 488b, 513–516, 517f, 1179
  visual laser ablation of, 513–514
  zonal anatomy of, 515f
Prostate surgery, 511–534
Prostatectomy
  radical
    laparoscopic, 532–533
    retropubic, 513, 527–529, 528f–529f
    robotic-assisted laparoscopic, 534, 534f–535f
    (total) perineal, 529–532, 530f–532f
  simple perineal, 522–524, 522f–524f
  simple retropubic, 519–520, 521f
  suprapubic, 520–521, 522f
Prostate-specific antigen, 511
Prosthetic heart valves, 1024–1029
Prosthetic urethral sphincter, 545–546, 546f
Prosthetic vascular grafts, 982
Protect-point needle, 183t
Prothrombin time, 301t–303t, 363t, 1017t, 1190b–1191b
"Proud flesh," 254b
Proximal anastomosis, 1051
Proximal gastric vagotomy, 327, 329f
Pseudomonas aeruginosa, 50–51
Psychoeducation, 1204t
Psychoneuroimmunology, 1250
Pterional craniotomy, 864, 868–870, 868f–870f
Pterygium excision, 637
Ptosis, of upper eyelid, 635–636, 1138–1141, 1138f–1139f
Pulmonary angiography, 1016t
Pulmonary artery, 1002
Pulmonary artery catheters, 120, 980
Pulmonary aspiration, 130b, 278–280, 280t
Pulmonary circulation, 1002
Pulmonary embolus, 975, 1197–1198
Pulmonary function tests, 940, 941t, 1017t
Pulmonary stenosis, 1065
Pulmonary vascular resistance, 1148
Pulmonic valve
  anatomy of, 1006
  surgery of, 1065
Pulse lavage, 783, 783f
Pulse oximetry
  anesthesia monitoring using, 120–121
  principles of, 120
  sensor placement, 121
Pulse volume recording, 978
Purified protein derivative test, 51–52
Purkinje system, 1006
Purse-string suture, 184, 185f, 439f
Putti-Platt procedure, 753
Pyelography, 497–498
Pyelolithotomy, 553b, 554, 554f
Pyeloplasty, dismembered, 555–556
Pyelostomy, 553, 553b
Pyelotomy, 553, 553b
Pyloric stenosis, laparoscopic pyloromyotomy for, 1097–1098, 1098f
Pyloromyotomy, 327–328
Pyloroplasty, 327–328
Pylorus-preserving pancreaticoduodenectomy, 385f

Q

Qi gong, 1246t
Quality and Performance Improvement Standards for Perioperative Nursing, 5
Quality assurance, 118
Quality improvement programs, 11–12
Quaternary ammonium compounds, 83–84

R

Radial artery, 1054, 1055f
Radial head
  dislocation of, 759
  fractures of, 759
Radial nerve, 150–151, 151f
Radiation exposure
  monitoring of, 1220
  protection methods, 1221–1223, 1223f, 1277–1278
  safety precautions, 1277–1278
  shielding against, 1222–1223, 1223f
  sources of, 1277
Radical antrostomy, Caldwell-Luc operation with, 698–699, 698f
Radical endoscopy, 318
Radical hysterectomy, 459, 459f
Radical lymphadenectomy, 511
Radical neck dissection, 713–715, 714f, 715b
Radical prostatectomy
  laparoscopic, 532–533
  robotic-assisted laparoscopic, 534, 534f–535f
  (total) perineal, 529–532, 530f–531f
Radical retropubic prostatectomy, 513, 527–529, 528f–529f
Radical vulvectomy, 433–434, 434f
Radioactive iodine, 1178
Radiofrequency ablation, 1222b
Radiofrequency identification products
  patient verification using, 939b
  retained foreign object prevention using, 34–36
Radioimmunoguided surgery, 389–390
Radiology
  history of, 1217b
  interventional. *See* Interventional radiology
  modalities of, 1216
Radiology nurse, 1217–1218, 1218b
Radiology nursing, 1216–1238
Radionuclide imaging, 1014
Radiopaque contrast agents, 489t–490t
Radius
  Colles' fracture of, 759–760
  head of. *See* Radial head
"Ramping," 157–158, 157f
Random pattern flaps, 906–907
Rapid blood transfusion, 41
Rapid response teams
  carbon dioxide embolus, 226b
  contrast media reactions, 1235b
  description of, 19, 22b, 575b, 740b
  endoscopic minimally invasive surgery, 226b
  genitourinary surgery, 486b
  hernia repair, 406b
  malignant hyperthermia management by, 141b
  neurosurgery, 845b
  otorhinolaryngologic surgery, 679b
  plastic and reconstructive surgery, 895b
  postoperative care, 291b
  surgical adverse events, 947b
  trauma, 1202b
Rapid-sequence intubation, 129, 1198, 1198b
Reconstructive surgery
  neck, 717
  vaginal, 441–442, 442f
Recovery room. *See* Postanesthesia care unit
Rectocele repair, 435–438, 436f–437f
Rectosigmoidostomy, 346f, 347–348
Rectovaginal fistula repair, 438–440, 441f
Rectum
  anatomy of, 298–299, 298f
  surgery of, 352–355
    hemorrhoidectomy, 352–354
    pilonidal cyst and sinus excision, 354–355, 354f
Rectus muscles, 611, 612f
Rectus sheath, 399
Recurrent laryngeal nerve, 566, 584f
Red blood cell count, 301t, 303t
Red blood cells, 941t, 1017t, 1190b–1191b
Reduction mammoplasty, 929–933, 930t–931t, 932f, 932b
Reflexology, 1246t
Regional anesthesia, 118, 133–137
  pressure ulcer risks, 146
  Registered nurse first assistants, 15, 318b
Reiki, 1246t
Relaxation, 738t–739t
Relaxed skin tension lines, 886f
Renal artery, 478, 481f
Renal artery stenosis, 495f
Renal pelvis, 552
Replantation of amputated body part, 912–913
Reprocessors, 216

