Preface

This *Current Diagnosis and Treatment in Orthopedics* is the Fourth Edition of the orthopedic surgery contribution to the Lange Current Series of books. It is surprising to realize that it has been 10 years since the first edition of this book. The goal of this book has not changed. It is intended to fill a need for a ready source of up-to-date information on disorders and diseases treated by orthopedic surgeons and related physicians. The format in this edition is unchanged from previous: there is emphasis on the major diagnostic features of disease states, the natural history of the disease where appropriate, the work-up required for definitive diagnosis, and, finally, definitive treatment. The book focuses on orthopedic conditions, de-emphasizing the treatment of the patient from a general medical viewpoint, except when it pertains to the orthopedic problem under consideration. Importantly, pathophysiology, epidemiology, and pathology are included when they assist in arriving at a definitive diagnosis or an understanding of the treatment of the diseases or condition. In many conditions, such as infection or neoplasm, it is extremely important to understand the pathophysiology because the disease may be encountered at various time points in the progression of the disease.

This edition of the *Current Diagnosis and Treatment in Orthopedics* is truly current.

The entire book has been updated in its references to include only those references since 2000, except in cases where classic articles are necessary to refer back to major advances in understanding or treatment, or in situations where there has been little change in the sub-specialization in orthopedics, such as rehabilitation. These selected references to the older literature represent landmarks in the advancement of the understanding of orthopedic diseases and conditions, and serve as useful sources of the fundamental basis for understanding these diseases and conditions.

INTENDED AUDIENCE

The unique format of the Lange series textbooks allows readers of many levels of understanding to derive benefit from the information.

Students will find that the book encompasses virtually all aspects of orthopedics that they will encounter in classes and as sub-interns in major teaching institutions. Residents and house officers can use the book as a ready reference covering the majority of disorders and conditions in emergency and elective orthopedic surgery. Despite its small size, it is truly comprehensive. Because of the organization of the book on a sub-specialty basis, review of individual chapters will provide house officers rotating on sub-specialty orthopedic services with an excellent basis for further in-depth study.

For emergency room physicians, especially those with medical backgrounds, the text provides an excellent resource in managing orthopedic problems seen on an emergent basis. Similarly, family practice, pediatricians, general practitioners, and internists will find the book particularly helpful in the referral decision process, and as a resource to explain disorders to patients. Finally, practicing orthopedic surgeons, particularly those in sub-specialties of orthopedics, will find the book a helpful resource in reassuring them that their treatment in areas outside their sub-specialty interest is current and up-to-date.

ORGANIZATION

The book is structured similarly to the structure of orthopedic surgery. Natural sub-specialization has occurred in orthopedic surgery over the years, which has resulted in some overlap in anatomic areas. This has resulted in the book having some overlap and some artificial division of subjects. Because of the primarily sub-specialization structure, the reader is encouraged to read entire chapters, or for more discrete topics, go directly to the index for information. For example, the house officer rotating on the pediatric orthopedic service would find reading the pediatric chapter to be a prudent method of developing a baseline knowledge in pediatric orthopedic surgery. Knee problems however, might be best approached by looking in the sports medicine chapter, or in the adult reconstruction chapter, since these areas overlap, mostly in age of patient.

The first chapter serves as a basis for the rest of the book because it summarizes current basic information that is fundamental in the understanding of orthopedic surgery. Chapter Two introduces aspects of interest in the perioperative care of the orthopedic patient, including social aspects of the patient/physician relationship. Management of orthopedic problems arising from trauma is covered in Chapter Three, while Chapter Four deals with sports medicine with an emphasis on the knee and shoulder. Chapter Five covers all aspects of spine surgery, including degenerative spinal problems, spinal deformity, and spinal trauma.

Chapter Six provides comprehensive coverage of tumors in orthopedic surgery, including benign and malignant soft tissue and hard tissue tumors. Adult joint reconstruction, including the disorders that lead to joint reconstruction are covered in Chapter Seven. In Chapter Eight, infections, with their special implications for orthopedic surgery are covered. Chapter Nine discusses foot and ankle surgery, and Chapter Ten, hand surgery. Chapter Eleven covers diseases in orthopedics unique to children. The final two chapters deal with amputation and all aspects of rehabilitation fundamental to orthopedic surgeons in returning patients to full function.

OUTSTANDING FEATURES

- Illustrations have been carefully selected to maximize their benefits in pointing out orthopedic principles and concepts. The effect of changes in imaging technology on optimal diagnostic studies is emphasized, including cost-effectiveness.
- Bone and soft tissue tumor differential diagnoses are simplified by comprehensive tables that categorize tumors by age, location, and imaging characteristics. The molecular basis of the current understanding of tumor etiology is expanded.
- Concise, current, and comprehensive treatment of the basic sciences underlying the understanding of orthopedic surgery is provided.

NEW TO THIS EDITION

- Information on shoulder evaluation has been widely expanded, including tables to elucidate the diagnosis of shoulder problems.
- Advances in treatment of back pain, including disk replacement, are included.
- The latest on molecular biology of neoplasm has been expanded in the musculoskeletal tumor section.
- Surgical management of osteoporosis, including techniques such as kyphoplasty and vertebroplasty, and information on shoulder replacement have been widely expanded.
- Guidelines for predicting function, such as ambulatory capability after spinal cord injury, are updated.
- New materials in orthopedics that are making changes in the way replacement arthroplasty is performed are included.
- The latest information on important growth factors in orthopedics is elucidated with current usage.

I am pleased to be able to say, with the concurrence of my co-authors, that these new features added to the information in the previous edition, make this edition a significant improvement over the last.

Harry B. Skinner, MD, PhD

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Current Diagnosis & Treatment in Orthopedics, Fourth Edition

Notice

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Orthopedic Infections

Biomechanics & Biomaterials: Introduction

Authors: Ranjan Gupta, MD, Vincent Caiozzo, PhD, Stephen D. Co

Orthopedic surgery is the branch of medicine concerned with resto

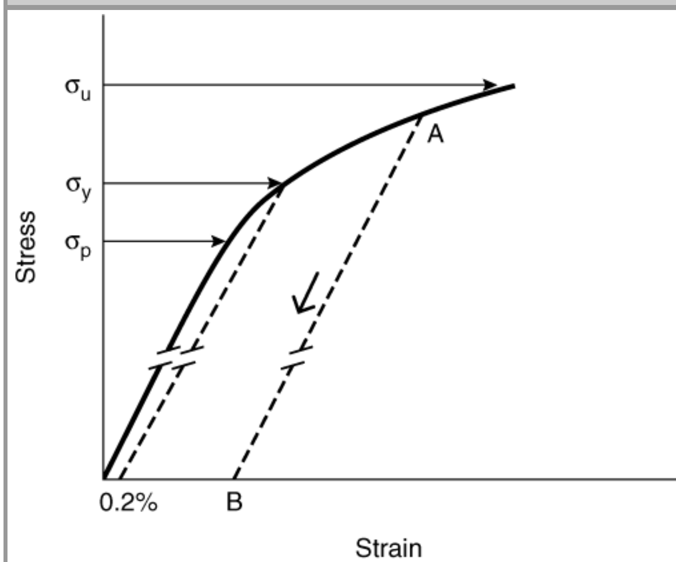
BASIC CONCEPTS & DEFINITIONS

Most biologic tissues are either **porous materials** or **composite**

Generally, composites are made up of a matrix material, which abs

The mechanical characteristics of a material are commonly describ

Figure 1–1.



A generalized stress–strain diagram illustrating the mechanical pr

Mechanical characteristics can also be illustrated by a **load-elong**

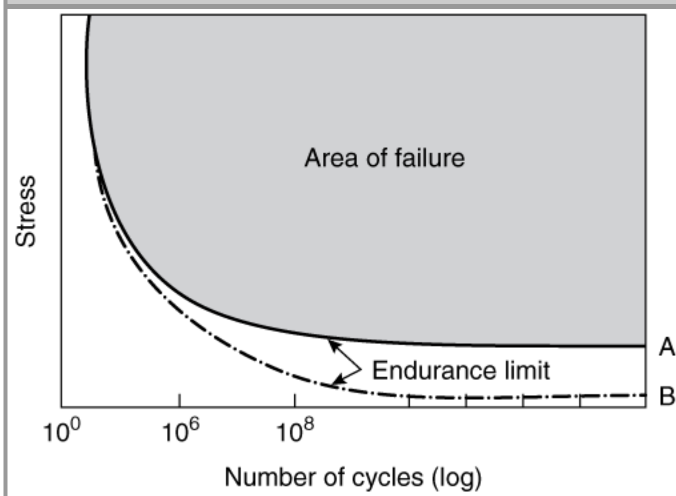
Because of this difference between the stress–strain curve and loa

The initial linear or elastic portion of the stress–strain curve (see F

The **proportional limit,** or σ_p, of a material is the stress at which

When subjected to repeated loading in a physiologic environment,

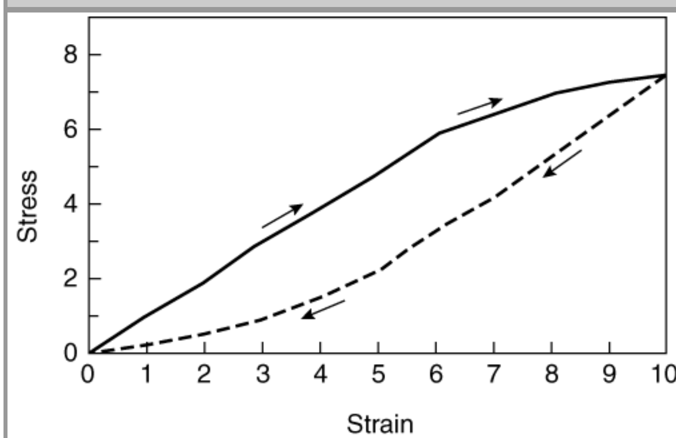
Figure 1–2.



