Orthopedic Surgery Clerkship

A Quick Reference Guide for Senior Medical Students

Adam E. M. Eltorai
Craig P. Eberson
Alan H. Daniels
Editors

Springer

Orthopedic Surgery Clerkship

Adam E. M. Eltorai • Craig P. Eberson
Alan H. Daniels
Editors

Orthopedic Surgery Clerkship

A Quick Reference Guide for Senior Medical Students

Springer

Editors
Adam E. M. Eltorai
Warren Alpert Medical School
Brown University
Providence, RI
USA

Alan H. Daniels
Department of Orthopaedic Surgery
Division of Spine Surgery
Rhode Island Hospital
Providence, RI
USA

Craig P. Eberson
Department of Orthopedic Surgery
Division of Pediatric Surgery
Warren Alpert Medical School
of Brown University
Providence, RI
USA

ISBN 978-3-319-52565-5 ISBN 978-3-319-52567-9 (eBook)
DOI 10.1007/978-3-319-52567-9

Library of Congress Control Number: 2017943119

© Springer International Publishing AG 2017
This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

This quick-reference review is the first book written specifically for third- and fourth-year medical students completing orthopedic surgery rotations. Organized by body part, *Orthopedic Surgery Clerkship* focuses on diagnosis and management of the most common pathologic entities. Each chapter covers history, typical presentation, relevant anatomy, physical examination, imaging, options for nonoperative and operative management, and expected outcomes.

Orthopedic Surgery Clerkship is the ideal on-the-spot reference for those seeking fast facts on diagnosis and management. Its bullet-pointed outline format makes this book a perfect addition to a white coat pocket, allowing busy students to find the information they need rapidly. Its content breadth covers the most commonly encountered orthopedic problems in practice.

Students can read the text from cover to cover to gain a general foundation of orthopedic knowledge and then reread specific chapters for more focused subspecialty review. This book will serve as tool to propel students to the next level and help them start their journey as orthopedists on the right foot.

Providence, USA

Adam E. M. Eltorai
Craig P. Eberson
Alan H. Daniels

Acknowledgments

This collaborative project would not have been possible without the thoughtful comments, insights, and advice of the many orthopedic residents and members of faculty, whom we gratefully acknowledge for their support in the development of *Orthopedic Surgery Clerkship*. Our special thanks to Kristopher Spring, Prakash Jagannathan, and the contributing authors.

Contents

Contributors

Robert Ablove, MD Department of Orthopaedics, Jacobs School of Medicine and Biomedical Sciences, Buffalo, NY, USA

Eildar Abyar Orthopedics, University of South Florida Morsani Center, Tampa, FL, USA

Amiethab A. Aiyer Department of Orthopaedic Surgery, University of Miami, Miami, FL, USA

John Alexander, MD Department of Orthopaedics, Hand and Upper Extremity Center, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Tonya W. An Orthopedics, Cedars-Sinai Medical Center, Los Angeles, CA, USA

Christopher Arena Department of Orthopaedics and Rehabilitation, Penn State Milton S. Hershey Medical Center, Hershey, PA, USA

David Arsanious University of Vermont College of Medicine, Burlington, VT, USA

Hisham M. Awan, MD Hand and Upper Extremity Center, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Navkirat Bajwa Department of Orthopaedic Surgery, University of South Alabama, Mobile, AL, USA

Karl Balch, MD Orthopaedic Surgery, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Domenico Barbuti Imaging Department, Bambino Gesù Children's Hospital, Rome, Italy

Giulia Battafarano Bone Physiopathology Group, Multifactorial Disease and Complex Phenotype Research Area, Rome, Italy

Patrick F. Bergin, MD Department of Orthopedic Surgery, University of Mississippi Medical Center, Jackson, MS, USA

Geoffrey Bernas, MD Department of Orthopaedics, Jacobs School of Medicine and Biomedical Sciences, Buffalo, NY, USA

Matthew Binkley, MD Department of Orthopedic Surgery, Erie County Medical Centre, Buffalo, NY, USA

Charles Bishop, MD Department of Orthopaedics, Marshall University School of Medicine, Huntington, WU, USA

Leslie J. Bisson Jacobs School of Medicine and Biomedical Sciences, University at Buffalo, Amherst, NY, USA

Richard Boe Department of Orthopaedics, Marshall University Medical Center, Huntingston, WV, USA

Chad S. Boomershine, MD, PhD Rheumatology and Immunology, Vanderbilt University, Nashville, TN, USA

Allen Borne, MD Department of Orthopaedic Surgery, University of Arkansas for Medical Sciences, Little Rock, AR, USA

Phillip A. Bostian, MD Department of Orthopedics, West Virginia University, Health Science Center South, Morgantown, WV, USA

Erik Bowman, MD Department of Orthopaedic Surgery and Rehabilitation, University of Nebraska Medical Center, Omaha, NE, USA

Keely Boyle, MD Department of Orthopaedics Surgery, SUNY University at Buffalo, Buffalo, NY, USA

Matthew J. Brown, MD Department of Orthopaedics, Jacobs School of Medicine and Biomedical Sciences, Buffalo, NY, USA

Timothy P. Bryan, MD Department of Orthopaedics, State University of New York at Buffalo, Buffalo, NY, USA

Grant S. Buchanan, MD Department of Orthopaedic Surgery, Joan C. Edwards School of Medicine, Marshall University, Huntington, WV, USA

Andrew Campbell, MD Hand Upper Extremty Center, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Brian Carpenter Department of Orthopaedic Surgery, John Peter Smith Hospital, Fort Worth, TX, USA

Department of Orthopaedic Surgery, UNT Health Science Center, Fort Worth, TX, USA

David Cealrey, MD Augusta University, Augusta, GA, USA

Michael J. Chambers, MD Marshall University Orthopaedics, King's Daughters Medical Center, Ashland, KY, USA

Nileshkumar M. Chaudhari, MD Division of Orthopaedic Surgery, Department of Surgery, University of Alabama – Birmingham, Birmingham, AL, USA

Anne Marie Chicorelli, DO, MPH Orthopaedics and Sports Medicine, The Ohio State University Wexner Medical Center, Wooster, OH, USA

Nicolette Clark Department Orthopaedics and Sports Medicine, University of South Florida, Tampa, FL, USA

Corey T. Clyde, MD Department of Orthopaedic Surgery, University at Buffalo, Buffalo, NY, USA

Jenna Cooley, DO Division of Rheumatology, Cooper University Hospital, Camden, NJ, USA

Aristides I. Cruz Jr, MD Warren Alpert Medical School at Brown University, Rhode Island Hospital/Hasbro Children's Hospital, Providence, RI, USA

Scott D. Daffner, MD Department of Orthopaedics, West Virginia University, Morgantown, WV, USA

D. Daniel Rotenberg Desert Orthopaedic Center, Las Vegas, NV, USA

Alan H. Daniels, MD Department of Orthopaedic Surgery, Division of Spine Surgery, Rhode Island Hospital, Providence, RI, USA

Department of Orthopedic Surgery, Warren Alpert Medical School, Brown University, Providence, RI, USA

James B. Day, MD, PhD Director of Orthopaedic Trauma, Department of Orthopaedics, Joan C. Edwards School of Medicine, Marshall University, Huntington, WU, USA

Andrea Del Fattore Bone Physiopathology Group, Multifactorial Disease and Complex Phenotype Research Area, Imaging Department, Bambino Gesù Children's Hospital, Rome, Italy

J. Mason DePasse, MD Department of Orthopedic Surgery, Division of Pediatric Surgery, Warren Alpert Medical School of Brown University, Providence, RI, USA

Alex C. DiBartola Department of Orthopaedics, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Kyle Duncan Department of Orthopaedic Surgery, John Peter Smith Hospital, Fort Worth, TX, USA

Thomas Duquin, MD Department of Orthopaedics, State University of New York at Buffalo, Buffalo, NY, USA

Craig P. Eberson, MD Department of Orthopedic Surgery, Division of Spine Surgery, Warren Alpert Medical School of Brown University, Providence, RI, USA

Hossein Elgafy, MD, FRCSEd, FRCSC Department of Orthopedic Surgery, University of Toledo Medical Center, Toledo, OH, USA