Resection
abdominal aortic aneurysm, 985–987, 985t–986t, 988f
abdominoperineal, 348–350, 349f
bowel, 1105
endoscopic thyroid, 580b
hepatic, 387–388, 388f–389f
Miles', 348
segmental, 960, 961f
sigmoid colon, 346f, 347–348
small intestine, 311, 341
wedge, 961, 962f
Resectoscope, 516, 516f, 536f
Resident microorganisms, 49b
Residual volume, 938, 941t
Resolution, 217b
Respiratory system. *See also* Lung(s)
assessment of, 1012
lateral position effects on, 172
lithotomy position effects on, 167
patient positioning effects on, 156, 164
postoperative complications of, 272–283
prone position effects on, 169–170
supine position effects on, 164
Retained foreign objects, 34–36, 34b, 36b, 190b, 202, 1125, 1125f–1126f, 1126b
Retention suture, 183–184, 185f
Retina
anatomy of, 648
disorders of, 1141
Retinal detachment, 648–649, 654f, 655
Retinal neovascularization, 648
Retinopathy
diabetic, 642f, 648–649, 649f
of prematurity, 1141
Retinopexy, 654–655, 655f
Retractors
Bookwalter self-retaining, 367f
brain surgery, 870f
description of, 197–198, 197f
endoscopic minimally invasive surgery, 211–212, 214f
Lowsley, 522, 523f
neurosurgery, 870f
perineal prostatectomy, 522, 523f
purpose of, 211–212
rib, 959f, 1021
self-retaining, 870f, 1022f
sternal, 1021, 1022f
Retrobulbar block, 623, 623f, 643–644
Retrograde cardioplegia, 1049
Retromastoid craniectomy, 874–875
Retroperitoneal lymph node dissection, 511
Reusable drapes, 104–105
Reusable instrumentation, 215–217
Reuse, 49b
Reverse cutting needle, 181, 183t
Reverse Trendelenburg's position
description of, 162b–163b, 164–165, 165f
minimally invasive surgery, 226
Revision arthroplasty, of knee, 794–795
Rewarming, 276, 276f
Rheumatic fever, 1010–1011
Rhinologic surgery, 692–699
Rhinoplasty, 921–922
Rhombencephalon, 821
Rhytidectomy, 919–920, 919f–920f
Rib(s)
anatomy of, 936, 937f
fracture of, 1209–1210
Rib retractors, 959f, 1021
Richter hernia, 414–415, 416f
Right colocystoplasty, 549
Right coronary artery, 1002–1003
Right hemicolectomy and ileocolostomy, 345–347, 346f
Rigid endoscope, 204, 206f
Robotics coordinator, 16
Robotics/robotic surgery
advantages of, 377b
description of, 222–223, 223f, 308, 534
hysterectomy, 454–455, 454b
laparoscopic pancreatic procedures, 384
laparoscopy
cholecystectomy, 376, 377b
hepatic surgery, 388–389
radical prostatectomy, 534, 534f–535f
lobectomy, 955f
mitral valve surgery, 1063, 1065f
myths about, 378t
thoracic surgery, 955
Rod fixation, of fractures, 749, 749f
Roles
emerging, 16
perioperative nursing, 15–16
Root cause analysis, 19, 19b
Rotation-advancement method, for cleft lip repair, 1132f
Rotational flaps, 906–907
Rotator cuff
anatomy of, 722–723
tear of, 752–753
Round bones, 719, 722f
Round ligament, 420f, 422, 422f
Roux-en-Y cystojejunostomy, 383f
Roux-en-Y gastric bypass, 337, 338f–340f, 1101
Russell-Taylor rod, 768

S

Saccular aneurysm, 1068
Sacrococcygeal teratoma, 473, 474f, 1114–1115, 1114f
Safe patient handling and movement, 1258–1261
Safety
during anesthesia, 113
associations and entities involved in, 25b
cardiac surgery, 1021
communication's role in, 23
culture of, 1267
focus on, 18
genitourinary surgery, 486
geriatric surgery, 1173–1174
hand-offs/handovers, 25–30, 26b, 31b
as individual responsibility, 18
Institute of Medicine study, 18
medication administration, 38–39, 39b
ophthalmic surgery, 617–620
radiology nursing, 1216
Safety *(Continued)*
retained foreign objects. *See* Retained foreign objects
specimens, 36–37
surgical site marking, 6b
trocar, 318b
wrong site, person, or procedure surgery, 31–34
Sagittal synostosis, 1129
Saline implants, 929
Salivary glands
anatomy of, 660
parotidectomy, 700–702, 703f–704f
submandibular gland excision, 700, 701f
surgery of, 699–704, 701f
Salpingectomy, 451–452, 452f
Salpingo-oophorectomy, 463, 594b
Salpingostomy, 451–452, 453f
Saphenous vein, 999, 1054, 1055f
Saphenous vein grafts, 982
Saw palmetto, 1253t–1255t
Scab, 253
Scalp
anatomy of, 818–819, 820f
arterial supply of, 818–819
Scalpels, 194, 194f–195f
Scaphoid fractures, 761, 762f
Scapula, 722, 722f
Scars
revision of, 918, 918f
sternal, 1036b
Schwannomas, 842
Sciatic nerve, 153, 154f
Scientifically based care, 1–2
SCIP. *See* Surgical Care Improvement Project
Scissors
endoscopic, 210, 210f
types of, 194, 194f, 200–201
Sclera, 612
Scleral buckling, 652–654, 654f
Sclerosing agents, 1226–1227
Scoliosis
anterior spinal fusion with Isola instrumentation, 813–814
clinical features of, 811, 811f
Cotrel-Dubousset system procedure for, 812–813, 813f
Luque segmental spinal rod procedure for, 812
posterior spinal fusion with Harrington rods for, 811–812
Texas-Scottish Rite Hospital crosslink system, 813, 813f
Scrotal hernia, 1179
Scrotum
anatomy of, 481
surgery of, 506–511
Scrub nurse, 15
Scrub sinks, 67, 67f
Scrubbing of hands, 94–95, 95f
Seafood allergy, 1219b
Sealed-tube carbon dioxide laser, 230
Secondary intention, 251, 252f
Secretin-pancreozymin test, 364t
Sedation
conscious, 118, 137–138
interventional radiology, 1227–1228, 1229t–1230t
Sedatives, 1206t–1207t, 1251–1252
Segmental resection, 960, 961f
Seldinger technique, 1236, 1238f
Selective vagotomy, 327
Self-expanding metal stents, 323
Self-retaining retractors, 197–198, 197f, 403, 1022f
Sella turcica
anatomy of, 819
tumors of, 826–827
Sellick maneuver, 129
Semicritical items, 60t–61t, 82
Semi-Fowler position, 162b–163b, 167–168, 168f
Semi-implantable hearing aids, 692
Semilunar valves, 1006
Seminal vesicle, dilated, 518f
Semmelweis, Ignaz, 58b
Senna, 1253t–1255t
Sensitivity, 217b
Sensorineural hearing loss, 666t
Sentinel events, 19, 19b
Sentinel lymph node biopsy, 603–605, 715b
Sepsis, 388b
Sequential compression devices, 155, 171, 307, 367–368, 855, 1197
Sequential volume plethysmography, 978
Seroconversion, 52
Seropositivity, 52
Serum amylase, 364t
Serum lipase, 364t
Sestamibi-guided parathyroidectomy, 587
Sexual abuse, 1090b
Sexual impotence, 503
Shaken baby syndrome, 1090b
Sharps. *See also* Needlestick injuries
count record for, 35f
disposal of, 190, 193b, 1265b
injuries
HIV transmission through, 53
prevention of, 192b
report of, 1268f–1270f
safety issues, 1263–1265
no-touch technique for, 189–193
Standard Precautions for, 63
sterilization of, 68
Shear/shearing
avoidance of, 147
definition of, 144
in Trendelenburg position, 164
Shelf life, 74
Shirodkar procedure, 472, 472f
Shoes, 91–92
Short bones, 719, 722f
Short-gut syndrome, 342
Shoulder
anatomy of, 722–723, 722f
arthroplasty of. *See* Total shoulder arthroplasty
arthroscopy of, 806–808, 807f
dislocation of, 753–754
recurrent anterior dislocation of, 753–754
surgical procedures of, 750–754
Shoulder girdle, 722–723, 722f
Shoulder positioner, 732f
Shouldice repair, of hernia, 408–409
Showering, preoperative, 102b
Shunt
arteriovenous, 997
carotid artery, 994, 995f
ventriculoatrial, 1129, 1129f
ventriculoperitoneal, 1129
description of, 828
placement of, 866–867, 867f
Side-to-side anastomosis, 345
Side-to-side fistula, 997–998
Sigmoidocystoplasty, 549
Sigmoidoscopy, 321–322
Silastic band, 465, 466f
Silicone dressings, 264t–265t
Silk sutures, 178t–179t, 179
Silver nitrate, 368t
Simple hysterectomy, 459f
Simple mastectomy, 604f, 606, 607f
Simple perineal prostatectomy, 522–524, 522f–524f
Simple retropubic prostatectomy, 519–520, 521f
Simple vulvectomy, 433
Single-use items
drapes, 104–105
endoscopic minimally invasive surgery, 215–217
reprocessing/reuse of, 84–85, 85b–86b, 216–217, 216f
Sinoatrial node, 1006
Sinus
anatomy of, 660
ethmoid, 696f
maxillary, 696f
Sinus surgery, 695–699, 695b, 696f–697f
Sinusitis, 694
Six Sigma, 14
Skeletal system
anatomy of, 719–727, 720f–729f
traumatic injuries to, 1213–1214
Skene's ducts, 419
Skene's glands, 419
Skin
age-related changes in, 1166t
anatomy of, 250, 251f
antisepsis of, in patient, 101–104, 103f
child abuse-related injuries, 1090b
excess moisture effects on, 144
functions of, 250
microbial contamination of, 93
prepping of, 733, 855, 894, 980, 1034, 1173–1174
pressure ulcers. *See* Pressure ulcers
radiation exposure effects on, 1223t
Staphylococcus epidermidis on, 48
tissue metabolism affected by temperature increases, 144–145
Skin cancer, 897–899
basal cell carcinoma, 897, 900f
melanoma, 897, 898b–899b, 900f
squamous cell carcinoma, 897, 900f
Skin grafts, 904–907
burn surgery using, 900–901
pressure ulcers treated with, 903f
split-thickness. *See* Split-thickness skin grafts