A generalized diagram comparing two fatigue curves, or S-N curve

Materials can be evaluated in terms of ductility, toughness, viscoel
Ductility is defined as the amount of deformation that a material
Toughness is defined as the energy imparted to a material to cau
Because all biologic tissues are viscoelastic in nature, a thorough u
Viscoelastic materials have three important properties: hysteresis,

Figure 1–3.



When a viscoelastic material is subjected to cyclic loading, the stre

Friction refers to the resistance between two bodies when one sli
Wear can occur from friction and is defined as the removal of surf

Adhesive wear results when a thin film of material is transferred

Three-body wear occurs when another particle is located betwee

BIOMECHANICS IN ORTHOPEDICS

An analysis of the factors that influence normal and prosthetic join

Force, Moment, & Equilibrium

Forces and moments are vector quantities—that is, they are descr

The force generated by gravity on an object acts at the center of

Newton's first law states that a body (or object) is in equilibrium if

Free-Body Diagrams

A free-body diagram can be used schematically to represent all th

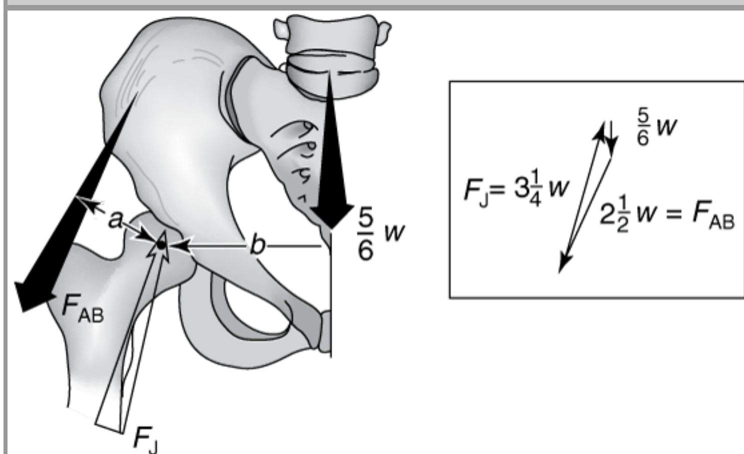
Example 1: Determine the force on the abductor muscle of a pers

$$F_{AB} \times a = \frac{B}{nw} \times b$$

In solving the equation, assume that a = 5 cm and that b = 15 cm

After this equation is solved, two of the three forces are known. T

Figure 1–4.



A free body diagram and force triangle illustrating the method for

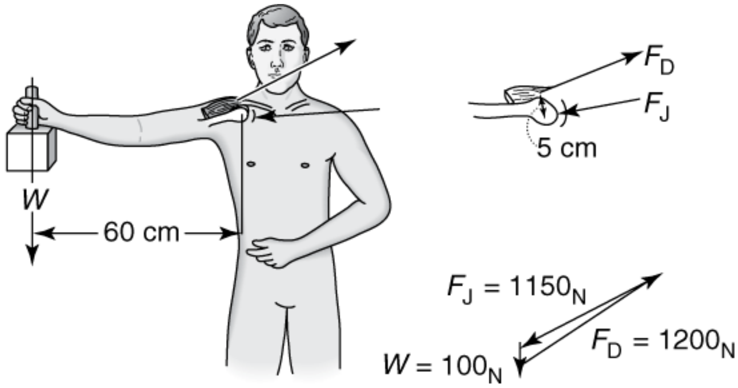
Example 2: Determine the force on a person's deltoid muscle (the

$$F_D \times a = w \times b$$

In solving the equation, assume that a = 5 cm and that b = 60 cm

After this equation is solved, an F_J of 1150 N is determined using

Figure 1–5.

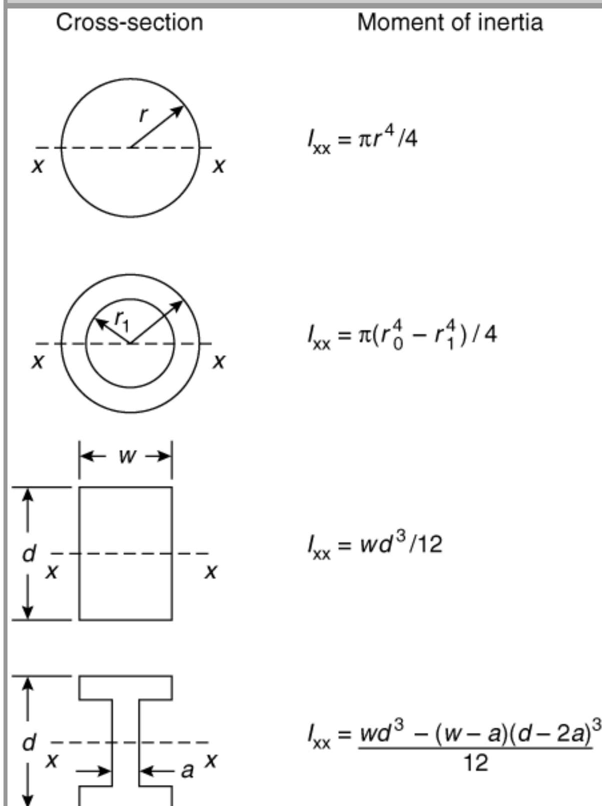


A free body diagram and force triangle illustrating the method for

Moments of Inertia

The orientation of the bone's or implant's cross-sectional area with

Figure 1–6.



Summary of the area moments of inertia for representative shape

Knowledge of moments of inertia is important for understanding m

Hills BA: Boundary lubrication in vivo. Proc Inst Mech Eng [H] 200

BIOLOGIC TISSUES IN ORTHOPEDICS

The functions of the musculoskeletal system are to provide suppor

Bones

Bones are dynamic tissues that serve a variety of functions and ha

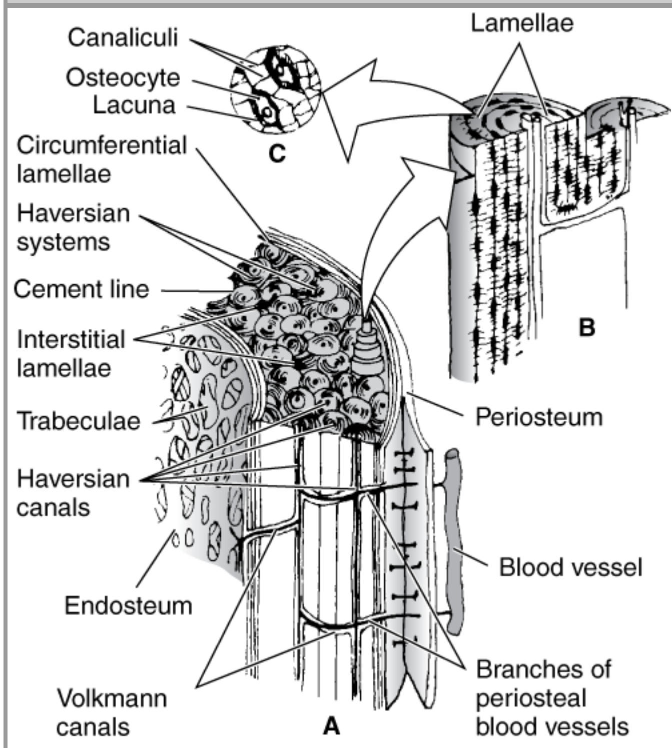
STRUCTURAL COMPOSITION

Bone is a composite consisting of two types of material. The first r

Woven bone, which is also called **primary bone,** is characterized

Lamellar bone is a slower forming, mature bone that is characteriz

Figure 1–7.



The structure of bone. **A:** A section of the diaphysis of a long bone
(Reproduced, with permission, from Nordin M, Frankel VH: Biome

Bone can be classified macroscopically as cortical tissue and cance

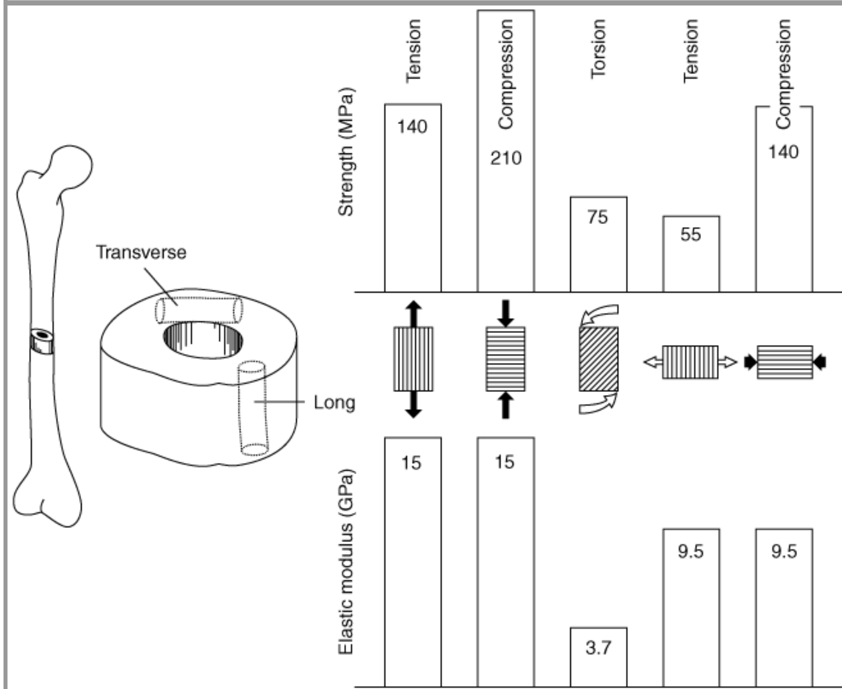
The organization of cortical and cancellous tissue in bone allows fo

BIOMECHANICAL BEHAVIOR

The mechanical properties of cortical bone differ from those of can

Variations in the strength and stiffness of bone also result from sp

Figure 1–8.