Jordan Ernst Orthopedics, John Peter Smith, Fort Worth, TX, USA

Paul Esposito Department of Orthopaedic Surgery, University of Nebraska Medical Center, Children's Hospital and Medical Center, Omaha, NE, USA

Reed Estes, MD Department of Surgery, Division of Orthopedic Surgery, University of Alabama at Birmingham, Birmingham, AL, USA

Joshua S. Everhart Department of Orthopaedics, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Michael R. Ferrick, MD Department of Orthopaedic Surgery, SUNY Buffalo, Women and Children's Hospital of Buffalo, Amherst, NY, USA

Brooks W. Ficke, MD Division of Orthopedic Surgery, University of Alabama at Birmingham, Birmingham, AL, USA

Marc Fineberg, MD University of SUNY Buffalo, Buffalo, NY, USA

Department of Orthopaedics, University at Buffalo, Buffalo, NY, USA

David C. Flanigan Department of Orthopaedics, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Joseph Fox, MD Department of Orthopaedic Surgery, Jacobs School of Medicine, University at Buffalo, Buffalo, NY, USA

John France Department of Orthopaedic Surgery, West Virginia University, Stewart Hall, Morgantown, WV, USA

Dominic J. Gargiulo, DO Pediatric Orthopedics, Children's Hospital New Orleans, New Orleans, LA, USA

Orthopedic Department, Louisiana State University School of Medicine, New Orleans, LA, USA

Lauren E. Geaney, MD Department of Orthopaedic Surgery, UCONN Health, Farmington, CT, USA

Daniel J. Gehling Department of Orthopaedic Surgery, University of Toledo – Health Science Campus, Toledo, OH, USA

Thomas Gill, MD Department of Orthopedic Surgery, Marshall University/ Cabell Huntington Hospital, Huntington, WV, USA

Jonathan Gillig, MD Department of Orthopaedic Surgery, University of South Alabama, Mobile, AL, USA

Andrew H. Glassman, MD, MS Orthopaedic Surgery, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Akshay Goel, MD Department of Orthopaedics, Three Rivers Medical Center, Louisa, KY, USA

Kanu Goyal, MD Ohio State University Wexner Medical Center, Columbus, OH, USA

Bobby Kwanghoon Han, MD Division of Rheumatology, Cooper University Hospital, Camden, NJ, USA

Andrew E. Hanselman, MD Department of Orthopedics, Health Sciences South, Morgantown, WV, USA

Jared L. Harwood, MD Department of Orthopaedics, The Ohio State University wexner Medical Center, Columbus, OH, USA

Michael Heffernan, MD Orthopedic Department, Children's Hospital Of New Orleans, Louisiana State University, New Orleans, LA, USA

Henry C. Hilario, DPM Department of Orthopedics, John Peter Smith Hospital, Fort Worth, TX, USA

Ilia Iliev Department of Orthopaedic Surgery, Joan C. Edwards School of Medicine, Marshall University, Huntington, WV, USA

Carlos Isales Regenerative Medicine, Orthopaedic Surgery, Medical College of Georgia, Augusta, GA, USA

Rajiv J. Iyengar, BS Warren Alpert Medical School, Brown University, Providence, RI, USA

Aprajita Jagpal, MBBS Division of Clinical Immunology and Rheumatology, School of Medicine, University of Alabama at Birmingham, Birmingham, AL, USA

Margaret Jain Hand and Upper Extremity Surgery, University of Toledo School of Medicine, Toledo, OH, USA

David Johannesmeyer, MD Department of Surgery, Division of Orthopedic Surgery, University of Alabama at Birmingham, Birmingham, AL, USA

Anna Johnson Department of Orthopedic Surgery, University of South Alabama Medical Center, Mobile, AL, USA

Brock Johnson, MD Department of Orthopedic Surgery, Marshall University/Cabell Huntington Hospital, Huntington, WV, USA

Michael D. Johnson, MD Department of Orthopaedics, University of Alabama – Birmingham, Birmingham, AL, USA

Grant L. Jones Department of Orthopaedics, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Paul J. Juliano, MD Department of Orthopaedics and Rehabilitation, Penn State Health Milton S. Hershey Medical Center, Hershey, PA, USA

Jonathan M. Karnes, MD Department of Orthopedics, West Virginia University, Morgantown, WV, USA

Daniel C. Kim, MD Department of Orthopaedic Surgery, University of South Alabama Hospitals, Mobile, AL, USA

Jeffrey Kim, MD Department of Orthopaedic Surgery, Cabell Huntington Hospital/Marshall University School of Medicine, Huntington, WV, USA

Joseph J. King, MD Orthopaedics and Rehabiliation, UF Health Shands Hospital, Gainesville, FL, USA

Alexander J. Kish, MD Department of Orthopaedic Surgery, University of Maryland Medical Center, Baltimore, MD, USA

Alan R. Koester, MD Department of Orthopaedic Surgery, Joan C. Edwards School of Medicine, Marshall University, Huntington, WV, USA

Sean Kraekel, MD Department of Orthopedic Surgery, The George Washington University, Washington, DC, USA

Kafai Lai Orthopaedics, The University of Toledo Medical Center, Toledo, OH, USA

Darin Larson, MD Department of Orthopaedic Surgery and Rehabilitation, University of Nebraska Medical Center, Omaha, NE, USA

Tracye J. Lawyer, MD, PhD Department of Orthopedic Surgery, University of Mississippi Medical Center, Jackson, MS, USA

Benjamin Leger-St. Jean, MD Department of Orthopaedics, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Nathaniel Lempert, MD Department of Orthopedic Surgery, University of Toledo Medical Center, Toledo, OH, USA

S. Louis Bridges Jr, MD, PhD Division of Clinical Immunology and Rheumatology, School of Medicine, University of Alabama at Birmingham, Birmingham, AL, USA

John P. Lubicky, MD Department of Orthopaedics, West Virginia University, Morgantown, WV, USA

Jonathan Ludwig, MD Orthopedic Surgery, University of Alabama at Birmingham Hospital, Birmingham, AL, USA

Dana Lycans, MD Department of Orthopaedic Surgery, Marshall University/Cabell Huntington Hospital, Huntington, WV, USA

Adam Martin, MD Hand and Upper Extremity Center, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Warren Alpert Medical School, Brown University, Providence, RI, USA

John M. Marzo, MD Department of Orthopaedics, Jacobs School of Medicine and Biomedical Sciences, Buffalo, NY, USA

J. Mason DePasse, MD Department of Orthopaedic Surgery, Warren Alpert Medical School of Brown University, Rhode Island Hospital, Providence, RI, USA

John R. Matthews, MD Department of Orthopaedic Surgery, SUNY University of Buffalo, Buffalo, NY, USA

Robert C. Matthias, MD University of Florida, Gainesville, FL, USA

Joel Mayerson, MD Department of Orthopaedics, The Ohio State University wexner Medical Center, Columbus, OH, USA

James L. McFadden, MD Orthopaedic Surgery, University of Alabama at Birmingham, Birmingham, AL, USA

Ryan J. McNeilan Department of Orthopaedics, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Nicole Meschbach Warren Alpert Medical School, Brown University, Providence, RI, USA

Joseph Meyerson, MD Hand and Upper Extremity Center, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Amit Momaya, MD Department of Surgery, Division of Orthopedic Surgery, University of Alabama at Birmingham, Birmingham, AL, USA

Steven R. Niedermeier, MD Hand and Upper Extremity Center, The Ohio State University, Wexner Medical Center, Columbus, OH, USA

Thomas E. Niemeier University of Alabama at Birmingham, Birmingham, AL, USA

Mark Oliver, MD Orthopaedic, University of Toledo Medical Center, Toledo, OH, USA

Dana Olszewski, MD, MPH Childrens Orthopaedics of Atlanta, Atlanta, GA, USA

Howard Y. Park, MD Department of Orthopedic Surgery, UCLA Medical Center, Santa Monica, CA, USA

Viral Patel, MD Orthopedic Department, Gillette Children's Hospital, University of Minnesota, St. Paul, MN, USA

Albert Pearsall, MD Department of Orthopedic Surgery, University of South Alabama Hospitals, Mobile, AL, USA

Jeffery Pearson Orthopedic Surgery, UAB, Birmingham, AL, USA

Noah Porter, MD Department of Orthopaedic Surgery and Rehabilitation, University of Nebraska Medical Center, Omaha, NE, USA