Skin meshers, 890, 891f
Skin staples, 184–185, 185f
Skin stimulation, 738t
Skin substitutes, 261–262, 262t
Skin tape, 185, 186f
Skinning vulvectomy, 433, 434f
Skull. *See also* Head
  anatomy of, 819, 820f–821f
  cranial fossae, 819, 822f
  deformities of, 819
  fontanelles, 819, 820f
  fractures of, 819, 1205–1208, 1208f
  function of, 819
Skull clamps, 854, 854b
Slave monitor, 221
Slings
  male perineal, 543–544
  tension-free vaginal tape, 540–541
  transvaginal, with bone anchor, 541–542, 542f
Slip knot, 211
Slips, trips, and falls, 1261–1263
Small bowel/intestine
  anatomy of, 295–296, 296f
  duodenum. *See* Duodenum
  functions of, 297
  surgical procedures of, 338–342
    appendectomy. *See* Appendectomy
    enteroscopy, 321
    ileostomy, 341–342
    Meckel's diverticulectomy, 338–339
    resection, 311, 341
    transplantation, 342
  traumatic injury of, 1211–1212
Small cell carcinoma, 957f
Smallpox, 65t–66t
Smoke evacuation systems, for laser surgery, 237–239, 237f, 239f, 239b–240b
Sodium, 301t–303t, 1190b–1191b
Soiled linens, 108
Solid organ transplants. *See also* Transplantation
  history of, 358b
  mycophenolic acid monitoring for detecting rejection in, 361b
Solutions, 87–88, 88f
Somatosensory evoked potentials
  anesthesia monitoring using, 120
  neuromonitoring using, 853
  peripheral neuropathy prevention using, 154, 155b
Sorbitol, 248, 489t–490t
Source, 49b
Space surgical site infection, 49b, 254b
Spaulding classification system, 60t–61t, 82
Specimens
  care and handling of, 36–37, 37b, 61
  errors involving, 36, 37b
  frozen section, 37
  gastrointestinal surgery, 309
  handling of, 586b
  mislabeling of, 37
  multiple, 586b
  transmission-based precautions for, 37
  types of, 37
Spermatocelectomy, 510
Sphenoethmoidal recess, 659–660
Sphincter of Oddi, 359, 380
Sphincteroplasty, transduodenal, 380–381, 382f
Spigelian hernia, 416
Spinal accessory nerve, 835
Spinal analgesia, 281
Spinal anesthesia, 133–134
Spinal column. *See also* Vertebral column
  anatomy of, 835–836, 837f
  fractures of, 1208–1209
Spinal cord
  anatomy of, 836–837, 840f
  arterial supply to, 838–840
  lesions of, 840–844
  trauma to, 840
  vasculature of, 838–840
Spinal cord injury, 840, 1208–1209
Spinal cord stimulators, 879–881
Spinal epidural abscess, 842–843
Spinal fusion
  discharge planning and instructions after, 860t–861t
  Isola instrumentation for, 813–814
  lumbar, 860t–861t
  thoracic, 860t–861t
Spinal nerves
  anatomy of, 135, 838, 843
  rami, 843
Spinal stenosis, 877–878
Spine, 722. *See also* Vertebral column
  anatomy of, 721–722, 835–836, 837f
  cervical, 722, 836
  lumbar, 722
  magnetic resonance imaging of, 846, 847f
  thoracic, 722
  traumatic injuries of, 840
  vasculature of, 838–840
  x-rays of, 845, 846f
Spine surgery, 809–816, 875–882
Spinothalamic tracts, 837
Spleen
  anatomy of, 360–361, 361f
  functions of, 361
  imaging studies of, 361
  surgical procedures of, 393–394
    asepsis, 369
    blood products, 369–370
    discharge planning and instructions, 370–371, 370t
    drainage materials, 369
    draping of patient, 368
    evaluation, 370
    family education, 370–371
    hemostatic agents, 368t
    implementation, 364–371
    instrumentation, 368–369
    nursing considerations, 361–371
    nursing diagnoses, 362
    outcome identification, 362
    pain management, 371
    patient education, 370–371
    plan of care, 365b–366b
    planning, 362–364
    sequential compression devices for, 367–368
    splenectomy. *See* Splenectomy
    thermoregulation during, 367
  traumatic injuries of, 1211, 1211t
Splenectomy
  laparoscopic, 393–394
  open, 393–394
Splints, 736
Split-thickness skin grafts, 904–905
  operative procedure for, 905–906
  vaginal reconstruction using, 442f
Sponges
  bar-code technologies used with, 36
  blood loss estimations by weighing of, 39–40, 40b
  count record for, 35f, 191f, 1196–1197
  discarding of, 108
  hemostasis using, 185, 187b, 858
  laparotomy, 187b, 309
  radiofrequency identification of, 34–36
  radiopaque 4x4s, 187b
  retained, 34–36, 202b
  types of, 187b, 309
Spore, 49b
Spring clip, 465, 465f
Squamous cell carcinoma
  of lungs, 957f
  of skin, 897, 900f
St. John's wort, 1011t, 1253t–1255t
Stab wounds, 1186
Stainless steel
  history of, 193
  sutures, 178t–179t, 180, 180t
Standard Precautions, 62–63, 1275–1276
Standards of care, 12
Standards of Perioperative Administrative Practice, 3–4
Standards of Perioperative Clinical Practice, 4
Standards of Professional Practice, 4–5
Stapedectomy, 686
Stapedius, 657
Stapedotomy, 686–687, 686f
Stapes, 657, 658f
Staphylococci, 48–50
  characteristics of, 48
  S. aureus. *See Staphylococcus aureus*
  S. epidermidis, 48, 400b
Staphylococcus aureus
  infections caused by, 48–50
  methicillin-resistant, 56
    discovery of, 53–54
    incidence of, 56, 102b
    infections caused by, 56, 102b
    treatment of, 54t
  in respiratory passages, 48–50
  surgical site infections caused by, 102b, 400b, 1030–1031
  vancomycin intermediate-resistant, 56
Staplers
  automatic, 308–309
  description of, 211, 212f
  Roux-en-Y gastric bypass, 338f
Staples
  description of, 184–185, 185f
  laparotomy closure using, 317
  pediatric uses of, 1093
  wound care after removal of, 259t
Stapling instruments, 198–199, 199f
Steam quality, 68
Steam sterilization, 67
  automatic washer-sterilizer used before, 69
  biologic testing, 75
  biological indicators, 75, 75t
  chemical indicators, 74–75
  container systems for, 71, 73
  cooling after, 73–74
  drying after, 73–74
  flash, 78, 78t
  gravity displacement sterilizer, 76, 76f
  high-speed steam sterilizer, 78
  mechanisms of, 68
  microbial destruction, 67–68
  monitoring, 74–76, 75t
  packaging after, 71–73, 72f
  pouches for, 71, 73f
  presterilization preparations, 68–71
  prevacuum steam sterilizer, 77–78, 77f
  principles of, 68
  quality control practices for, 74–76
  recording thermometers, 74
  sharp instruments, 68
  soiled instruments, 68
  sterilizers, 76–78, 76f–77f
  sterilizing procedure, 73
  storage after, 73–74
  textile wrappers used in, 71, 72f
  time–temperature parameters for, 73, 74t
Stented tube grafts, 1024, 1024f
Stereotactic magnetic resonance imaging, 846
Stereotactic neurosurgery
  equipment, 850
  image-guided navigation, 852–853
  procedures, 851f, 864
Stereotactic radiosurgery, 863–864
Sterile enclosure, 87
Sterile field, 85–86
Sterile items, 87–88, 88f
Sterility assurance level, 67
Sterilization, 67–81
  chemical, 78
  classification of items for, 82
  definition of, 67
  dry heat, 81
  low-temperature hydrogen peroxide gas plasma, 80–81, 81f
  ozone, 215
  plasma, 80–81, 81f, 215
  steam, 67
Sterilization process-monitoring device, 49b
Sterilization (reproductive)
  tubal ligation. *See* Fallopian tubes, ligation of
  vasectomy, 508–509
Sternal retractors, 1021, 1022f
Sternal scars, 1036b
Sternal wire, 1042b
Sternoclavicular dislocation, 750
Sternocleidomastoid muscle, 663–664
Sternum
  anatomy of, 936
  wire closure of, 1023f
Stillbirth, 443b
Stochastic effect, 1222b
Stockinette, 733–734
Stoma, 322, 550f, 709t–710t
Stomach
  anatomy of, 295, 296f
  functions of, 295
  greater curvature of, 295
  lesser curvature of, 295
  surgical procedures of, 327–333
Strabismus surgery, 637, 1137–1138, 1137f, 1138b
Streptococci, 51
Stress incontinence, 440–441
Stretcher transfer, 1259f
Stroke, 973–975, 994b
Stroke volume, 1016t
Stroke volume index, 1016t
Stryker Navigation total knee arthroplasty, 793–794, 793f
S-type retractors, 209, 209f
Subarachnoid block, 133
Subarachnoid hemorrhage, 829–830
Subarachnoid injection, of anesthetic, 135
Subarachnoid space, 836
Subclavian artery, 566
Subcostal incision, 312f, 313–314, 314f
Subcutaneous mastectomy, 606
Subcuticular suture, 184, 185f
Subdural hematoma
  description of, 819, 830
  evacuation of, 865
  illustration of, 832f, 1205f
Subdural hemorrhage, 828–829
Subgaleal space, 818
Subglottis, 661
Sublingual gland, 660
Submandibular gland
  anatomy of, 660
  excision of, 700, 701f
Submental liposuction, 926f
Submucous resection of the septum, 692–693, 693f
Suboccipital craniectomy, 873–874, 874f
Substernal thyroidectomy, 582
Substitution cystoplasty, 547–549
Subthalamus, 824
Subtotal gastrectomy, 333f
Subtotal thyroidectomy, 577
Subtrochanteric fractures, 762–763, 763f
Subxiphoid incision, 1052t–1053t
Suction curettage, 444, 445f
Sulci, 821–822
Sulfur hexafluoride gas, 654–655
Superficial bladder cancer, 537
Superficial surgical site infection, 49b, 254b
Superior mesenteric artery, 359–360, 360f
Superior pancreaticoduodenal artery, 296, 297f
Superior thyroid artery, 582
Supine position
  description of, 162–164, 162b–163b, 164f
  neurosurgery in, 855
  to prone position, 170
Supracondylar fractures
  of femur, 770–772
  of humerus, 756–758
Supraglottic laryngectomy, 712t
Supraglottis, 661