The effects of specimen orientation and loading configuration on t

Tensile loading is the application of equal and opposite forces (lo

The converse of tensile loading is **compressive loading,** which is

The application of either a tensile load or a compressive load produ

Bone is a viscoelastic material, and its mechanical behavior is ther

Bone fractures can be produced either from a single load that exce

REMODELING MECHANISMS

Bone has the ability to alter its size, shape, and structure in respo

Bone mass and body weight are positively correlated, especially fo

The resorption of bone in response to a stiff implant, which alters

HEALING MECHANISMS

The fracture healing process involves five stages: impact, inflamm

Three types of fracture healing are described. The first type, endo

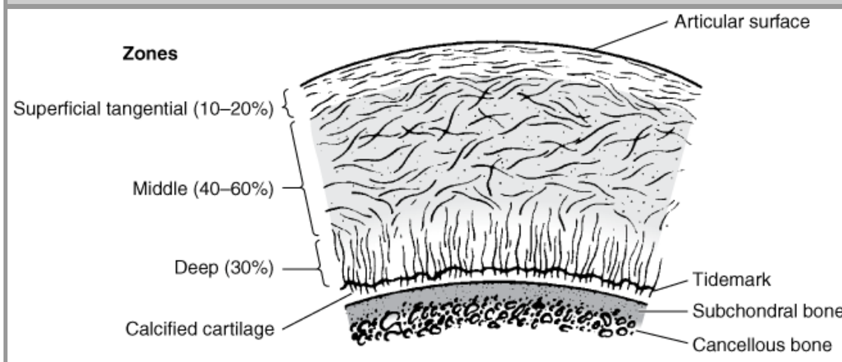
Articular Cartilage

Articular cartilage is primarily avascular and has an abnormally sm

STRUCTURAL COMPOSITION

Articular cartilage is composed of chondrocytes and an organic ma
The basic collagen unit consists of tropocollagen molecules, which
The mechanical properties of the cartilage are attributed to the inh

Figure 1–9.



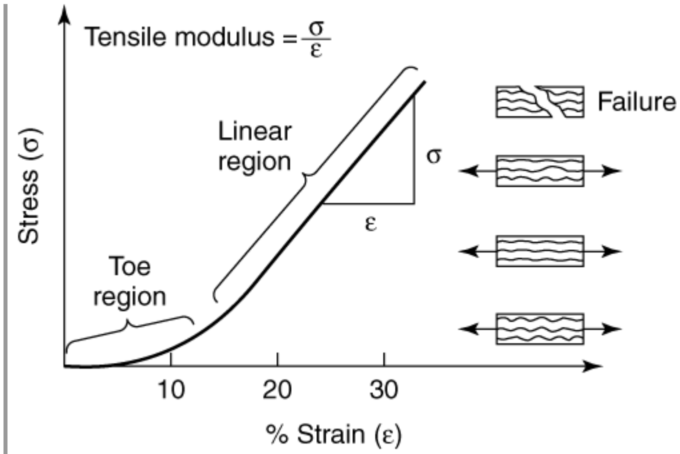
Orientation of the collagen fiber network in the three zones of the
(Modified and reproduced, with permission, from Mow VC et al: Bi

Proteoglycans are monomers that consist of a protein core with gly
The water content of normal cartilage permits the diffusion of gase
Important structural interactions occur between proteoglycans and

BIOMECHANICAL BEHAVIOR

The biomechanical behavior of articular cartilage is best understoo
Similar to creep, stress relaxation is the response of the tissue to
Under uniaxial tension, articular cartilage demonstrates anisotropi
The shape of the stress–strain curve (Figure 1–10) can be describ

Figure 1–10.



A stress–strain diagram for articular cartilage during tensile loadin
(Reproduced, with permission, from Mow VC et al: Biomechanics c

When the cartilage is tested in pure shear under infinitesimal strai

LUBRICATION MECHANISMS

Sophisticated lubrication processes are responsible for the minima

The boundary mechanism protects the joint from surface-to-surfac

The fluid film mechanism relies on a thin layer of lubricant that cau

The mixed lubrication mechanism is a combination of the boundary

Self-lubrication, or weeping, relies on the exudation of fluid in fron

Synovial fluid is a key component in the lubrication process in joint

WEAR MECHANISMS

Wear is the removal of material from a surface and is caused by th

Interface wear occurs when bearing surfaces come into direct cont

Fatigue wear results from the accumulation of microscopic damage

Numerous structural defects of the articular cartilage are caused c

Several biomechanical hypotheses cover cartilage degradation. Fac

Biomechanically, conditions that cause excessive stress concentrat

Tendons & Ligaments

Tendons and ligaments are similar both structurally and biomechan

STRUCTURAL COMPOSITION

Both the tendons and the ligaments are parallel-fibered collagenou

The fibroblasts secrete a precursor of collagen, procollagen, which

Tendons and ligaments are surrounded by loose areolar connective

Tendons and connective tissues of the musculotendinous junction h

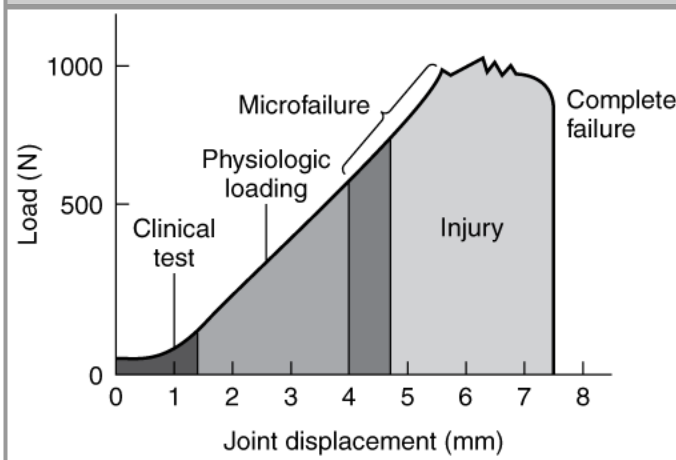
The tendon insertions and ligament insertions to the bone are stru

MECHANICAL BEHAVIOR

Tendons and ligaments are viscoelastic structures that have specif

Figure 1–11 shows the load-elongation curve for progressive failur

Figure 1–11.

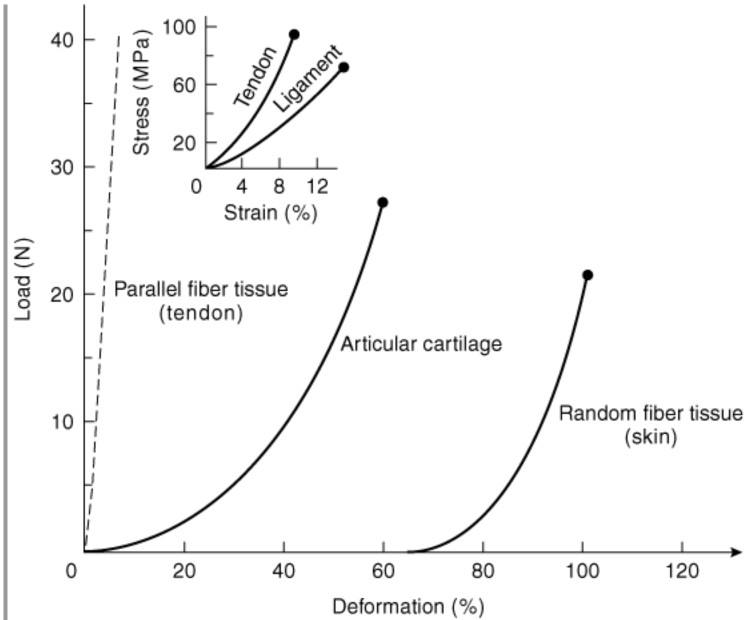


The load-elongation curve for progressive failure of the anterior cr

(Reproduced, with permission, from Carlstedt CA, Nordin M: Biom

The mechanical behavior characteristics of the anterior cruciate lig

Figure 1–12.