Brien Rabenhorst University of Arkansas for Medical Sciences, Little Rock, Arkansas, USA

Viorel Raducan, MD Department of Orthopaedic Surgery, Marshall University/Cabell Huntington Hospital, Huntington, WV, USA

Satheesh K. Ramineni Orthopaedic Surgery, University of Toledo Medical Center, Toledo, OH, USA

Erin F. Ransom, MD Division of Orthopaedic Surgery, Department of Surgery, University of Alabama – Birmingham, Birmingham, AL, USA

Raj Rao, MD Department of Orthopedic Surgery, The George Washington University, Washington, DC, USA

James Reagan, MD Department of Orthopaedic Surgery, CabellHuntington Hospital/Marshall University School ofMedicine, Huntington, WV, USA

Brady W. Rhodes, DPM Department of Orthopedics, John Peter Smith Hospital, Fort Worth, TX, USA

Yoseph A. Rosenbaum, MD Hand and Upper Extremity Center, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Michela Rossi Bone Physiopathology Group, Multifactorial Disease and Complex Phenotype Research Area, Rome, Italy

Shane D. Rothermel Department of Orthopaedics and Rehabilitation, Penn State Health Milton S. Hershey Medical Center, Hershey, PA, USA

Robert D. Santrock, MD Department of Orthopedics, Health Sciences South, Morgantown, WV, USA

Sylwia Sasinowska, MD Division of Rheumatology, Cooper University Hospital, Camden, NJ, USA

Anthony A. Scaduto, MD Department of Orthopaedic Surgery, Orthopaedic Institute for Children/UCLA, Los Angeles, CA, USA

Susan A. Scherl, MD The University of Nebraska, Department of Orthopaedic Surgery, Omaha, NE, USA

Edward Schleyer, MD Department of Orthopaedics, University at Buffalo, Buffalo, NY, USA

Francisco A. Schwartz-Fernandes Department Orthopaedics and Sports Medicine, University of South Florida, Tampa, FL, USA

Ryan Scully, MD Department of Orthopaedic Surgery, George Washington University Medical Center, Washington, DC, USA

Megan N. Severson, MD Division of Orthopedic Surgery, Department of Surgery, University of Alabama – Birmingham Hospital, Birmingham, AL, USA

Jyoti Sharma, MD Orthopaedic Surgery, Penn State Hershey Medical Center, Hershey, PA, USA

Kevin Shepet, MD Department of Orthopaedics, West Virginia University, Health Science Center – South, Morgantown, WV, USA

Evan Sheppard, MD Department of Surgery, Division of Orthopedic Surgery, University of Alabama at Birmingham, Birmingham, AL, USA

Franklin D. Shuler, MD, PhD Department of Orthopaedic Surgery, Joan C. Edwards School of Medicine, Marshall University, Huntington, WV, USA

Justin Siebler, MD Department of Orthopaedic Surgery and Rehabilitation, University of Nebraska Medical Center, Omaha, NE, USA

Martin Skie, MD Orthopedic Surgery, University of Toledo Medical Center, Toledo, OH, USA

Amy Speeckaert, MD Hand and Upper Extremity Center, The Ohio State University Wexner Medical Center, Columbus, OH, USA

John M. Stephenson, MD Department of Orthopaedic Surgery, University of Arkansas for Medical Sciences, Little Rock, AR, USA

Christopher Sugalski, MD Department of Orthopaedic Surgery, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Anne C. Sullivan, MD Department of Orthopaedic Surgery, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Steven M. Theiss Orthopedic Surgery, UAB, Birmingham, AL, USA

John Tidwell Department of Orthopaedics, UCSF Fresno, Fresno, CA, USA

LeeAnne Torres, MD Department of Orthopaedic Surgery, Marshall University/Cabell Huntington Hospital, Huntington, WV, USA

Christopher Treager Regenerative Medicine, Orthopaedic Surgery, Medical College of Georgia, Augusta, GA, USA

Joshua Troyer Department of Orthopaedics, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Christopher E. Urband, MD Department of Orthopaedics, Jacobs School of Medicine and Biomedical Sciences, Buffalo, NY, USA

John W. Uribe Department of Orthopedic Surgery, Herbert Wertheim College of Medicine at Florida International University, Coral Gables, FL, USA

Matthew A. Varacallo, MD Department of Orthopaedic Surgery, Hahnemann University Hospital, Philadelphia, PA, USA

Surahbhi S. Vinod, BS Division of Clinical Immunology and Rheumatology, School of Medicine, University of Alabama at Birmingham, Birmingham, AL, USA

James Vogler University of South Florida, Tampa, FL, USA

Ettore Vulcano Department of Orthopedics, Mount Sinai Health System, New York, NY, USA

M. Wade Shrader, MD Department of Orthopedic Surgery, Children's of Mississippi, University of MS Medical Center, Jackson, MS, USA

Maegen Wallace, MD Department of Orthopaedic Surgery, University of Nebraska Medical Center/Omaha Children's Hospital, Omaha, NE, USA

Colleen Watkins, MD Department of Orthopedics, West Virginia University, Health Science Center South, Morgantown, WV, USA

Eric Wherley Herbert Wertheim College of Medicine at Florida International University, Miami, FL, USA

Stephen White, MD Department of Orthopaedic Surgery, University of South Alabama, Mobile, AL, USA

Erik White Hand and Upper Extremity Surgery, University of Toledo School of Medicine, Toledo, OH, USA

Brad Wills, MD Surgery – Orthopaedics, University of Alabama at Birmingham, Birmingham, AL, USA

William M. Wind Jacobs School of Medicine and Biomedical Sciences, University at Buffalo, Amherst, NY, USA

Megan R. Wolf, MD Department of Orthopaedic Surgery, UCONN Health, Farmington, CT, USA

Theresa Wyrick, MD Department of Orthopaedic Surgery, University of Arkansas for Medical Sciences, Little Rock, AR, USA

Gautam P. Yagnik Department of Orthopedics, West Kendall Baptist Hospital, Miami, FL, USA

Part I

The Basics

General Orthopedic Terminology

1

Anne C. Sullivan and Christopher Sugalski

Introduction

- Orthopedic surgery encompasses the breadth of surgical and medical management of musculoskeletal injuries and disorders.
- Orthopedic surgeons work closely with a variety of ancillary support staff:
  - Physical and occupational therapists and athletic trainers
  - Physician assistants
  - Nurses and orthopedic/cast techs
- Orthopedics, not unlike other medical specialties, has its own language, with a substantial vocabulary. This makes it particularly important to come to your orthopedic rotation or clerkship prepared.
- There are many definitive and authoritative texts and online sites with which to familiarize oneself with the terminology as well as with the study of orthopedics. For brevity and efficiency, we present the basics here.

A.C. Sullivan, MD (✉) • C. Sugalski, MD
Department of Orthopaedic Surgery,
The Ohio State University Wexner Medical Center,
Columbus, OH, USA
e-mail: suileabhainac@gmail.com;
sullivan.63@osu.edu

Subspecialties

Adult Reconstruction (Joint Replacement/Arthroplasty)

- Expertise in joint replacement, traditionally for management of hip and knee arthritis, includes partial and total hip and knee arthroplasty, as well as revision total hip and knee arthroplasty.
- The need for hip and knee arthroplasty in the United States is projected to increase 174 % and 673 % between 2005 and 2030 [1].
- Replacement of other joints (elbow, ankle, shoulder) often falls to specialists in areas of regional expertise or may be included in arthroplasty practice.

Trauma

- Expertise in care of complex articular fractures, pelvic fractures, and polytrauma, including sequelae of trauma such as nonunion/malunion and infections.
- Most orthopedic surgeons, regardless of specialty, utilize a base of trauma knowledge to care for fractures they encounter while on call.
- Treatments include casting, splinting, open/closed reduction, internal fixation, external fixation, intramedullary nailing, and fracture plating. Trauma surgeons may do variable amounts of arthroplasty and reconstruction.

© Springer International Publishing AG 2017

A.E.M. Eltorai et al. (eds.), *Orthopedic Surgery Clerkship*, DOI 10.1007/978-3-319-52567-9_1

Shoulder and Elbow

- Comprehensive surgical treatment of acute and chronic shoulder and elbow conditions.
- Manage rotator cuff tears, shoulder and elbow instability, arthritis, and fractures.
- Utilize both open and arthroscopic surgical techniques.
- May also include shoulder and elbow arthroplasty and complex reconstructive techniques.