Suprapubic cystolithotomy, 537
Suprapubic cystostomy, 535–536, 535f
Suprapubic prostatectomy, 520–521, 522f
Supraumbilical incision, 376f
Sural nerve, 154f
Surgeon's knot, 211
Surgery. *See also specific surgery*
  hypothermia associated with, 6b
  teamwork effects on, 403b
Surgical adverse events, 947b
Surgical Apgar score, 40b
Surgical attire, 90–93, 91f
Surgical capsule, 511
Surgical Care Improvement Project, 14, 25b, 55b, 742t
Surgical fires
  description of, 104b
  laser-related, 235–237, 236f, 236b
  risk reduction for, 673b
Surgical gut sutures, 176t–177t, 177–178
Surgical masks, 91–93, 92f
Surgical microscope, 677–678
Surgical needles, 180–182
  blunt, 181, 181b, 1265, 1266b
  contaminated, 61
  counting of, 189, 191f–192f
Surgical services standards of care, 12
Surgical site
  hair removal at, 307
  marking of, 6b, 31, 366, 486, 729b
  postanesthesia care unit assessments of, 270
  verification of, 978
Surgical site infections
  antimicrobial prophylaxis for, 257, 258b
  bacteria that cause, 48
  causes of, 253–254
  classification of, 55b
  deep incisional, 49b, 55b, 254b
  definition of, 49b, 59t
  glove perforation as risk factor for, 182b
  healthcare-associated infections secondary to, 250
  incidence of, 55b, 250
  organ/space, 49b, 55b, 254b
  patient education for prevention of, 59t
  preoperative showers to reduce risk of, 400b
  prevention of, 55b, 59t, 257, 260b, 400b, 599b, 980b
  Staphylococcus aureus as cause of, 102b, 1030–1031
  superficial, 49b, 55b, 254b
  wound healing delays caused by, 253–254, 261b
Surgical smoke, 237–239, 237f, 238b–239b, 239f
Surgical stretchers, 162
Surgical suite. *See also* Operating room
  infection control considerations, 66–67
  restricted area of, 88–89
  semirestricted area of, 88–89
  traffic control in, 88–90
  unrestricted area of, 88–89
Surgical technologist, 15
Surgitie ligating loop, 212f
Surgiwip suture ligature, 213f
Suture(s)
  absorbable, 176t–177t, 177–180, 741
  barbed, 180
  cardiac surgery, 1022–1023
  characteristics of, 174–175, 175b
  collagen, 178
  color-coded packaging of, 183
  continuous, 183, 185f
  cotton, 180
  definition of, 174
  diameter of, 174
  endoscopic minimally invasive surgery, 211, 212f–213f
  extracorporeal, 211, 213f
  gastrointestinal surgery, 309
  handling characteristics of, 174
  handling of, 188–189, 188f
  history of, 174, 175b
  interrupted, 183, 185f
  monofilament, 175f
  multifilament, 175f
  neurosurgery, 859
  nonabsorbable, 178t–179t, 179–180, 741
  nursing considerations for, 188–193
  nylon, 178t–179t, 180
  ophthalmic, 627
  orthopedic surgery, 741
  pediatric surgery, 1093
  physical characteristics of, 174
  plastic and reconstructive surgery, 892
  pledgetted, 983f
  polyester fiber, 178t–179t, 180
  polypropylene, 180
  purse-string, 184, 185f
  retention, 183–184, 185f
  selection of, 182–183
  silk, 178t–179t, 179
  stainless steel, 178t–179t, 180, 180t
  storage of, 182–183
  subcuticular, 184, 185f
  synthetic absorbable, 176t–177t, 178–179, 309
  tensile strength of, 174, 176t
  tissue-reaction characteristics of, 174–175, 176t
  vascular surgery, 982–983, 983f
  wound care after removal of, 259t
Suture line, primary, 183, 184f
Suture needle injuries, 1265
Suture packaging
  description of, 182–183
  opening of, 188
Suturing
  endoscopic, 184
  knot-tying techniques for, 184
  laparotomy closure, 317
Suturing instruments
  endoscopic minimally invasive surgery use of, 211
  needle holders, 211, 211f
S-VHS output, 217b
S-Video, 217b
Swaged needle, 181
"Swine flu." *See* H1N1
Sylvian fissure, 821–822
Sympathectomy
  cervicothoracic, 882
  endoscopic thoracic, 953–955, 954b
Sympathetic nervous system, 841f, 1248f
Synarthrotic joints, 719
Syndactyly repair, 1134–1135
Synovial joints, 719
Synthetic absorbable sutures, 176t–177t, 178–179, 309
Systemic vascular resistance, 1148