Load-elongation curves for several soft tissues. The range in mech

The viscoelastic behavior of ligaments is best exemplified in the bo

The mechanical properties of ligaments are closely related to the r

Tendons and ligaments remodel in response to mechanical demand

Studies of nonsteroidal antiinflammatory drugs (NSAIDs) such as i

INJURY MECHANISMS

Tendons and ligaments are subjected to less than a third of their u

Clinically, ligament injuries are characterized according to degree c

HEALING MECHANISMS

During tendon and ligament healing and repair, fibroblastic infiltrat

Sutured tendons heal with a progressive penetration of connective

Tendon mobilization during healing is important to avoid adhesion

Direct apposition of the surfaces of a divided ligament provides the

The anterior cruciate ligament is often severely damaged in cases

Bellucci G, Seedhom BB: Tensile fatigue behaviour of articular cart

Ding M: Age variations in the properties of human tibial trabecular

Ding M et al: Mutual associations among microstructural, physical

Fung YCB: *Biomechanics: Mechanical Properties of Living Tissues.*

Jay GD et al: Lubricating ability of aspirated synovial fluid from em

Kjaer M: Role of extracellular matrix in adaptation of tendon and s

Kopperdahl DL et al: Quantitative computed tomography estimate

Mazzuco D, Spector M: The role of joint fluid in the tribology of tot

Mountney J et al: Tensile strength of the medial patellofemoral liga

Mow VC, Guo XE: Mechano-electrochemical properties of articular

Musgrave DS et al: Gene therapy and tissue engineering in orthop

Shinar H et al: Mapping the fiber orientation in articular cartilage a

Silva MJ et al: Recent progress in flexor tendon healing. J Orthop S

Silver FH, Bradica G, Tria A: Viscoelastic behavior of osteoarthritic

Vanwanseele B et al: Knee cartilage of spinal cord-injured patients

Wu JZ, Herzog W: Elastic anisotropy of articular cartilage is associ

Skeletal Muscle

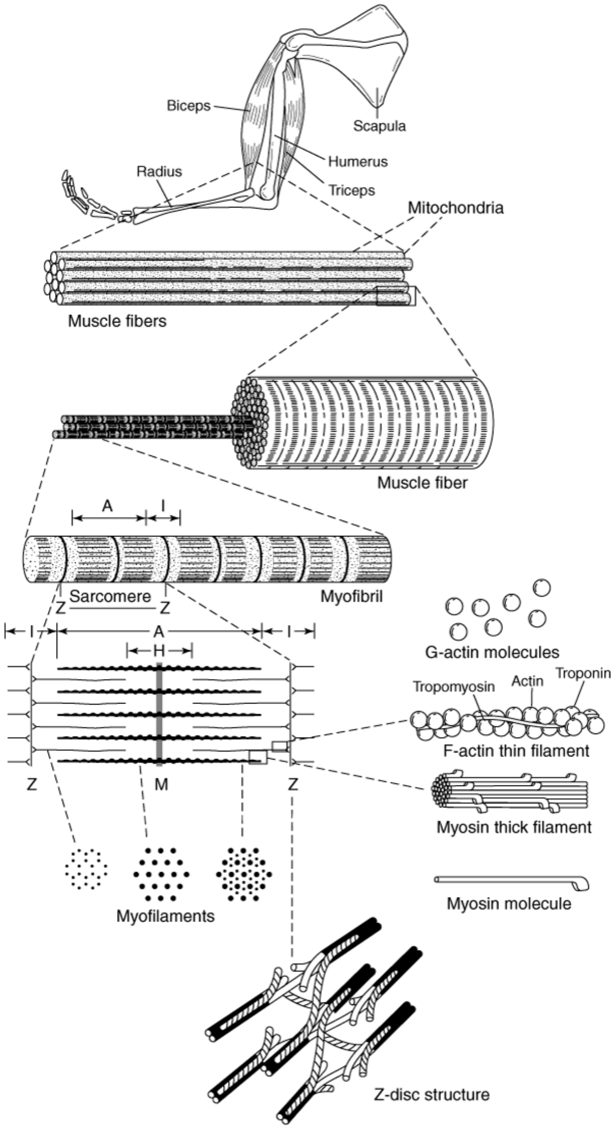
Skeletal muscles perform a wide variety of mechanical and biologic

SKELETAL MUSCLE STRUCTURE

Macroscopic Anatomy

Figure 1–13 provides both a macroscopic and microscopic perspec

Figure 1–13.



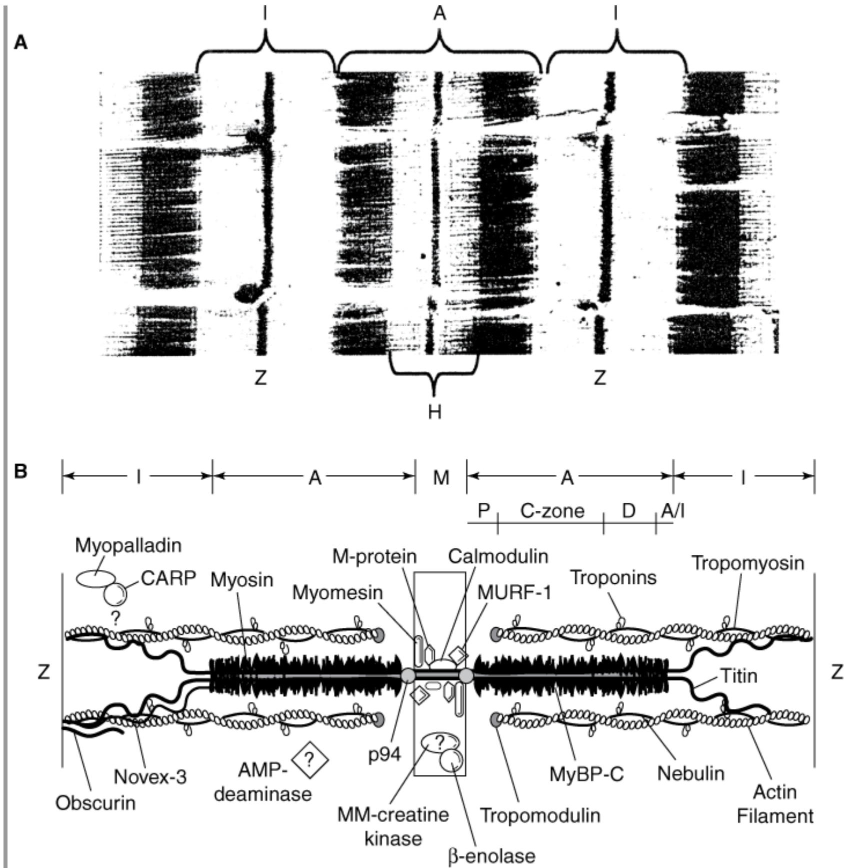
Overview of macroscopic and microscopic structure of skeletal mu
(Reprinted, with permission, from McMahon TA: *Muscles, Reflexes*

From an architectural perspective, muscles are often classified on
Consistent with the theme of structure–function relationships, mus

Molecular Anatomy of the Myofibril

The structure of skeletal muscle at the molecular level is quite com
In a general sense, sarcomeres consist of Z-lines, thin filaments, a

Figure 1–14.



Striation pattern and various proteins associated with sarcomere.
(**A** reproduced, with permission, from Aidley DJ: *The Physiology o*

Changes in sarcomere length and, as a result, muscle fiber length

Table 1–1. Effect of Different Types of Contractions o

Type of Contraction	Z-line	I-band	A-band	H-zone	M-line	Sarco
Isometric	↔	↔	↔	↔	↔	↔

↔ = no change in length; σ= increase in length; σ = decrease in len

Molecular Anatomy of the Sarcomere

As shown in Figure 1–14 and in Table 1–2, the overall structure of

Table 1–2. Overview of Proteins Involved with the Sa

Classes and Types	Molecular Wt (kDa)	Location	Function
Contractile Proteins			
Myosin heavy chain	~200	Thick filament	
Sarcomeric Proteins	**Molecular**	**Location**	**Function**

and Types of Sarcomeric Proteins	Wt (kDa)	Location	Function			

MHC = myosin heavy drain; LIM = cysteine-rich double zinc finger

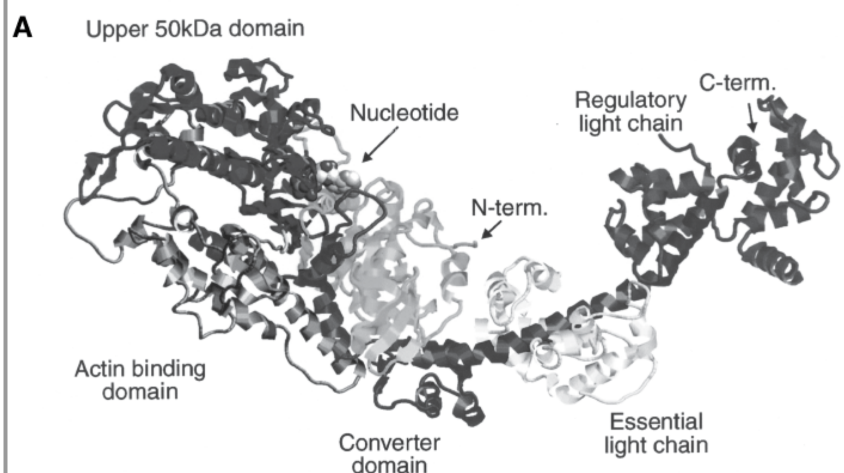
As shown in Table 1–2, the primary contractile proteins are simply crossbridge cycling.