Hand

- A subspecialty shared with both plastic and general surgeons who have completed an additional year of fellowship training in hand surgery
- Concerned with the intricate and vital function of the hand and wrist, including chronic and traumatic conditions
- Surgically manage fractures, instability, arthritis, and nerve compression and have the microsurgical skills to perform digit replantation and various other procedures

Spine

- Surgically treat acute and chronic neck and back pathology and trauma.
- Often work closely with nonsurgical spine physicians to manage and treat chronic neck and back pain.
- Surgeries include deformity correction for scoliosis, lumbar decompression and fusion, cervical decompression and fusion, and lumbar microdiscectomy.
- Share a scope of practice which overlaps spinal neurosurgeons.

Foot and Ankle

- Experts in foot and ankle biomechanics and gait.
- Manage complex fractures of the distal tibia, talus, and calcaneus, along with other foot and ankle trauma.
- Manage degenerative conditions and deformities of the foot and ankle, frequently performing ankle, hindfoot, and midfoot fusions or arthroplasty, tendon transfers, and nerve decompression.
- Share a scope of practice that partially overlaps with podiatry.

Sports Medicine

- Assess and manage injuries and conditions of musculoskeletal pathology encountered in athletes and the active population.
- For arthroscopy specialists, procedures are designed to be minimally invasive to allow the quickest possible return to sport or activity.
- Depending on the population served, sports medicine specialists may also use minimally invasive or cartilage preservation techniques to allow older persons to remain active by addressing early degenerative conditions with less surgical trauma.
- Often focus on the knee and shoulder, tendons, ligaments, and cartilage. Other joint foci are per surgeon preference.
- Nonoperative sports medicine specialists may be family practice physicians, pediatricians, or physical medicine and rehabilitation specialists who have done an additional fellowship (usually 1 year).

Oncology

- Diagnose and surgically treat musculoskeletal tumors, both benign and malignant.
- Perform a wide variety of procedures ranging from minor open biopsies to hemipelvectomies.
- Frequently perform large tumor resections coupled with limb salvage procedures such as bulk allograft or prosthetic replacement of major joints.

Pediatrics

- The general orthopedist for the pediatric population.
- Sports injuries, forearm fractures, scoliosis, neuromuscular disorders, and developmental problems such as hip disorders and club foot are among the common conditions seen by pediatric orthopedists.
- Often, pediatric orthopedists will develop a subspecialty niche within general pediatric orthopedics (sports, spine, etc.).

General Anatomy and Motion

Anatomy

- Anterior: front.
- Volar: front, especially referring to the front of the forearm or hand when in anatomic position. This is a convenient reference plane which is fixed relative to the hand, despite rotation of the forearm.
- Posterior: back.
- Dorsal: back, sometimes referring to the thoracic region of the spine but commonly used in hand surgery, referring to the back of the forearm or hand, opposite side of the limb to volar, above. Also, top of the foot.
- Plantar: bottom of the foot (analogous to volar in the hand).
- Medial: toward midline.
- Lateral: away from midline.
- Superior: up.
- Inferior: down.
- Proximal: closer to the center of the body.
- Distal: farther from the center of the body.
- Supra: above.
- Infra: below.
- Intra: within.
- Inter: between.
- Extra: outside of.
- Meta: adjacent or near.
- Retro: reverse or behind.
- Antero: front or forward.
- Mid: middle.

Postural/Positional or Deformity Descriptions

- Varus: curvature or bowing of a long bone or joint with apex relatively lateral
- Valgus: curvature or bowing of a long bone with apex relatively medial
- Procurvatum: curvature or bowing of a long bone or joint with apex anterior
- Recurvatum: curvature or bowing of a long bone or joint with apex posterior
- Kyphosis: curvature of the spine with apex posterior
- Lordosis: curvature of the spine with apex anterior
- Cavus: high-arched foot
- Equinus: plantar flexed foot or ankle (like a horse that walks on its toes)

Motion Descriptors

- Elevation: upward movement
- Depression: downward movement
- Anterograde: moving or directed from proximal to distal
- Retrograde: moving or directed from distal to proximal
- Extension: bending movement that increases angle of joint (or fracture site) or moves toward the 180 degree or maximally open position
- Flexion: bending movement that decreases angle of joint (or fracture site) from the maximally open or 180 degree position
- Internal rotation: rotating toward midline
- External rotation: rotating away from midline
- Pronation: turning palm of the hand or arch of the foot down
- Supination: turning palm up or raising the arch of the foot
- Adduction: movement toward midline of the body or limb
- Abduction: movement away from midline of the body or limb
- Eccentric: muscle lengthening against resistive force

- Concentric: muscle shortening against resistive force
- Isometric: muscle contraction without a change in length

Bone Growth and Anatomy

- Epiphysis: end of bone closest to joint.
- Metaphysis: the portion of a long bone between the physis or physeal scar and the diaphysis, seen as the "flared" portion of the bone, largely cancellous in structure.
- Diaphysis: the shaft of a long bone.
- Trochanter: a large protruding knob of bone, specifically at the proximal extent of the shaft of the femur.
- Tuberosity: a medium-sized normal knob or protrusion of bone, often serves as a tendon attachment.
- Tubercle: a smaller knob of bone, often a tendon attachment.
- Malleolus: a moderate sized knob of bone, specifically on the medial and lateral sides of the ankle.
- Sesamoid: a relatively small bone which is largely contained within a tendon and serves to enhance tendon function. The patella is the largest sesamoid bone and the sesamoid bones of the hand are variably present.
- Facet: a relatively small and flat cartilage-covered surface of a bone, one of the gliding surfaces of the joint in focus.
- Foramen: a normal hole in a bone, through which a traversing structure, such as a nerve or blood vessel, passes.
- Canal: a longer tunnel or hole through a bone.
- Medulla: central portion of a structure, often relatively soft and protected by some surrounding resilient structure.

Bone Types

- Woven: immature, disorganized bone deposition
- Lamellar: mature, organized bone deposition, having layered histologic appearance
- Cortical: strong, compact, outer layer, usually lamellar
  - Layers (lamellae) of bone surrounding multiple central canaliculi (channels) which allow communication between osteocytes.
  - Haversian unit is the (histologic) canaliculus surrounded by a set of lamellae of cortical bone.
- Cancellous: porous, spongy inner core of bone consisting of interconnected trabeculae

Bone Cells

- Osteoblasts: form bone and regulate bone metabolism
- Osteocytes: mature bone cells surrounded by osteoid matrix
- Osteoclasts: macrophage-like cells responsible for bone resorption and turnover

Bone Growth and Healing

- Intramembranous ossification
  - Bone forms without cartilage intermediary.
- Endochondral ossification
  - Initial cartilage model is replaced by woven bone and then remodeled to lamellar bone.
  - Replicated in fracture healing.
- Physis: Growth plate. Site of bone growth
  - Organized into zones
    - Reserve
    - Proliferative
    - Hypertrophic
    - Bone deposition
  - Physeal Scar: a variable anatomic landmark which marks the position of the physis in mature bone after it is fused and no longer growing
  - Generally located transversely at the point of maximum width of each end of the bone
- Fracture healing
  - Primary healing
    - Rigid fixation/absolute stability without fracture gap

    - Facilitated by lag screw fixation or compression plates
    - Intramembranous, direct bone healing without callous via Haversian remodeling
- Secondary fracture healing
  - Less rigid fixation/relative stability.
  - Seen after application of a cast, intramedullary nail, external fixator, or bridge plating.
  - Stages as below with cartilage model:
    - Blood clot and hematoma
    - Callus (cartilage)
    - Woven, immature bone
    - Remodeling to lamellar, compact, and mature bone
  - Optimal fracture healing produces bone that is identical to the original tissue in histology and biomechanics.
  - Bone healing is true healing, not scar formation.

Cartilage

Hyaline Cartilage

- Covers smooth articular surfaces.
- Proteoglycans retain water and provide resistance against compression.
- Type II collagen.
- Chondrocytes.