T

Tables, sterility of, 87
Taeniae coli, 298
Tail of Spence, 588, 589f
Talocalcaneal articulations, 808
Talus, 727
Tannic acid, 368t
Taper point needle, 181, 183t
Tarsal strip, 633
Tarsus, 610
Teamwork, 1281b
Technetium 99m-pertechnetate, 571–572, 572f
Teflon, 1023, 1024f
Telephone orders, 269b
Temporal lobe, 824
Tenckhoff catheter, 416
Tendons, 719
Tenotomy, 1131
Tension-free vaginal tape sling, 540–541
Tentorium cerebelli, 820
Teratoma, 826
  benign cystic, 462
  sacrococcygeal, 473, 474f, 1114–1115, 1114f
Tertiary intention, 251, 252f
Testes
  biopsy of, 510
  function of, 481
  orchiectomy, 510–511
  orchiopexy, 1121–1122, 1123f–1124f
Testicular implants, 510
Testosterone, 424t, 481, 510
Tetralogy of Fallot, 1148–1149, 1149f–1150f
Texas-Scottish Rite Hospital crosslink system, 813, 813f
Textile wrappers, 71, 72f
Thalamus, 824
The Joint Commission
  hand-offs, 25–26
  rapid response teams, 19, 22b
  safety activities by, 19
  sentinel events, 19
  Universal Protocol, 19, 32b–33b
The Leapfrog Group, 25b
Therapeutic donor insemination, 468t
Therapeutic touch, 1244–1246, 1246t, 1247b
Thermal burns
  injuries caused by, 1186
  laparoscopic instruments as cause of, 308b
  management of, 1214–1215
  risk for, 37–38
Thermoregulation. *See also* Body temperature; Hypothermia
  in elderly, 1173b
  pediatric, 1086
  postoperative complications of, 276–277
Thigh lift, 928f
Thomas splint balanced suspension, 737f
Thoracic aorta surgery, 1066–1072
Thoracic aortic aneurysmectomy, 1066
Thoracic aortic aneurysms
  ascending, 1069, 1070f
  descending, 1069–1072, 1072f
Thoracic outlet, 936
Thoracic outlet syndrome decompression, 966–967, 967f
Thoracic surgery, 947
  ambulatory, 948b
  anatomic considerations, 936–938, 937f–939f
  anesthesia for, 944
  blood replacement for, 944
  bronchoscopy. *See* Bronchoscopy
  chest drainage systems, 944–946, 946f, 959f
  diagnostic tests, 940
  discharge planning and instructions for, 947
  documentation for, 946
  draping for, 943
  endoscopic procedures, 947–955
  equipment for, 944
  family education about, 947
  historical events in, 956b
  instrumentation for, 943
  laboratory tests, 940, 941t
  monitoring during, 944
  nursing considerations for, 938–947
  patient education about, 947
  patient positioning for, 943, 944f
  postprocedure concerns, 946
  pulmonary function tests, 940, 941t
  robotic-assisted, 955
  transfer report after, 946
  video-assisted, 952–953, 955f, 961–963, 1100
Thoracic sympathectomy, 953–955, 954b
Thoracic vertebrae, 722
Thoracoabdominal incision, 314–315, 316f
Thoracoscopy
  discharge planning and instructions, 947
  mediastinum, 954f
Thoracostomy, 966, 966f
Thoracotomy, 956
  discharge planning and instructions, 947
  emergency, 1201–1202, 1201f, 1211
  indications for, 956
  lateral, 1052t–1053t
  lung cancer evaluations, 956, 957f
  patient positioning for, 943
  posterolateral, 1052t–1053t
Thoratec Heartmate left ventricular assist device, 1073, 1074f
Thorax
  anatomy of, 936, 937f
  muscles of, 938f
Three-dimensional computed tomography angiography, 846
Threshold dose, 1222b
Throat
  anatomy of, 660–664, 661f–663f
  larynx, 661–663
  oral cavity, 660, 661f
  pharynx, 660–661
  trachea, 663
Thrombin, 368t
Thrombolytics, 1226
Thrombosis. *See* Deep vein thrombosis
Thymectomy, 967
Thyroglossal duct cystectomy, 583–584, 585f
Thyroid cancer, 571
Thyroid cartilage, 661–663
Thyroid dysfunction, 571b
Thyroid gland
  anatomy of, 566, 567f–568f, 570f
  assessment of, 571–572
  blood supply to, 566, 570f
  excision of, 569
  hormones produced by, 566
Thyroid isotope scan, 571–572
Thyroid lobectomy, 577
Thyroid nodules
  description of, 568–569, 571
  fine-needle aspiration of, 572
  malignant, 580b
  ultrasonic scan of, 572
Thyroid scintigraphy, 571–572
Thyroid storm, 573–574, 574b, 575t
Thyroid surgery
  ambulatory, 579b
  anatomy, 566–567
  cosmetic surgery to enhance results of, 580b
  discharge planning and instructions, 577
  in elderly, 1177–1178
  family education about, 577
  history of, 567b
  minimally invasive approaches, 578
  nursing considerations for, 567–577
  patient education about, 577
  patient positioning for, 574–576
  perioperative care, 574b
  skin preparation for, 576–577
Thyroidectomy
  home care after, 578t
  intrathoracic, 582
  minimally invasive, 582–583
    description of, 578
    open procedure, 582
  minimally invasive video-assisted, 578–579
  open, 581–582, 581f
  procedural considerations for, 579–581
  substernal, 582
  subtotal, 577
  total, 577–578
Thyroid-stimulating hormone, 566, 571b
Thyroplasty, 711
Thyroxine, 566, 569
Tibia
  anatomy of, 726–727, 726f–727f
  dynamic compression plating of, 776