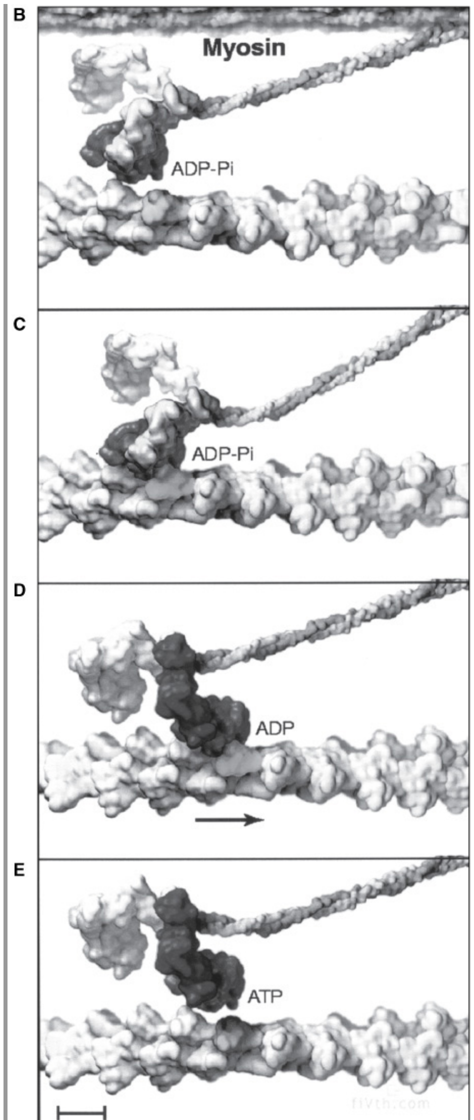
Structural and costameric proteins play several essential roles. Firs

Molecular Anatomy of Myosin Molecule

Although the term *myosin molecule* is often used, in reality the my cardiomyopathy. As noted earlier, the light chains are thought to p

Figure 1–15.

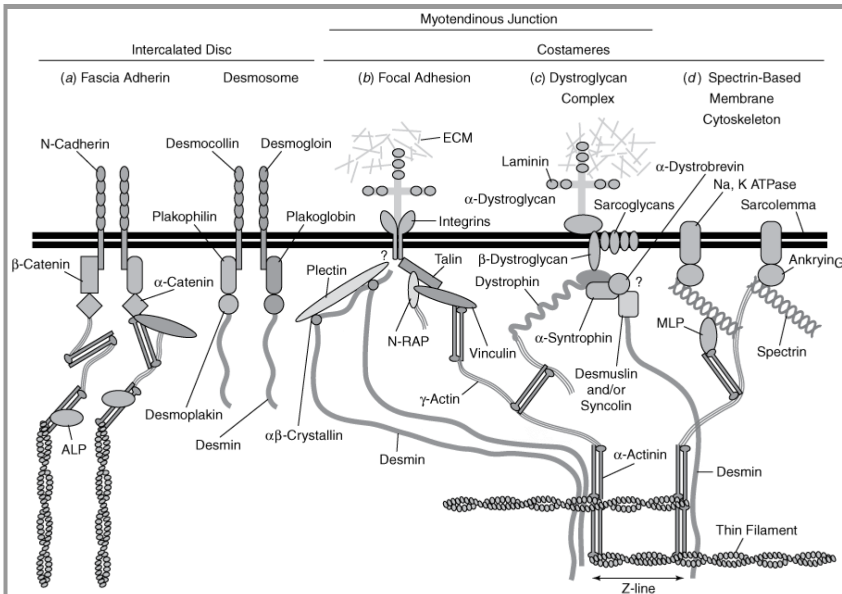




Molecular anatomy of myosin molecule (**A**) and stop-motion movie
(The ribbon structure of the S2 [lever arm] and S1 [globular head

The complexity of the myosin molecule is further complicated by t
Note that there are isoforms for myosin heavy chains, myosin ligh
The sequence of the crossbridge cycle is shown in Figure 1–15. Fir
In thinking about the plasticity of the sarcomere and its constituen
Factors such as mechanical unloading (eg, as accompanies cast im
Molecular Anatomy of the Connection between the Cytoskel
Costameres are important structures that link the cytoskeleton of

Figure 1–16.



Molecular anatomy of a costamere, a structure believed to play a
(Reproduced, with permission, from Clark KA et al: Striated musc

The On-and-Off Switch of the Molecular Motor: Excitation-Co

From a mechanical perspective, all of the sarcomeres must becom
occupied by the sarcomere, binding to troponin-C. This then cause

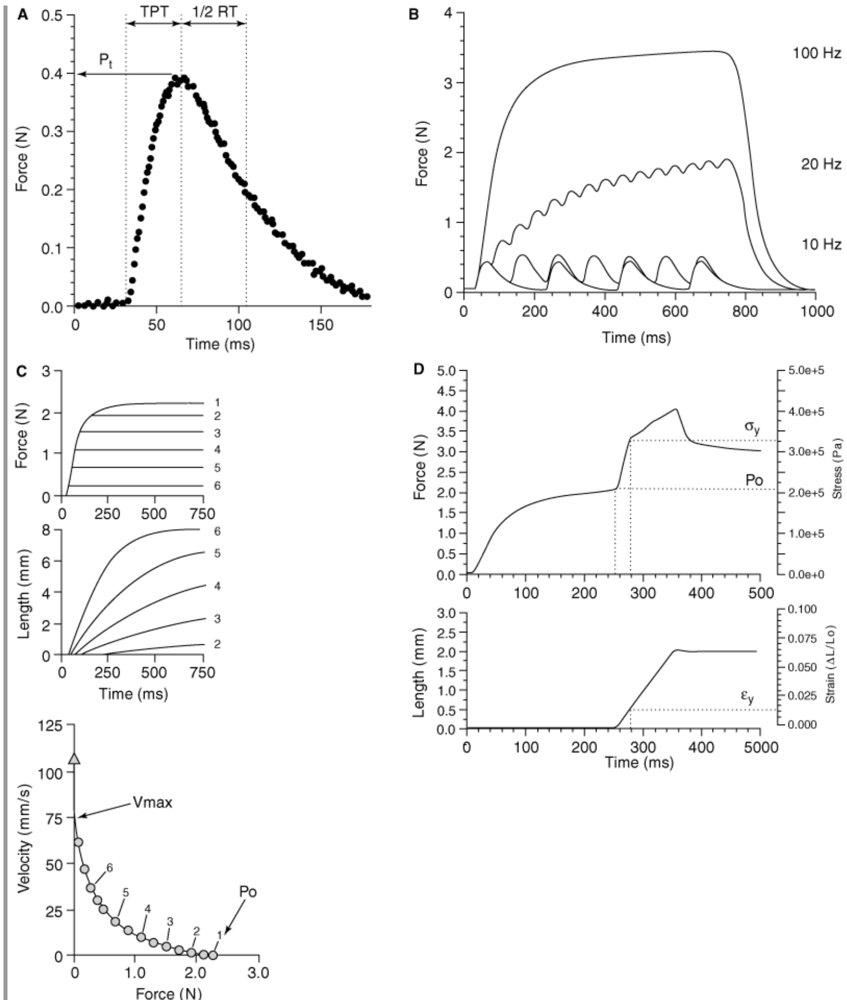
The contractile activity of the sarcomere is turned off by resequest

As mentioned earlier, there are a number of isoforms for the contr

SKELETAL MUSCLE FUNCTION

In a general sense, the mechanical activity of skeletal muscle depe

Figure 1–17.



Various mechanical measurements that are typically made. The ki

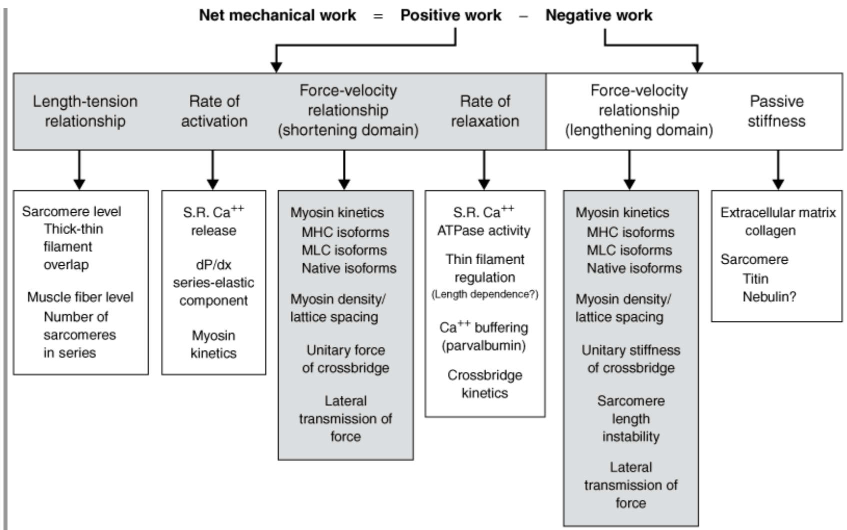
The amount of Ca^{2+} released by the sarcoplasmic reticulum can be

As noted earlier, the loading of skeletal muscle also plays a key rol

Conceptual Framework of Factors That Determine Muscle Fu

From an orthopedics perspective, it would be beneficial to have a f

Figure 1–18.