Fibrocartilage

- Menisci, labrum, annulus fibrosus, and pubic symphysis
- Proteoglycans and water
- Type I collagen
- Chondrocytes

Pharmacology

Anticoagulation

- Venous thromboembolism (VTE) = blood clot
  - Deep venous thrombosis (DVT)
  - Pulmonary embolism (PE)
  - Orthopedic patients are at an increased risk for VTE in the perioperative period
    - Virchow's triad: stasis, endothelial injury, and hypercoagulability
- Often prescribed medications to decrease their risk of VTE
  - Risk of VTE has been weighed against the risk of bleeding while taking these medications.
- Sequential compression devices (SCDs) decrease stasis by actively promoting venous return from the distal limb and may decrease the need for pharmacologic VTE prophylaxis.
- Heparin
  - Activates antithrombin III which inactivates thrombin, factor Xa
  - 5000 units SQ TID to prevent VTE
- Enoxaparin (Lovenox, low-molecular-weight heparin, LMWH)
  - Same mechanism of action of heparin, more predictable anticoagulant effects
  - 30 mg SQ BID or 40 mg qday
  - Generally the preferred method of anticoagulation for patients at significant VTE risk
- Warfarin
  - Inhibits vitamin K-dependent factors II, VII, IX, X, protein C, and protein S.
  - International normalized ratio (INR) must be monitored.
  - Used when long-term anticoagulation is required.
- Aspirin (ASA)
  - Irreversibly binds to cyclooxygenase (COX), decreasing prostaglandin and thromboxane synthesis and platelet aggregation
    - Fondaparinux (Arixtra)
    - Related to LMWH, injected
  - Activates antithrombin III to inhibit factor Xa
- Newer oral anticoagulants:
  - Do not require coagulation monitoring
  - Limited orthopedic indications currently in US, some bleeding concerns
  - Rivaroxaban (Xarelto); apixaban (Eliquis)
    Direct factor Xa inhibitors
  - Dabigatran (Pradaxa)
    Direct thrombin inhibitor

Antibiotics

- Ancef/cefazolin, first-generation cephalosporin
  - Typical pre-/postoperative antibiotic utilized during orthopedic surgical procedures and in open fractures
  - Blocks cell wall synthesis, modest activity against gram-negative organisms
- Clindamycin
  - Utilized in cases of penicillin or cephalosporin allergy
  - Interferes with function of 50S ribosomal subunit and subsequent protein synthesis
- Vancomycin
  - Indicated when methicillin-resistant *Staph aureus* (MRSA) is suspected
- Aminoglycosides
  - Gentamycin, tobramycin
  - Added in more severe open fractures, grade III, for synergistic effects and gram-negative coverage
- Penicillins
  - Added in farm injuries or if there is concern for anaerobic organisms such as clostridium

NSAIDs (nonsteroidal anti-inflammatory drugs)

- Ibuprofen, naproxen, meloxicam, and others
  Inhibit COX1/2 decreasing inflammation and platelet aggregation
- Celebrex
  Inhibit COX2 selectively
  Spares gastrointestinal side effects (bleeding) and decreases platelet effect

Bisphosphonates

- Inhibit osteoclast bone resorption
- Nitrogen containing bisphosphonates
  - Inhibit farnesyl pyrophosphate synthase
  - Disrupt function of ruffled border and osteoclast ability to resorb bone
- Primarily utilized in treatment of osteoporosis
- Also indicated in other conditions such as metastasis to bone and Paget's disease

Orthopedic Implants

Screws

- Cortical screws
  - Utilized for hard cortical bone
  - Less thread required for equal pullout strength
- Cancellous screws
  - Increased thread depth theoretically increases pullout strength in weaker, less dense cancellous bone; wider spaced threads so thread number is compromised.
- Lag screws
  - Threads only engage the far cortex/aspect of the fracture. This allows the near side to slide and compress across the fracture site.
  - Can be by:
    - Design: base of screw does not have threads.
    - Technique: fully threaded screw, but near cortex is overdrilled to the outer diameter of the screw, to prevent thread engagement in the near cortex and pull the far cortex in to compress the fracture line.
- Locking screws
  - Head of the screw locks into the plate.
  - Provides an "internal fixator," fixed angle device.
  - Utilized for osteoporotic bone, comminuted fractures, and other situations with compromised bone quality.
- Cannulated screws
  - Central core of screw is hollow.
  - Screw is placed over a wire, allowing for fine-tuning of trajectory.
  - Not as strong as similar-sized solid core screws.

Intramedullary Nails

- Placed within long bone for treatment of fracture or, less commonly, prevention of impending pathologic fracture due to weakened bone
- Commonly utilized for the femur and tibia
- Also available for the humerus, radius, ulna, clavicle, and fibula

External Fixator

- Pins are placed into bone and left protruding external to skin:
  - Can cause irritation or be portal for infection
  - Connected to an external frame providing stability across a fracture or unstable joint
- Often utilized as a temporizing measure in polytrauma or when the soft tissue is not amenable to internal fixation, as in the case of massive soft tissue injury or open wounds
- Can be utilized as definitive fixation until fracture healing or for definitive correction of limb deformity

Percutaneous Pins

- Threaded or smooth pins, placed through skin and across fractures or joints to provide either temporary or permanent fixation
- Can be left protruding outside the skin for ease of later removal
- Can cause irritation, or be portal for infection, especially if placed through abundant, mobile soft tissue

Arthroplasty

- Joint replacement or resurfacing aims to preserve motion and reduce pain at a joint that has been damaged by trauma or degenerative disease.
- Commonly performed for the knee, hip, shoulder, ankle, and elbow utilizing metal, polyethylene, and/or ceramic implants.
- Hemiarthroplasty refers to the replacement of the ball of the hip or shoulder with preservation of the native socket.
- Unicompartmental arthroplasty is a partial (knee) replacement, which resurfaces the femur and the tibia on only the medial or lateral side of joint. Reserved for cases when degenerative changes are isolated to one compartment.
- Total joint arthroplasty refers to replacement of both sides of the articular surface.
- Resurfacing arthroplasty is less common and replaces surface of joint with minimal intramedullary fixation.
- Metal, polyethylene, silicone, and soft tissue interposition arthroplasty are often utilized for the hand and wrist.
- Disc replacement is performed for degenerative disc disease in the cervical and lumbar spine.

Miscellaneous

- Autograft: tissue transferred from self to repair damage tissue such as tendon, ligament, or bone.
- Allograft: cadaver tissue.
- Arthrocentesis: aspiration of a joint.
- Arthrodesis: joint fusion.
- Arthroscopy: minimally invasive surgery where cameras are utilized to visualize and perform intra-articular surgery.
- Bursa: synovial tissue sac that reduces friction between two surfaces.
- Crepitus: grating, grinding, and popping caused by friction from the bone, cartilage, or other soft tissues.
- Curettage: scrape out.
- Dislocation: disruption of normal relationship of bones meeting in a joint, usually requiring significant trauma and soft tissue disruption, often maintained in abnormal position by geometry of the joint and spasm of surrounding muscles. Interposed tissue may prevent reduction.
- Effusion: increase in joint swelling or fluid.
- Fascia: fibrous tissue separating the subcutaneous layer from the deep muscular layer. Also separates muscular compartments.
- Fluoroscopy: live X-ray imaging.
- Fracture: broken bone. May or may not be visible on X-ray.
- Iatrogenic fracture: unintentional fracture caused by event in the course of treatment.
- Lavage: irrigation and washing.
- Malunion: improperly healed fracture.
- Nonunion: failure of fracture healing.
- Occult fracture: not readily visible on X-ray.
- Open fracture: fracture which communicates with a break in skin that allows physical continuity between fracture and the outside environment, presumed contaminated with bacteria.

- Osteotomy: cutting of bone.
- Paresthesia: altered sensation.
- Pathologic fracture: fracture caused by weakened bone.
- Reduce: restore normal alignment and position of a structure, such as a bone or joint that has been disrupted by injury.
- Sprain: ligament injury.
- Strain: muscle injury.
- Stress fracture: repetitive use injury causing microfractures to bone with resultant pain. May lead to a true displaced fracture if weakened bone is overloaded.
- Subluxation: incomplete joint dislocation.