Tibial fractures
plateau, 768–770, 771f–772f, 772
shaft, 775–776, 776f–777f
Tibial neuropathy, 154
Time-out, 31, 307, 366, 486, 978
Tissue expanders, for breast reconstruction, 907–908, 908f
Tissue grafts, 904–907
flaps, 906–907
Tissue procurement, 1215
Titanium clips, 186
TNM staging, 594, 956, 957b–958b, 959f
Tocolytics, 469t–471t
Toe-to-hand transfer, 913–914, 914f
Toluene, 362t
Tongue carcinoma, 700f
Tonsillectomy, 1125–1127
Topical anesthetics, 894
Total abdominal hysterectomy, 455–458
laparoscopic-assisted vaginal hysterectomy as alternative to, 453
Total ankle arthroplasty, 798, 800f
Total artificial heart, 1076
Total gastrectomy, 332–333, 334f–335f
Total hip arthroplasty, 782–788
lateral position for, 732
Total intravenous anesthesia, 127–128
Total joint arthroplasty, 781–800
in elderly, 1179–1180
Total knee arthroplasty, 788–795
Total laryngectomy, 711–713, 712t, 713f–714f
Total lung capacity, 941t
Total lymphocyte count, 301t–303t
Total ossicular replacement prosthesis, 685, 687
Total parenteral nutrition, 311
Total shoulder arthroplasty, 795–797, 796f–797f
Neer, 795–797, 798f
procedural considerations for, 795
Total spinal anesthesia, 133
Total thyroidectomy, 577–578
Totally extraperitoneal patch, 410–413, 411b, 412f
Tourniquets, pneumatic, 136, 734–735, 734f, 735b, 891
Towel clamps, 196
Toxic anterior segment syndrome, 626b
Trabeculae, 720–721
Trabeculectomy, 645–646, 646f, 1141
Trachea, 663
Trachelorrhaphy, 442–443
Tracheostomy, 707–708, 708f, 709t–710t
Tracking medical devices, 893b
Traction, 735, 736f–737f
Transabdominal cerclage, 472
Transbronchial needle aspiration, 940
Transconjunctival blepharoplasty, 635
Transcranial Doppler ultrasound, 853
Transcutaneous electrical nerve stimulation, 282
Transcyte (skin substitute), 262t
Transduodenal sphincteroplasty, 380–381, 382f
Transesophageal echocardiography, 980, 1013–1014, 1031t
Transfer report, 1043f
Transferrin, 301t–303t
Transfixion ligature, 186
Transfusion reaction, 41
Transhiatal esophagectomy, 323–324
Transient erythema, 1222b
Transient microorganisms, 49b
Transmissible spongiform encephalopathies, 57
Transmission-based precautions, 37, 57–66
airborne precautions, 63–64
contact precautions, 64
droplet precautions, 64
indications for, 107–108
Transmyocardial revascularization, 1057
Transperineal biopsy, 514
Transplantation
corneal, 638–639, 639f
heart, 1076–1077, 1076f–1077f
heart-lung, 1077
lung, 967–968
organ and tissue procurement, 1215
pancreas and kidney, 387f
pancreatic, 385–387, 386f, 386b
small bowel, 342
Transpositional flaps, 906–907
Transrectal, ultrasonically guided biopsy, 514
Transrectal cryosurgical ablation of the prostate gland, 526–527
Transrectal guided ultrasound of the prostate, 494b
Transrectal seed implantation, 524–526, 526f
Transsphenoid hypophysectomy, 875
Transthoracic esophagectomy, 324
Transthoracic thalamotomy, 877
Transtracheal airway, 131b
Transurethral incision
of the ejaculatory ducts, 518
of the prostate gland, 517–518
Transurethral microwave therapy/transurethral needle ablation, 519, 520f
Transurethral resection
of bladder tumors, 536–537, 537f
of the prostate gland, 487, 488b, 513–516, 517f, 1179
Transurethral ureteropyeloscopy, 498–499, 499f
Transvaginal sling with bone anchor, 541–542, 542f
Transvenous pacing electrodes, 1079–1080, 1079f
Transversalis fascia, 399f, 408
Transversalis muscle, 398
Transverse colectomy, 346f, 347
Transverse colon, 297–298, 298f
Transverse colostomy, 343, 345f
Transverse fracture, 745–746, 746f
Transverse incisions, 312f, 314–315, 315f–316f
Transverse rectus abdominis myocutaneous (TRAM) flaps
breast reconstruction using, 909–910, 911f
free, 910
Trapezius muscle, 663–664
Trauma
abdominal, 1211–1212
bariatric, 1200–1201, 1201b
biomechanics in, 1184t
blast, 1186, 1186t
blood losses, 1199t
blunt, 1184–1185
cardiac, 1209–1211, 1210f
chest, 1209–1211
computed tomography evaluations, 1191
critical incident–stress debriefing, 1204
diagnostic procedures, 1191–1193
in elderly, 1200
end-of-life care, 1203–1204
eyelid injuries caused by, 636–637
facial, 1209
falls, 1185
fluid losses, 1199t
genitourinary, 1212–1213, 1213f, 1213t
grading of, 1144, 1145t
head, 1205–1209, 1205f–1206f, 1206t–1207t, 1208f
hepatic, 1211, 1212t
hypothermia secondary to, 1214
infection risks, 1196
laboratory tests for evaluating, 1187, 1188t, 1189–1191, 1189b–1191b
mechanism of injury evaluations, 1184–1186, 1184t, 1185f
missed injuries, 1194b
mortality caused by, 1182
motor vehicle collisions, 1185, 1185f, 1185b
neck, 1209
neurovascular status assessments, 1188b
ocular, 1209
pediatric, 1141–1145, 1142b, 1145t
penetrating, 1185–1186, 1186f, 1212
radiologic evaluations, 1191–1193
rapid response teams, 1202b
skeletal, 1213–1214
spinal cord, 840
splenic, 1211, 1211t
thermal, 1214–1215
urethral, 1213, 1213f
vertebral column, 840
vital signs assessment, 1187–1189
wounds caused by, 250
Trauma centers
classification of, 1182–1183
massive transfusion policies, 1191
Trauma surgery, 1204
admission assessment, 1193–1194
anesthesia for, 1198–1199
autotransfusion, 1197
Trauma surgery *(Continued)*
damage control, 1204–1205
deep venous thrombosis prophylaxis, 1197–1198
discharge planning and instructions for, 1203
emergency thoracotomy, 1201–1202, 1201f, 1211
evidence preservation, 1197
family education about, 1203
"golden hour" of care, 1182
multiple operative procedures, 1195–1196
nursing considerations for, 1186–1203
mechanism of injury evaluations, 1184–1186, 1184t, 1185f
organ procurement issues, 1215
outpatient follow-up procedures after, 1202b
patient education about, 1203
patient positioning for, 1196
during pregnancy, 1199–1200, 1200t
preparation for, 1196–1197
rapid-sequence intubation for, 1198, 1198b
timing importance, 1182
tissue procurement issues, 1215
vena cava filters, 1197–1198, 1198b
Trendelenburg's position, 162b–163b, 164, 164f
minimally invasive surgery, 226
reverse, 162b–163b, 164–165, 165f
Triage
"Decision Schemes,", 1182–1183, 1187t
description of, 1182–1184
history of, 1183b
Triangle of Calot, 359, 375
Triangular needles, 181
Tricuspid valve
anatomy of, 1006, 1007f
annuloplasty of, 1063–1064
surgery of, 1063–1064, 1065f
Trigeminal nerve, 664, 834, 835f, 836t
Trigeminal neuralgia, 834, 835b, 874
Triiodothyronine, 566, 569
Trimalar fracture, 916
Trimalleolar fracture, 778
Triple arthrodesis, 778
Triple endoscopy, 707
Triple-negative breast cancer, 596–597
Trocar(s)
endoscopic minimally invasive surgery use of, 198, 208–209, 208f–209f
laparoscopic cholecystectomy, 375f
laparoscopic pancreatic cyst–gastrostomy, 383f
Roux-en-Y gastric bypass positioning of, 338f
safety considerations, 318b
Trocar cystostomy, 537, 538f
Trochlea, 723
Trochlear nerve, 833–834, 836t
True aneurysm, 971–972
True latex allergies, 98
True pelvis, 422–423
True prostatic capsule, 481
Trumpet valve, 248f
Truncal vagotomy, 327, 328f
T-tube, 266f
Tubal ligation. *See* Fallopian tubes, ligation of
Tube grafts, 1024, 1024f
Tubercle bacilli, 51
Tuberculosis, 956b
latent, 51–52
Mycobacterium tuberculosis, 51–52
Tularemia, 65t–66t
Tunable dye laser, 232
Tunica vaginalis, 507–508
Turbinates, 659–660, 660f
Turbulent blood flow, 969–970
Two-dimensional echocardiography, 1013–1014, 1015f
Tympanic fibrosis, 682–683
Tympanic membrane, 657, 658f, 683f
Tympanoplasty, 683–685