Various factors that limit the production of mechanical work and p

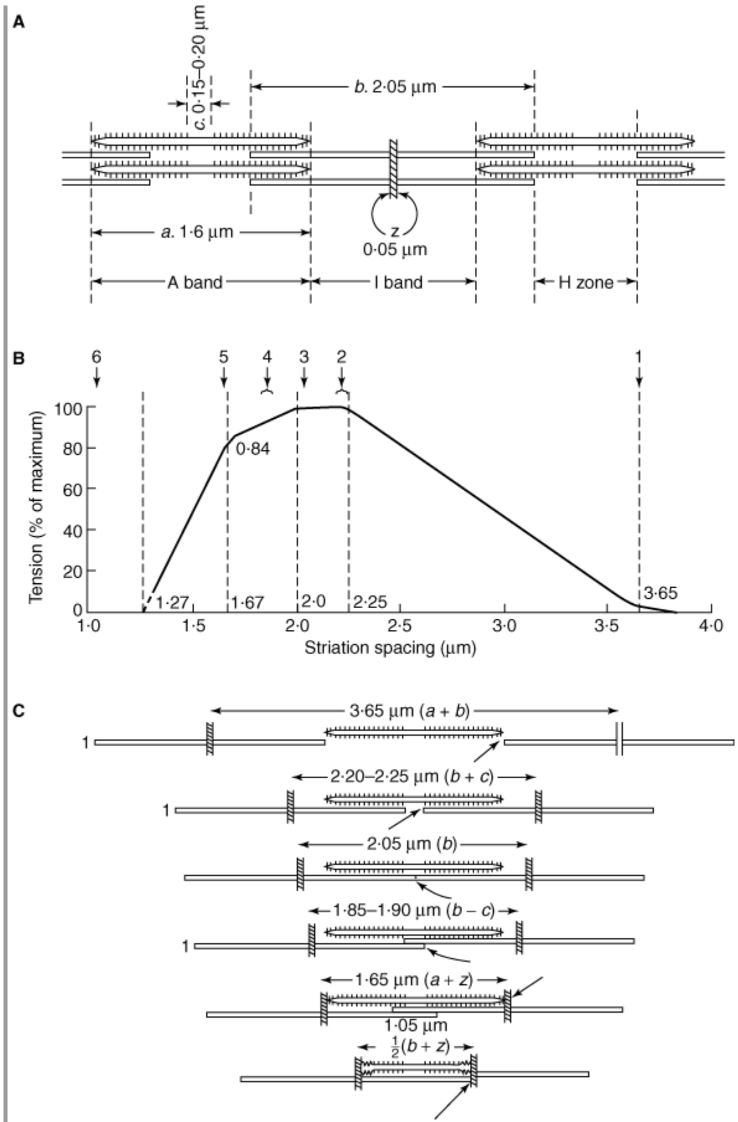
(Modified, with permission, from Caiozzo VJ: Phenotypic plasticity

The four determinants of the amount of positive work that can be

Length–Tension Relationship

The amount of force a muscle can generate depends on muscle le

Figure 1–19.



Length–tension relationship.

(Reproduced, with permission, from Gordon AM et al: The variatio

The length–tension relationship of the sarcomere is thought to rep

Force–Velocity Relationship in the Shortening Domain

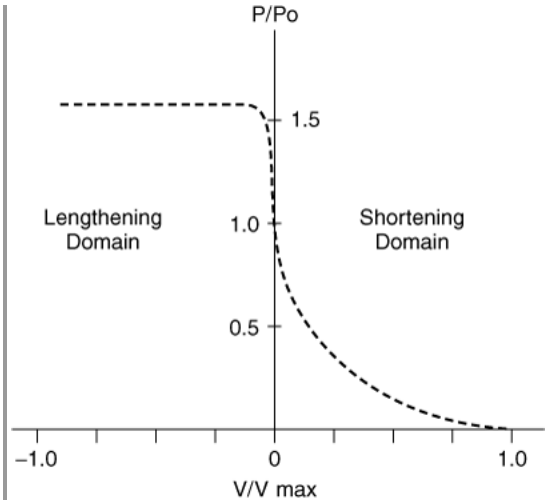
When a muscle contracts against a light load, it is able to shorten
unchanged. In this context, the force–velocity relationship can be

The product of force x velocity is mechanical power. Hence, the for

Force–Velocity Relationship in the Lengthening Domain

When a muscle is maximally activated and then forcibly lengthene

Figure 1–20.



Force–velocity relationship in both the shortening and lengthening
(Reproduced, with permission, from Caiozzo VJ: Phenotypic plastic

An example of the response of skeletal muscle to a lengthening co

From a functional perspective, the force–velocity relationship in th

Passive Stiffness of Skeletal Muscle

The passive stiffness of skeletal muscle is influenced by both sarcc
impact the passive stiffness of skeletal muscle, but it should be en

Although the extracellular matrix (ECM) is composed of a number

Skeletal muscle fibers can be exposed to a variety of forces (eg, n

Anderson JB et al: Physiology: Postprandial cardiac hypertrophy in

Caiozzo VJ: Phenotypic plasticity of skeletal muscle: Mechanical co

Clark KA et al: Striated muscle cytoarchitecture: An intricate web

Gordon AM et al: The variation in isometric tension with sarcomere

Tyska MJ, Warshaw DM. The myosin power stroke. Cell Motil Cytos

Vale RD, Milligan RA. The way things move: Looking under the hoo

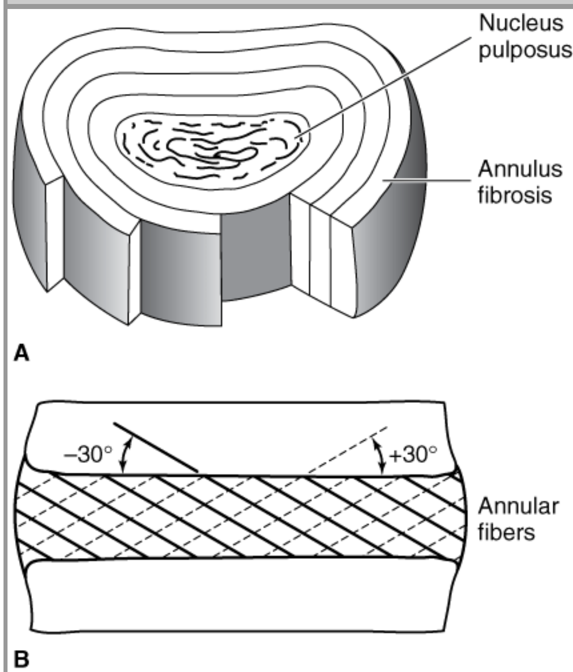
Intervertebral Disks

The intervertebral disks sustain and distribute loads and also prev

STRUCTURAL COMPOSITION

Each intervertebral disk has a nucleus pulposus surrounded by a t

Figure 1–21.



The intervertebral disk consists of a nucleus pulposus surrounded
(Reproduced, with permission, from White AA, Panjabi MM: *Clinica*

The nucleus pulposus lies in the center of the intervertebral disk, e

The annulus fibrosus is the ringlike outer portion of the disk and c

BIOMECHANICAL BEHAVIOR

The interaction between the nucleus pulposus and the annulus fibr

During compressive loading, the stress is transferred from the ver

When the nucleus pulposus ages, its hydration decreases and its h

The nucleus pulposus has no effect during tensile loading of the in

DISC REPLACEMENT

Pain located in the low back or neck, without radiation to the extre

Bass EC et al: Biaxial testing of human annulus fibrosus and its im

Carl A et al: New developments in nucleus pulposus replacement t

Dipaola CP et al: Molecular signaling in intervertebral disk develop

Kumaresan S et al: Contribution of disc degeneration to osteophyt

Kurtz SM et al: Analysis of a retrieved polyethylene total disc repla

Lee SH et al: In vitro measurement of pressure in intervertebral d

Simunic DI, Broom ND, Robertson PA: Biomechanical factors influe

Zigler JE: Lumbar spine arthroplasty using the ProDisc II. Spine J

Peripheral Nerves

Peripheral nerves are heterogeneous composite structures compris

STRUCTURAL COMPOSITION

The peripheral nerve is composed of motor, sensory, and sympath
large fascicle, whereas oligofascicular patterns consist of a few fas
system consisting of vascular plexa in the epineurium, perineurium

ROLE OF MYELIN SHEATH

One of the primary functions of a myelin sheath is to provide faste
primary myelin dysfunction. Furthermore, mice with mutations in g
axon–Schwann cell communication network in the paranodal regio

Myelin is formed from the extension of the plasma membrane of S

Gupta R et al: Schwann cells up-regulate vascular endothelial grov

Rowshan K et al: Current surgical techniques in nerve repair. Oper

Rummler LS et al: The anatomy and biochemistry of myelin and m

IMPLANT MATERIALS IN ORTHOPEDICS

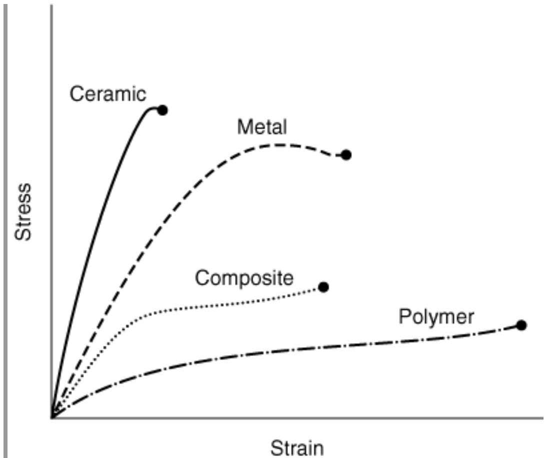
The body is a harsh chemical environment for foreign materials. A

Implant materials can be classified as biotolerant, bioinert, and bic

Minimizing the local and systemic response to an implanted materi

In addition to acceptable biocompatibility characteristics, biomater

Figure 1–22.