References

1. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am. 2007;89(4):780–5.
2. Terry Canale S, Beaty JH. Campbell's operative orthopedics. 12th ed. St. Louis: Mosby; 2012.
3. Tornetta P III, Court-Brown C, et al. Rockwood, Green, and Wilkins' 'Fractures in adults' and 'fractures in children'. 8th ed. Philadelphia, PA: LWW; 2014.
4. Flynn JM. OKU 10 : orthopedic knowledge update. Rosemont, IL: American Academy of Orthopedic Surgeons; 2011.
5. Hoppenfeld S, de Boer P, Buckley R. Surgical exposures in orthopedics: the anatomic approach. 4th ed. Philadelphia, PA: LWW; 2009.

Radiology: The Basics

2

Anne Sullivan, Christopher Sugalski,
and D. Daniel Rotenberg

Types (Modalities) of Musculoskeletal Imaging

- Plain X-ray = radiograph = roentgenogram = plain film, in common use "X-ray" or "film"
  - Standard, two-dimensional image, generated when X-rays travel through a substance (tissue) and are variably absorbed, reflected, or transmitted by the tissue to a receiving plate of unexposed photographic film, or digitally recorded by a fluorescent receiving grid.
  - Views: AP (or PA), lateral, and oblique; views correspond to the projection of (the shadow of) the structure, relative to anatomic position, against the receiving device; special named or anatomic views may provide specialized anatomic information to help understand the pathology more specifically for surgical planning.
- Ultrasound = sonogram = sonographic image
  - Image generated by the relative transmission versus reflection of high-frequency sound energy as it travels through tissues, related to tissue density; the reflected waves are received by a transducer and electronically interpreted to produce an image.
  - Musculoskeletal ultrasound is improving in quality and finding new applications, for example, in assessing integrity of tendons and other structures, as well as providing guidance for percutaneous procedures.
- Nuclear medicine scan = radioisotope-labeled scan, may also be named isotope, e.g., indium-111 or technicium-99
  - Image created by measurement of radioisotope labeling:
    - A substance or cell used by the body is radiolabeled and injected into the circulation, allowing the isotope to pass through the circulation and be metabolized, concentrating in areas which accumulate more of the radiolabeled substance.
    - The whole body or region of interest is then imaged by a radiation receiver (essentially a Geiger counter), and areas of isotope concentration are recorded, formatted to produce an image, and

A. Sullivan, MD (✉) • C. Sugalski, MD
Department of Orthopaedic Surgery,
The Ohio State University Wexner Medical Center,
Columbus, OH, USA
e-mail: suileabhainac@gmail.com;
anne.sullivan@osu.edu

D. Daniel Rotenberg
Desert Orthopaedic Center,
Las Vegas, NV, USA

© Springer International Publishing AG 2017

A.E.M. Eltorai et al. (eds.), *Orthopedic Surgery Clerkship*, DOI 10.1007/978-3-319-52567-9_2

interpreted in the context of the clinical situation.
    - Reliability and resolution are variable, often used for screening or confirmation of diagnosis, in conjunction with other modalities.
- Computed (axial) tomography images = CT scan = CAT scan
  - Three-dimensional imaging technology involving X-rays transmitted from a source revolving around the body or structure and striking a revolving receiver that is 180 degrees opposed.
  - This data is then reformatted to generate complementary series of high-resolution thin slice/section images of the structure or region of interest for diagnosis and treatment decision-making.
  - Views: axial, coronal, sagittal, and special anatomic reconstruction.
  - Three-dimensional CT reconstructions may be very detailed and may be used to pattern physical models for surgical planning.
- Magnetic resonance imaging = MRI
  - High-resolution three-dimensional imaging generated by the signal generated by the excitation and relaxation of protons of water molecules in response to perturbations of their alignment in a high-strength magnetic field (pulse sequences). The signal generated by the protons in the changing field is characteristic to the tissue and its water content and is used to generate a high-resolution gray-scale image of the structure being imaged. MRI scanners come in different magnet field strengths measured in teslas or T, usually between 0.5 T and 3.0 T. They also come in varying sizes, including open and wide bore. Higher-tesla magnets typically result in higher-resolution images.
  - MR images are well suited to visualize soft tissues and soft tissue pathologic processes, as well as subtle changes in bone marrow.
  - Planes of reconstruction: axial, coronal, sagittal, special anatomic (e.g., longitudinal or radial with respect to an axis), or three-dimensional reconstruction, similar to CT scanning.
  - Different pulse sequences of excitation-relaxation cycles produce different characteristic signal patterns which are contrasted and compared to identify pathologic processes:
    - T1 sequences can be identified by fatty tissues showing bright or white signal and water showing dark signal representation, particularly useful for visualizing fine anatomic detail.
    - T2 sequences are identified by water showing bright signal and fat showing dark signal, useful for demonstrating edema and related pathologic processes.
    - "Fat suppression" and other advanced pulse sequences enhance visualization of various tissue characteristics.

Types/Patterns of Fractures

- Fracture – break in the bone.
- Closed fracture – fracture in which the skin is intact.
- Open fracture – fracture in which the zone of injury communicates with a break or laceration of the skin or mucosa (anus, vagina), exposing the broken bone to air and potential bacterial contamination.
  - Gustilo classification:
  - Grade 1 – relatively low-energy injury; the skin wound is 1 cm or less, often an inside-out injury resulting from piercing of the skin by a spike of bone.
  - Grade 2 – moderate injury fracture with wound <10 cm and no neurovascular compromise, minimal accompanying deep soft tissue damage, and the ability to close the defect with local tissues.
  - Grade 3 – more severe open fracture with major soft tissue damage, characterized by wound >10 cm in length or similar soft tissue compromise:
    - 3a no neurovascular injury, local soft tissue coverage possible without flap
    - 3b flap coverage required
    - 3c (neuro)vascular injury requiring immediate repair/reconstruction

- Stress fracture = fatigue fracture = fracture that is the result of repetitive stress (fatigue) over time, which exceeds the bone's ability to heal and therefore results in cycle of partial healing and repeated cumulative injury and weakened bone.
  - Often not visible on plain film or may be visible as incomplete fracture or sclerotic incomplete healing response.
  - The "dreaded black line" is a radiographic appearance of a radiolucent line surrounded by sclerotic callus, representing a stress fracture which may complete in the near future.
  - May eventually become complete fracture.
- Torus/buckle fracture – incomplete fracture with a buckling of the cortex, no obvious fracture "line" through the cortex, usually in pediatric/immature bone which is relatively flexible.
- Greenstick fracture – incomplete, angulated fracture. Break in outer cortex (tension side), with the inner cortex intact or showing plastic deformation, usually in pediatric/immature, or sometimes pathologic bone which is relatively flexible.
- Compression fracture is structural failure of bone under compressive load, often resulting in decreased volume of bone, common in osteoporotic or compromised bone, especially in areas that are mostly cancellous (vertebral body).
- Burst fracture (vertebrae) is fracture occurring under compressive load, in which the bone is resilient enough to partially resist the load and ultimately fail in a propulsive manner, resulting in the fracture fragment propulsion approximately 90 degrees to the direction of the load.
- Stable fracture is fracture configuration that remains anatomically aligned and resists displacement under normal physiologic load in a normal loading direction and may often be treated nonoperatively with external bracing or support.
- Pathologic fracture – any fracture occurring under normal physiologic load, indicative of abnormality of bone strength, or other compromise. Common causes include destructive lesion of bone such as metastasis or infection, metabolic bone disease such as osteoporosis, or genetic abnormality.
- Common eponyms
  - *Bennett* fracture is an unstable fracture of the base of the first metacarpal.
  - *Colles* fracture – a distal radius fracture with apex pointing volar.
  - *Charcot* fracture or joint (neuropathic arthropathy) is a destructive process due to neuropathy; lack of protective sensation impairs the ability of the structure to resist harmful loading and heal micro- or macroinjuries, leading to catastrophic failure.
  - *Galeazzi* fracture is a forearm fracture consisting of radial fracture and dislocation of the distal radial ulnar joint (DRUJ).
  - *Lisfranc* joint is the tarso-metatarsal joint, named for the Napoleonic era surgeon who described (eponymously named) fracture dislocation injuries to this area.
  - *Maisonneuve* fracture (complex) is a pronation-external rotation injury to the ankle syndesmosis, which disrupts the entire length of the interosseous (tibiofibular) membrane and produces an oblique or spiral fracture of the proximal fibula, usually requiring operative stabilization at the ankle mortise. The fibular fracture heals secondarily.
  - *Monteggia* fracture is a forearm and elbow injury involving an ulno-humeral dislocation, and usually radial forearm injury requires imaging of the elbow and wrist to look for associated injury.
  - *Jones* fracture is an acute or chronic or completed stress fracture of the proximal end of the fifth metatarsal, at the watershed area of blood supply in the meta-diaphyseal region of the bone.