U

Ulna, 723
Ulnar nerve
anatomy of, 151, 151f–152f
neuropathy of, 152
patient positioning-related injury of, 152, 152f
protection of, 153f
transposition of, 758–759
Ultrasonic aspirator, 850
Ultrasonic cleaning, 69–71
Ultrasonic device surgery, 246–247
Ultrasound
B-mode, 978
breast imaging, 592
duplex, 978
high-intensity focused, 513b
spine imaging, 847
thyroid nodule evaluations, 572
transcranial Doppler, 853
transrectal guided, of the prostate, 494b
vascular imaging uses of, 977–978
Umbilical hernia
description of, 398f, 416
repair of, 1108
Umbilical incisions, 319
Universal Precautions, 57–66, 1274–1276
body substance isolation, 57–58, 62f
HIV exposure, 57–58
needle-stick injuries, 57–58
Universal Protocol, 19, 32b–33b, 364–366, 1236
Unlicensed assistive personnel
delegation to, 9–10
growth of, 10
Upper endoscopy, 321, 321b
Upper extremity
anatomy of, 722–723, 722f
neuropathies of, 150–155, 150f–153f
peripheral nerve blocks of, 135
Upper eyelid blepharoplasty, 921, 921f
Urachal remnant, 548f
Ureter(s)
anatomy of, 478–479, 481f
catheterization of, 497–498
reimplantation of, 552–553, 1124–1125
surgery of, 551–564

Ureteral catheters, 308, 488–493, 491f–492f
Ureteral reflux, 498f
Ureteral strictures, 498
Ureterectomy, 552
Ureterocutaneous transplant, 553
Ureteroenterostomy, 552
Ureterolithotomy, 553
Ureteroneocystostomy, 552
Ureteropelvic junction, 552, 555–556
Ureteropyeloscope, 499f
Ureteropyeloscopy
description of, 488
transurethral, 498–499, 499f
Ureteroscope, semirigid, 206f
Ureterosigmoid anastomosis, 553
Ureterosigmoidostomy, 552
Ureterostomy, 552
Ureteroureterostomy, 552
Ureterovaginal fistula repair, 438
Ureterovesical junction, 552
Urethra, 419, 421f
anatomy of, 479–480, 482f
anterior, 479–480
caruncle excision, 500
dilation of, 500–501
female, 480
male, 479–480
membranous, 479–480
posterior, 479–480
prostatic
description of, 511
prosthetic sphincter, 545–546, 546f
surgery of, *499–506*. *See also specific procedure*
traumatic injury of, 1213, 1213f
Urethral catheters, 488–493, 491f–492f
Urethral grafts, 501
Urethral meatotomy, 500
Urethral suture guides, 520f
Urethroplasty, 501–502, 1117
island flap for, 1120f
skin cover for, 1118, 1121f
vascularized flaps for, 1117–1118, 1120f
Urethrotome, 500f
Urethrotomy, internal, 500–501
Urethrovaginal fistula repair, 438, 440f
Urethrovaginal septum, 422
Urinalysis, 1017t, 1189b
Urinary bladder. *See* Bladder
Urinary diversions
continent, 550–551
cutaneous, 549–550
ileal conduit, 549–550
ileal reservoir, 550–551
Indiana pouch, 551
Urinary incontinence
Botox treatment for, 544b
in elderly, 1179
stress, 440–441
urge, 542
Urinary tract infections, 480, 1122b
Urinary tract obstruction, 551f
Urine
bilirubin in, 363t
description of, 478
urobilinogen in, 363t
Urobilinogen, 363t
Urogenital diaphragm, 420f
Urticaria, 1235b
Uterine artery embolization, 455
Uterine body, 419
Uterine fibroids
definition of, 458
embolization of, 432t
sites of, 458f
treatment of, 456b
Uterine leiomyomas. *See* Uterine fibroids
Uterosacral ligament, 420f, 422, 422f
Uterus
anatomy of, 419, 422f
fibroids of. *See* Uterine fibroids
ligaments of, 420f, 422, 422f
prolapse of, 456b
Uvulopalatopharyngoplasty, 702–704, 705f