Representative stress–strain curves for the classes of materials us

The most commonly used biomaterial combinations for orthopedic

Polymers and ceramics are also important classes of materials for

Metals

The suitability of a metal component for maintaining longevity of a

An understanding of the terminology used to describe the strength

The grain size, inclusion content, and surface porosity influence th

Corrosion is a chemical reaction process that weakens the metal. T

The surfaces of all metallic implants are passivated (made passive

Galvanic corrosion occurs when an electric current is establishec

Crevice corrosion generally occurs when the fluid in contact with

IRON-BASED ALLOYS

There are four major groups of iron-based alloys or stainless steel:

Iron-based alloys have a wide range of mechanical properties (Tab

Table 1–3. Minimum Mechanical Requirements for Me

Material Type	ASTM Number	Ultimate Elastic Modulus (
Iron-based alloys		

Corrosion of stainless steels occurs for one of several reasons. The

Another reason for corrosion is mismatch of implant components,

Leaving plates and screws used to fix fractures in younger patient:

COBALT-BASED ALLOYS

The mechanical properties that make cobalt-based alloys suitable f

Despite the advantages of cobalt-based alloys, some reported case

TITANIUM AND ZIRCONIUM ALLOYS

Commercially pure titanium and titanium-based alloys are metals c

The mechanical properties of titanium and titanium-based alloys a

New manufacturing techniques are attempting to improve titanium

Polymers

Polymers have a wide range of properties attributable to variations

All polymers are composed of long chains of repeating units. These

ULTRAHIGH-MOLECULAR-WEIGHT POLYETHYLENE

UHMWPE possesses an array of properties, including high abrasion

A variety of factors influence the wear of polyethylene. These inclu

UHMWPE is either machined from ram-extruded bar stock or comp

In general, as the thickness of the UHMWPE components decrease

Several manufacturers choose gamma irradiation for sterilizing UH
density.

Irradiation of polyethylene at much higher doses (50,000–150,000

POLYMETHYLMETHACRYLATE

Self-curing PMMA, commonly used as a grouting agent, is often ca

Implant design and cementing technique must compensate for we

Aside from the inherent mechanical weakness of PMMA, the polym

The fatigue properties of PMMA manufactured by different compar

Antibiotics were added to bone cement at the time of surgery for y

Ceramics

Ceramics are wear resistant and strong in compression, but they a

The mechanical properties of ceramics depend on grain size, poros

ALUMINUM OXIDE

The catastrophic effects of implant loosening associated with polye

In clinical practice, all-alumina acetabular components have not pe

Despite the excellent wear and friction characteristics of aluminum

ZIRCONIUM OXIDE

Zirconium oxide (Zirconia) temporarily became an attractive mater

In comparison with aluminum oxide, zirconium oxide exhibits incre

HYDROXYAPATITE

Calcium phosphate ceramics, classified as polycrystalline ceramics,

Tribasic calcium phosphate [$Ca_{10}(PO_4)_6(OH)_2$], which is commonly

Bulk hydroxyapatite (HA) is manufactured from a starting powder,

Although the static mechanical properties of bulk HA are good, the
the fixation of the prosthesis to bone may be related to the quality

Several formulations of an injectable hydroxyapatite are now avail

PYROLYTIC CARBON

Carbon occurs naturally in many forms, each having different stru

Pyrolytic carbon is a manufactured material formed by the pyrolys

Pyrolytic carbon was evaluated in cardiovascular, dental, soft-tissu

Baleani M et al: Fatigue strength of PMMA bone cement mixed wit

Catledge SA et al: Surface crystalline phases and nanoindentation

Cook SD et al: Long-term follow-up of pyrolytic carbon metacarpo

Endo MM et al: Comparative wear and wear debris under three di

Ezzet KA et al: Oxidized zirconium femoral components reduce po

Food and Drug Administration, HHS: Medical devices; reclassificat

Friedman RJ et al: Current concepts in orthopaedic biomaterials a

Gott VL, Alejo DE, Cameron DE: Mechanical heart valves: 50 year

Hannouche D et al: Fractures of ceramic bearings: History and pr

Haraguchi K et al: Phase transformation of a Zirconia ceramic hea

Hernigou P, Bahrami T: Zirconia and alumina ceramics in comparis

Jeffers JR, Browne M, Taylor M: Damage accumulation, fatigue an

Kurtz SM et al: In vivo degradation of polyethylene liners after ga

Laskin RS: An oxidized Zr ceramic surfaced femoral component fo

Lewis G, Carroll M: Rheological properties of acrylic bone cement

Lim TH et al: Biomechanical evaluation of an injectable calcium ph

Ma L, Sines G: Fatigue behavior of a pyrolytic carbon. J Biomed M

Mashoof AA et al: Supplementation of autogenous bone graft with

Masonis JL et al: Zirconia femoral head fractures: A clinical and re

McKellop H et al: Development of an extremely wear-resistant ult

Morscher EW, Wirz D: Current state of cement fixation in THR. Ac

Murphy BP, Prendergast PJ. The relationship between stress, poro

Oonishi H, Kadoya Y: Wear of high-dose gamma-irradiated polyeth

Porter AE et al: Bone bonding to hydroxyapatite and titanium surf

Ries MD et al: Polyethylene wear performance of oxidized zirconiu

Ries MD et al: Relationship between gravimetric wear and particle

Sakoda H et al: A comparison of the wear and physical properties

Schulz M et al: Early results of proximal interphalangeal joint repl

Sharkey PF et al: The bearing surface in total hip arthroplasty: Ev

Smith SL, Unsworth A: An in vitro wear study of alumina-alumina

Spector BM et al: Wear performance of ultra-high molecular weig

Sun L et al: Material fundamentals and clinical performance of pla

Urban JA et al: Ceramic-on-polyethylene bearing surfaces in total

Vallo CI: Flexural strength distribution of a PMMA-based bone cem

Weisman DL et al: In vitro evaluation of antibiotic elution from pol

Yamamoto T et al: Wear analysis of retrieved ceramic-on-ceramic

GROWTH FACTORS

Biology

Growth factors hold great promise for the treatment of a variety c

Growth factors are polypeptides that serve as signaling agents for hematopoietic and immune cell systems, the distinction is rather a

Although the same growth factor is often found throughout the bo

TRANSFORMING GROWTH FACTOR BETA

TGF-βs are a family of dimeric polypeptide growth factors and code cartilage has limited potential for repair, TGF-β 1 is used in animal

BONE MORPHOGENETIC PROTEIN

Related to the TGF-βs, the bone morphogenic proteins constitute a

FIBROBLAST GROWTH FACTORS

Fibroblast growth factors are currently a group of eleven polypept

INSULIN-LIKE GROWTH FACTOR

The pivotal role of IGF in regulating endochondral ossification in sk

Both IGF-1 and IGF-2 stimulate preosteoblastic cell replication by

PLATELET-DERIVED GROWTH FACTOR

PDGF was discovered in serum as having a major mitogenic activit

VASCULAR ENDOTHELIAL GROWTH FACTOR

Vascular endothelial growth factor (VEGF), a potent angiogenic age

Applications

Extensive efforts are being made to find methods by which growth

There are many challenges to the clinical application of growth fac

The therapeutic application of growth factors must also accommod

Anitua E et al: Autologous preparations rich in growth factors pror

Buxton B et al: Growth/differentiation factor-5 (GDF-5) and skelet

Dahlgren LA et al: Temporal expression of growth factors and mat

Meaney Murray M et al: The effect of selected growth factors on h

Miura Y et al: Brief exposure to high-dose transforming growth fa

Musgrave DS et al: Gene therapy and tissue engineering in orthop

Yoon ST, Boden SD: Osteoinductive molecules in orthopaedics: Ba

IMPLANT DESIGN & BIOLOGIC ATTACHMENT PROPERT

Total joint arthroplasty requires the type of implant materials and

Implant Fixation Mechanisms

Several types of implant fixation methods and surface texture des

GROUTING AGENTS

PMMA bone cement provides a mechanical interlock between the n

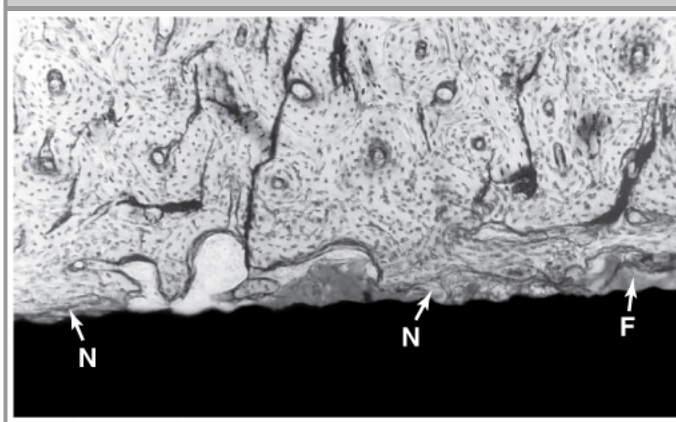
Improvements in the mechanical properties of cement and cement

DIRECT BONE APPOSITION

Optimal osseointegration at the bone-implant interface is affected

Evaluation of implant materials, including PMMA, commercially pur

Figure 1–23.