Steps to Reading Musculoskeletal Imaging from an Orthopedic Perspective

- Name the imaging modality, and view(s) or plane represented, if cross-sectional imaging.
- Name the skeletal region, joint, bone, or region of bone (e.g., proximal or distal portion of long bone), which is represented in the image, and laterality if appropriate.

- Describe the skeletal maturity: if able to be determined:
  - "This is an AP view plain film of the right shoulder of a skeletally mature individual."
  - "These are AP and frog-leg lateral views of the pelvis of a skeletally immature individual."
- (Optional) describe any technique details if appropriate: image quality, completeness, and sequence type (T1- or T2-type sequences):
  - "These are T1-weighted axial images of the right knee."
  - "This is a swimmer's view lateral c-spine film which appears underpenetrated and the C7–T1 junction is not visible."
- Begin to list pathologic findings:
  - Special appearance or characteristics of bone or bone quality, even if unable to completely characterize them:
    - Osteopenia – decreased density, darker on plain film
    - Sclerosis – increased density, whiter on plain film
    - Calcifications – represented by white appearance which may be irregular or correspond to a known structure
    - Callus – bone deposition at fracture site
    - Other obvious deformities or abnormalities
  - Beware of general appearance/expectations of appropriate penetration for analog films or appropriate contrast window in digital films.
  - Tip: If the bone looks clearly abnormal, note it; start by stating that the bone looks abnormal; if more details are possible (e.g., osteopenia, subtle bone destruction due to other pathologic processes), think about it, as you may be asked.
  - Special characteristics of soft tissue:
    - Foreign bodies such as gravel or glass.
    - Disruption of or air in tissues, which can indicate either open wound or gas production by an organism.
    - Calcification or ossification may be subtle difference.
    - Edema (extra-articular swelling).
    - Effusion – intra-articular swelling.
    - Soft tissue envelope may be notable for its dimensions.
  - Presence of implants/hardware or foreign bodies:
    - A radiopaque implant or replacement prosthesis is best described as "hardware" initially; further description may be given, e.g., a plate, prosthesis, or screw, if needed. Describing hardware incorrectly may be an unnecessary source of embarrassment!
    - Tip: Avoid overstating – it is safest to "under call" it and state that, for example, "a hip prosthesis is present," unless you are sure whether a hip arthroplasty is a "total hip" with a femoral stem with a small femoral head and a hemispheric metallic or polyethylene acetabular component or a "hemiarthroplasty" if there is a large spherical prosthetic head which fills the native acetabulum.
    - Tip: Beware of objects external to the body which may appear on X-rays such as coins in a pocket, body piercings, zippers or buckles, jewelry, EKG leads or monitors, external bracing or bandaging, and foreign bodies, e.g., gravel in a wound.
  - Traumatic or focal findings:
    - Fractures – see below for how to describe.
    - Subluxations and dislocations.
    - Malunions, deformities, and malalignments.
    - More subtle deformities and lesions of bone, joint, or soft tissue.
    - Other soft tissue defects or lesions.
- How to describe a fracture:
  - State brief demographics of patient: gender and age.
  - One or two noteworthy facts if known, e.g., mechanism of injury, significant history, or comorbidities.
- Name the bone that is fractured and if it is open or closed.
- Name the approximate direction and configuration of the fracture line(s):

  - Name the region of the bone where the fracture is located:
    - Is the fracture articular (the fracture line enters a joint) or non-articular?
    - Is it a physeal fracture (does the fracture line communicate with a physis)?
  - Note the characteristics of fracture pattern:
    - Displacement, bone loss, angulation, and shortening if present.
    - State the direction of the APEX if angulated, on both AP and lateral view.
    - Note the fracture pattern: transverse, long or short oblique, spiral, or comminuted.
    - Note if segmental – more than two major fragments along length of bone.
- "These are AP and lateral view X-rays of the distal radius and ulna (or wrist) of a skeletally immature individual. There is a complete, transverse, non-articular fracture of the distal radius with apex volar angulation. The fracture line involves the distal radial physis."
- Bonus: If it is a physeal fracture, which type is it per the Salter-Harris classification?
  - I. Nondisplaced disruption of the physis itself.
  - II. The fracture line involved the physis, where there is displacement, and the fracture line exits through the metaphysis, so that a small portion of the metaphysis, known as the "Thurstan-Holland fragment," remains attached to the physeal fragment.
  - III. The fracture is articular, and the fracture line is actually through the epiphysis, but not the metaphysis.
  - IV. The fracture line travels through the metaphysis, crosses the physis, and continues through the epiphysis to exit into the joint.
  - V. The fracture line is not visible and the physis is impacted.

Example

How to Describe a Fracture

Used with permission from D. Daniel Rotenberg, M.D.

A _ _ Y.O. [male/female] with a [open/closed] fracture of [which bone].

The fracture is an [intra-articular/extra-articular].

[spiral/oblique/transverse/greenstick/buckle/segmental/comminuted]

fracture of the [proximal third/middle third/distal third/__cm from the joint].

On the AP view, the fracture is angulated ___ degrees apex [medial/lateral].

On the lateral view, there is ___ degrees of angulation apex [anterior/posterior].

On the AP view, the fracture is displaced ___ percent [medially/laterally]

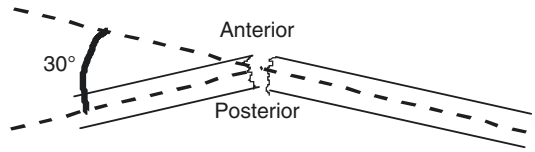
[with __ cm of shortening].

On the lateral view, the fracture is displaced ___ percent [anterior/posterior]

[with __ cm of shortening].

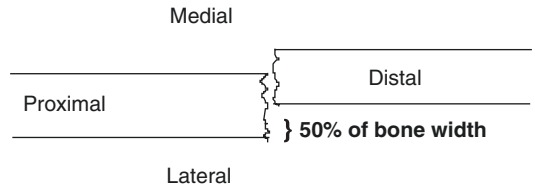
Angulation: the angle described by drawing a line through the center of fracture fragments,

i.e., 30° apex anterior (pictured below).



Displacement: described in terms of percent of bone width, where the distal fragment is shifted with respect to the proximal fragment,

i.e., the distal fragment is 50% displaced medially.



Suggested Readings

1. Terry Canale S, Beaty JH, Campbell WC. Campbell's operative orthopedics. 12th ed. St. Louis/London: Mosby; 2012.

2. Tornetta III P, Court-Brown C, et al. Rockwood, Green, and Wilkins' 'Fractures in adults' and 'fractures in children'. 8th ed. Philadelphia: LWW; 2014.
3. Flynn JM. OKU 10 : orthopedic knowledge update. Rosemont: American Academy of Orthopedic Surgeons; 2011.
4. Daniel Rotenberg D. "How to describe a fracture" teaching unit. Columbus, OH: Personal communication; 1994.
5. Herring W. Learning radiology: recognizing the basics. 3rd ed. Philadelphia, USA: Saunders (Elsevier); 2016. http://www.learningradiology.com.
6. Yochum TR, Rowe LJ, editors. Essentials of skeletal radiology, vol. 2. 3rd ed. Philadelphia: Wolters Kluwer Health ; 2012. ISBN-13: 978-0781739467.
7. Chew FS. Skeletal radiology: the bare bones; hardcover. Baltimore: Williams & Wilkins; 1997. ISBN-13: 978-0683016802.

Fractures

3

Tracye J. Lawyer and Patrick F. Bergin

Bone Composition [4]

- Bone consists of cells and a blend of mineral and matrix that coexist in a very exact relationship. The matrix phase consists of collagen and glycosaminoglycans.
- Calcium hydroxyapatite is the basic mineral crystal in bone. The bulk of calcium in the skeletal reservoir is bound in the crystals of hydroxyapatite. The organic component of the bone matrix, primarily type 1 collagen, contributes to bone strength.
- Osteoblasts are bone-forming cells that secrete the matrix components. As ossification occurs, the osteoblasts become trapped in the matrix they produce and are then referred to as osteocytes.
- Osteocytes represent terminally differentiated osteoblasts and function within syncytial networks to support bone structure and metabolism.
- Osteoclasts are the only cells that are known to be capable of resorbing bone. Their primary function is the degradation and removal of mineralized bone. They are derived from mononuclear precursor cells of the monocyte-macrophage lineage.