V

Vacuum-assisted closure, 260–261, 261f, 261b
Vagina
anatomy of, 420f, 422
cancer of, 427, 427t
discharge from, 426b
reconstruction of, 441–442, 442f
Vaginal surgery, 435–448
Vagotomy, 327, 328f–329f
Vagus nerve, 835
Valerian, 1245f, 1253t–1255t
Valvulae conniventes, 295–296
Valvular surgery
aortic valve, 1065–1066, 1067f
mitral valve, 1058–1063
patient-related factors that affect, 1063b
pulmonary valve, 1065
risks associated with, 1063b
tricuspid valve, 1063–1064, 1065f
Valvulotomes, 982, 983f
Vancomycin intermediate-resistant *Staphylococcus aureus*, 56
Vancomycin-resistant enterococci, 56
Vancomycin-resistant *Enterococcus faecalis*, 54
Varicella zoster virus, 1276
Varicocelectomy, 510
Varicoceles, 510
Varicose veins
endovenous laser ablation of, 999, 1000b
excision and stripping of, 998–1001
patient education about, 985t–986t
Vas deferens, 481
Vasa vasorum, 969
Vascular access, for pediatric surgery, 1096–1097
Vascular malformations, 830
Vascular prostheses, 982
Vascular surgery. *See also specific procedure*
anatomic considerations, 969–970, 970f–971f
discharge planning and instructions for, 984–985
documentation, 983–984
draping for, 980
in elderly, 1180
family education about, 984–985, 985t–986t
instrumentation for, 983
Vascular surgery (Continued)
intraoperative monitoring, 978–980
medications and solutions used in, 981–982
monitoring during
description of, 978–980
equipment for, 983
nursing considerations for, 976–985
patient education about, 984–985, 985t–986t
patient positioning for, 980
preoperative tests, 976–978
skin preparation for, 980
sutures used in, 982–983, 983f
Vasectomy, 508–509
Vasoconstrictors, 1226
Vasodilators, 1032t–1033t, 1226
Vasopressors, 1032t–1033t
Vasovasostomy, 509, 509f
Vein grafts, 982
Veins, 969, 970f–972f
Velopharyngeal insufficiency, 1132
Vena cava filter
illustration of, 999f
indications for, 998b
insertion of, 985t–986t, 998
pulmonary embolus prevention using, 1197–1198
in trauma patients, 1197–1198, 1198b
Venous air embolism, 856b
Venous cannulation, 1047–1048
Venous conduits, coronary artery bypass grafts with, 1054–1057
Venous disease, 975
Venous insufficiency
acute, 975
chronic, 975
Venous plexuses, 840
Venous sinuses, 820, 831f
Venous thromboembolism
anticoagulation therapy for, 742t
incidence of, 742t
patient positioning and, 155
in trauma patients, 1197
Ventilation-perfusion ratio, 156
Venting catheters, 1041f
Ventral hernia, 415–416
Ventricles of heart, 1002, 1003f–1004f
Ventricular aneurysmectomy, 1057–1058, 1059f
Ventricular assist devices, 1072–1073, 1074f
Ventricular fibrillation, 1040
Ventricular septal defect, 1058, 1147–1148, 1147f–1149f
Ventriculoatrial shunt, 1129, 1129f
Ventriculography, 1014, 1016t
Ventriculoperitoneal shunt, 1129
description of, 828
placement of, 866–867, 867f
Verbal orders, 269b
Veress needle
description of, 198
insufflation using, 224f
safety considerations, 318b
Versed. *See* Midazolam
Vertebrae
anatomy of, 721–722
cervical, 722, 836
lumbar, 722
thoracic, 722
Vertebral column, 722. *See also* Spinal column
anatomy of, 835–836, 837f
traumatic injuries of, 840
vasculature of, 838–840
x-rays of, 845, 846f
Vertebroplasty, 815–816, 816f
Vertical laryngectomy, 712t
Vesical fistula repair, 537–540
Vesicointestinal fistula, 537–538, 538f
Vesicosigmoid fistula, 539–540
Vesicoureteral reflux, 1122–1125, 1122b
Vesicourethral suspension, 441, 540
Vesicovaginal fistula
description of, 537–539
repair of, 438, 440f
Vestibular labyrinth, 658–659
Vestibular neurectomy, 688–689
Vestibular schwannomas, 689–690, 826
Vestibulectomy, 434–435
Vestibulocochlear nerve, 664
Vestibulodynia, 434
Vestibuloplasty, 434–435
Vest-over-pants repair, 415–416
Vicryl sutures, 176t–177t
Video monitor, 221, 221f
Video technology, 217–224
Video-assisted thoracic surgery, 952–953, 955f, 961–963, 1100
Video-assisted thoracotomy surgery, 324
Videoconferencing, 223–224, 224f
Videoscope, 220, 220f
Vinyl chloride, 362t
Violence, workplace, 1279–1281
Virchow's triad, 975
Virulence, 49b
Virus
classification of, 52
definition of, 49b
hepatitis, 52
HIV. *See* HIV
infections caused by, 52–53
replication of, 52
Visceral pleura, 936
Viscoadherents, 621t–623t
Viscoelastics, 621t–623t
Vision
age-related changes in, 1166
impairment of, 611b
physiology of, 613
Vision loss
perioperative, 156b
statistics about, 610
Visual analogue scale, 282f
Visual laser ablation of prostate, 513–514
Vital capacity, 938
Vital signs, 1145t, 1187–1189
Vitamin E, 1253t–1255t
Vitamin K, 358
Vitrectomy, 649–655
Vitreoretinal surgery, 647–649
Vitreous body, 613
Vitreous humor
anterior vitrectomy for replacement of, 645
description of, 611–612
Vocal cords
anatomy of, 663
polyps, 706f
Voiding cystourethrogram, 1122
Voltage, 241
Vulva
anatomy of, 419, 421f
cancer of, 425–427, 428f
surgery of, 433–435, 433f
Vulvectomy
patient and family education about, 432t
radical, 433–434, 434f
simple, 433
skinning, 433, 434f

W

Wada's test, 847
Wanding maneuver, 811f
Warren, John C., 111
Waste anesthetic gases
definition of, 1267
exposure symptoms, 1273, 1273b
operating room personnel exposure to, 1267–1273
scope and significance of, 1267–1273
Watson, Jean, 5b
Wavelength, 118t, 226–227
Wedge resection, 961, 962f
Weeks-Shaw, Clara, 5b
Wells, Horace, 111
Wertheim radical hysterectomy, 459, 459f–460f
Whipple procedure, 384–385, 385f
White balancing, 206, 217b, 219
White blood cell count differential, 301t–303t
White blood cells, 941t, 1190b–1191b
Whole blood, 40
Whole breast irradiation, 590–592
Wies procedure, for cicatricial entropion, 633, 634f
Wilms' tumor, 1113–1114, 1114f
Wilson frame, 170
Wong, Baker FACES pain rating scale, 282f, 1094
Wood's lamp, 892
Workplace issues
back injuries, 1258
blood exposure report, 1271f–1272f
bloodborne pathogens
exposure to, 1265–1267
safety regarding, 1263–1265
body fluid exposure report, 1271f–1272f
chemicals, 1273–1274
ergonomics, 1258, 1259f, 1260
infectious disease exposure, 1276–1277
latex allergies and sensitivities, 98, 369b, 1278–1279, 1280b
personal protective equipment, 1265
radiation safety, 1277–1278
safety culture, 1267
sharps
injury reports, 1268f–1270f
safety for, 1263–1265
slips, trips, and falls, 1261–1263
violence, 1279–1281
waste anesthetic gas exposure. *See* Waste anesthetic gases

World Health Organization
purpose of, 21
safety promotion by, 21–23
surgical hand preparation guidelines, 23b
surgical safety checklist of, 24b
Wound(s)
care of, 258, 259t, 292
chronic, 250
classification of, 254–257, 309
clean, 254–257
clean contaminated, 257, 369
contaminated, 257, 369, 1196
debridement of, 258, 262b
decontamination of, 1196
dehiscence of, 254b, 257f, 312
dirty, 257
dressings for. *See* Dressings
etiology of, 250
evisceration of, 254b, 257f
infected, 257
Wound(s) *(Continued)*
stab, 1186
streptococci introduction into, 51
surgical, 250
traumatic, 250
undressed, 263
Wound closure
in abdomen, 1212, 1212f
adhesives for, 185
delayed primary, 251, 252f
primary intention, 250–251, 252f
secondary intention, 251, 252f
skin staples for, 184–185, 185f
skin tape for, 185, 186f
strips for, 185, 186f
suturing techniques for, 183–185
tertiary intention, 251, 252f
types of, 250–251
Wound healing
complications of, 257f
delayed, 253–254
description of, 250
events in, 253f
factors that affect, 253–254, 1177b
full-thickness, 251–253
growth factors for, 262
hyperbaric oxygenation for, 258–259
inflammatory phase of, 253
nutritional status and, 253
phases of, 251–253, 252f–253f
postoperative assessments, 288–289
primary intention, 250–251, 252f
proliferative phase of, 253
remodeling phase of, 253
secondary intention, 251, 252f
Wound healing *(Continued)*
surgical site infection effects on, 253–254, 261b
terminology associated with, 254b
tertiary intention, 251, 252f
Wound infections
antimicrobial prophylaxis, 257, 258b
description of, 250
nursing diagnoses for, 257–258
Wound management, 258–262
Wound ostomy continence nurse, 299, 310–311
Wrist
anatomy of, 723–724, 724f
external fixation of, 748f
fractures of, 735–736
Wrong person surgery, 31–34
Wrong procedure surgery, 31–34
Wrong site surgery, 31–34
Wrubel, Judith, 5b

X

Xenon chloride, 232
Xenon fluoride, 232
Xenon light, 206
Xylene, 362t

Y

Y pouch, for ileoanal endorectal pull-through, 352, 352f–353f
Yersinia pestis, 65t–66t
Yohimbe, 1253t–1255t

Z

Zenker's diverticulum, 324
Zeolite beads, 368t
Z-plasty, 918, 918f
Zuckerkandl fascia, 478
Zygomatic fractures, 915–916
Zygote intrafallopian transfer, 468t

Uploaded by [stormrg]

This page intentionally left blank