T.J. Lawyer, MD, PhD • P.F. Bergin, MD (✉)
Department of Orthopedic Surgery, University of Mississippi Medical Center, Jackson, MS, USA
e-mail: pbergin@umc.edu

Anatomy [3]

- Microscopically, bone is described as either mature or immature.
- Mature bone has an ordered lamellar arrangement of haversian systems or osteons and canalicular communications.
- Immature bone has much more random appearance of collagen in a matrix with irregularly spaced cells. Immature bone is seen in the adult skeleton only under pathologic conditions like fracture callus or osteogenic sarcoma.
- Macroscopically, the lamellar bone is configured either as dense cortical bone or as spicules called trabeculae.
- Cortical bone is dense and solid and surrounds the marrow space, whereas trabecular bone is composed of a honeycomb-like network of trabecular plates and rods interspersed within the bone marrow compartment.
- Cortical bone has an outer periosteal surface and inner endosteal surface. Periosteal surface activity is important for appositional growth and fracture repair.
- Both cortical and trabecular bone are composed of haversian systems. Cortical and trabecular bone are normally formed in a lamellar pattern, in which collagen fibrils are laid down in alternating orientations.
- The normal lamellar pattern is absent in woven bone.

© Springer International Publishing AG 2017

A.E.M. Eltorai et al. (eds.), *Orthopedic Surgery Clerkship*, DOI 10.1007/978-3-319-52567-9_3

- The periosteum is a fibrous connective tissue sheath that surrounds the outer cortical surface of bone, except at joints where bone is lined by articular cartilage.
- The periosteum is tightly attached to the outer cortical surface of the bone by thick collagenous fibers called Sharpey's fibers.
- The endosteum is a membranous structure covering the inner surface of cortical bone, trabecular bone, and Volkmann's canal present in the bone. The endosteum contains blood vessels, osteoblasts, and osteoclasts.

Vascularity [1]

- The vascularity of bone is very important when it comes to fracture repair.
- In an intact adult long bone, there are three major sources of blood.
- The nutrient artery enters the cortical diaphysis and divides proximally and distally within the endosteal canal.
- Smaller metaphyseal arteries enter the bone near its ends. These arteries supply the metaphyseal region and form an anastomotic system with the endosteal blood supply coming from the nutrient artery.
- The bone is also perfused by small vessels from the periosteum that are adherent to the outer surface of the bone.
- The endosteal circulation perfuses approximately the inner two-thirds of the cortex. Most of the metaphyseal bone is also perfused by the endosteal circulation rising from the metaphyseal arteries.
- The outer one-third of the cortex is perfused by the periosteal vasculature.

Bone Healing [2]

- The primary goal of fracture healing is to reestablish the integrity of the injured bone, restoring function of the affected limb.
- Fracture healing is classically categorized into two types: direct bone healing and secondary bone healing.
- Direct bone healing refers to direct cortical healing of two fractured ends of a bone. There is no transitional cartilaginous stage. This process primarily occurs between rigidly opposed cortical fracture ends.
- Secondary bone healing involves healing processes within the bone marrow, periosteum, and the soft tissues surrounding the bone. A transitional cartilaginous or fibrocartilaginous stage precedes bone formation. This type of healing dominates when the fracture is held less rigidly, like seen when a fracture is treated with a cast.
- Direct bone healing occurs primarily after the fractured ends of cortical bone are directly reduced and rigidly opposed under compression. Rigid compression fixation of the opposed cortical ends creates a mechanical environment with minimal interfragmentary motion.
- Direct appositional bone healing must occur across the gaps before contact healing can proceed. However, on a microscopic scale, perfect apposition of the fractured cortices is not achieved. Cortical ends are connected with a series of contact points and gaps.
- Gap healing is primarily characterized by direct bone formation between the ends of the bone, thus enclosing the gap. Smaller gaps fill with mature lamellar bone. Larger gaps fill more slowly primarily with primitive woven bone.
- These gaps that have filled with primitive woven bone during the initial phase of gap healing require remodeling to achieve prefracture strength, which is achieved by contact healing.
- Contact healing occurs in a series of events controlled by basic multicellular units. They facilitate bone resorption and then direct formation in the tunnels spanning the fracture. These multicellular components form a cutting cone with osteoclast leading the path.

- The cutting cones burrow through the fracture cortices and across the fracture plane, creating a void. Osteoblasts then follow along the edges of the cutting cone and begin bone formation.
- Fractures treated by closed methods, intramedullary fixation, external fixation, or less than rigid plate unite by secondary bone healing.
- The fracture causes localized bleeding with formation of a hematoma. This initiates a set of inflammatory events.
- Secondary bone healing employs a combination of direct intramembranous bone formation and endochondral ossification, similar to bone formation processes seen in skeletal growth.
- In both mechanisms, mesenchymal cells migrate to the wound site in response to locally increased levels of growth factors and cytokines, where they differentiate into chondrocytes or osteoblasts. The mechanical environment influences this cell fate decision.
- Secondary bone healing initially produces primary woven bone. Following the initial repair, remodeling transforms the primitive woven bone into a more efficient secondary structure which restores the bony architecture to its normal state.

Inflammatory Phase [4]

- Fracture healing is a natural process that can reconstitute injured tissue and recover its original function and form.
- It is a very complex process that involved the coordinated participation of migration, differentiation, and proliferation of inflammatory cells, angioblasts, fibroblasts, chondroblasts, and osteoblasts which synthesize and release bioactive substance of extracellular matrix components.
- The inflammatory phase occurs shortly after a bone is fractured.
- The fracture includes injury not only to the osseous structures but also to the marrow elements, periosteum, and soft tissue surrounding the bone.
- These structures are all well vascularized in comparison with bone, and disruption of their vascular supplies leads to the accumulation of hematoma.
- Local cell death accompanies the damage to the vascular elements. The hematoma and necrotic tissue elicit an immune response that attracts cellular elements through chemotaxis.
- The process of chemotaxis gives rise to primitive mesenchymal elements that then begin to accumulate in the area of the fracture.
- The inflammatory response has two beneficial effects, hydraulic splinting of the limb and voluntary immobilization from pain and swelling, and mesenchymal cells proliferate and differentiate into osteoblasts.

Reparative Phase [4]

- The reparative phase of fracture healing is marked by changes in the microenvironment of the fracture itself.
- Changes in oxygen tension and acidity of the microenvironment lead to differentiation of the primitive mesenchymal cells into more differentiated cellular elements.
- These pluripotential mesenchymal cells differentiate into a variety of cell types. Granulation tissue develops, bringing with it new blood supply into the area of the fracture.
- Islands of cartilage formation are evident which eventually undergoes endochondral ossification as the fracture unites.
- Damage to the periosteum activates the cambium layer of the periosteum, and some new bone formation occurs.
- Altogether these changes are referred to as callus formation. Once callus is observed to be bridging the fracture site, the bone fragments are usually stable.

- As the callus matures, it is remodeled to its normal configuration. In this process, the newly formed bone in the area of the fracture undergoes osteoclastic resorption and osteoblastic deposition of mature lamellar bone (Fig. 3.1).

Fig. 3.1 (**a**, **b**) Show orthogonal views of a comminuted and displaced open tibial shaft fracture. (**c**, **d**) Reveal the same injury after reconstruction with interfragmentary screws and a tibial nail

References

1. Copenhaver WM, Kelly DE, Wood RL. The connective tissues: cartilage and bone. In: Bailey's textbook of histology. Philadelphia: Williams and Wilkins; 1978.
2. Dee R. Bone healing. In: Principles of orthopedic practice. New York: McGraw-Hill; 1988.
3. Recker RR. Embryology, anatomy, and microstructure of bone. In: Disorders of bone and mineral metabolism. New York: Raven; 1992.
4. Wiesel SW, Delahay JN, Conell MC. Essentials of orthopedic surgery: Philadelphia, Pennsylvania: WB Saunders Co.; 1993.