Histologic appearance of mechanically tested grit-blasted titanium

POROUS INGROWTH ATTACHMENT

The long-term problems associated with implant fixation with PMM

Porous coatings are effective as a means of biologic fixation becau

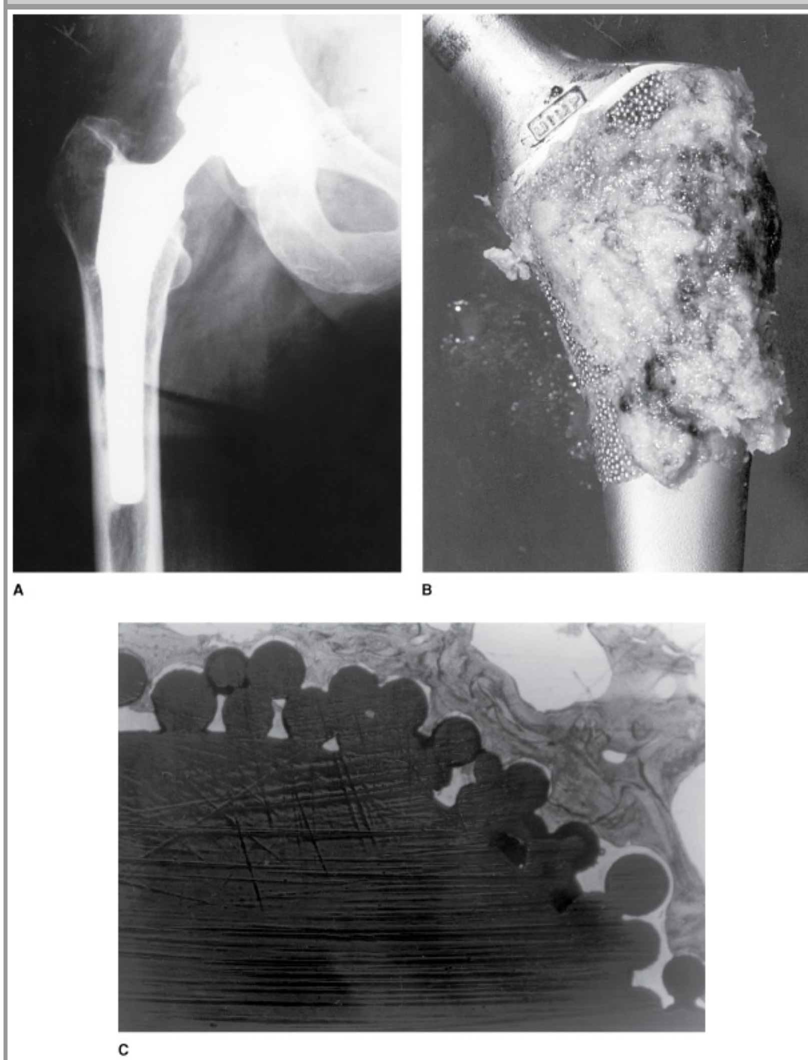
To maintain optimal bone growth into a porous structure, the pore
within the coating and between the coating and substrate. Too mu

Several different types of porous coatings were evaluated, includir
porous coating involves plasma-spraying titanium to either a titani

The extent to which implants are covered with porous coating vari

Clinically, the short-term results for porous-coated prostheses are

Figure 1–24.



Four years after implantation, an uncemented porous-coated femo

SURFACE TOPOGRAPHY AND COATINGS

Calcium phosphate coatings on metal surfaces were developed to

The bond between a metal substrate and a HA coating is critical to

A coating thickness of 50 μm is generally accepted as adequate for

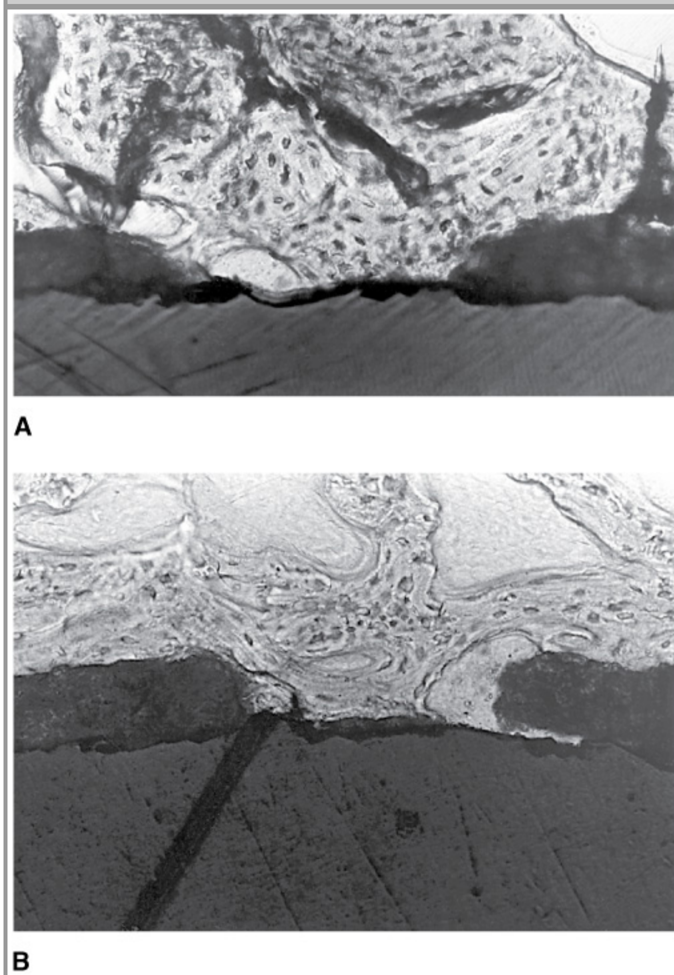
Chemical dissolution of an HA surface within the first few months

Plasma-spraying methods are used by most manufacturers to app

Because of the high temperatures necessary for plasma spraying,
osseointegration and were absorbed onto a carrier of β-tricalcium p

Clinical experience with HA-coated orthopedic prostheses is limited

Figure 1–25.



Histologic appearance of an HA-coated implant with a defect show

Not all studies in patients with HA-coated implants have reported

Factors That Affect Biologic Attachment

Attachment at the bone-implant interface is affected by the mater

MOTION AT THE BONE-IMPLANT INTERFACE

Motion of an implant within the surgical site has a primary influenc

Studies of implants suggest that relative motion of greater than 15
In a study of HA coating in a continuous loaded implant model, inv

SURGICAL FIT

The technical difficulties in cutting bone precisely to provide an exa
The effects of interface gaps and poor surgical fit of implants were

Aldini NN et al: Pedicular fixation in the osteoporotic spine: A pilot

Bach CM et al: No functional impairment after Robodoc total hip a

Bobyn JD et al: The optimum pore size for the fixation of porous-s

Clarke SA et al: The effect of osteogenic growth factors on bone g

DeGroot K et al: Plasma sprayed coatings of hydroxylapatite. J Bio

Fernandez-Pradas JM et al: Characterization of calcium phosphate

Freels DB et al: Animal model for evaluation of soft tissue ingrowt

Geesink RG: Osteoconductive coatings for total joint arthroplasty.

Hacking SA et al: Acid-etched microtexture for enhancement of bo

Hacking SA et al: Relative contributions of chemistry and topograp

Jinno T et al: Comparison of hydroxyapatite and hydroxyapatite tr

Karabatsos B et al: Osseointegration of hydroxyapatite porous-coa

Kim YH et al: Comparison of porous-coated titanium femoral stem

LeGeros RZ: Properties of osteoconductive biomaterials: Calcium p

Manso M et al: Biological evaluation of aerosol-gel-derived hydroxy

Nevelos JE et al: Wear of HIPed and non-HIPed alumina-alumina h

Noble PC et al: The anatomic basis of femoral component design.

Paprosky WG, Burnett RS. Extensively porous-coated femoral ster

Pilliar RM et al: Observations on the effect of movement on bone i

Soballe K et al: Hydroxyapatite coating converts fibrous tissue to b

Thomas KA et al: The effect of surface macrotexture and hydroxyl

Thomsen MN et al: Robotically-milled bone cavities: A comparison

TISSUE RESPONSE TO IMPLANT MATERIALS

The effect of an implanted material on adjacent tissues depends o

Biocompatibility

Biotolerant materials, such as stainless steel, PMMA, and UHMWPE

PMMA elicits adverse local and systemic effects from the moment o

Bioinert materials, such as titanium and cobalt-chromium alloys, u

Bioactive materials, such as calcium phosphate ceramics, offer the

One study used animal models to characterize tissue-specific react substitute materials.

Problems Associated with Maintaining Implant Longev

Implant loosening, which can result from bone loss that is caused

Although the exact cause of osteolysis is unknown, it is thought to

In addition to osteolysis, another problem with total joint implants

SURFACE DAMAGE OF POLYETHYLENE IMPLANTS

Osteolysis, loosening, and other complications that reduce implant

Fatigue is suggested as the primary mechanism of polyethylene su

The elastic modulus and thickness of the polyethylene are significa

The current practice is to try to minimize polyethylene wear debris

FATIGUE OF POROUS-COATED IMPLANTS

The primary failure mode of load-bearing orthopedic implants is fa

Sintering affects the fatigue properties of coated implants by alter

Investigators performed studies to determine the effects of sinteri

Aside from manufacturing processes, which may alter the fatigue p

The fatigue properties that are caused by sintering and the notch

The fatigue properties have to be considered in relation to newer a

METAL IMPLANTS: ION RELEASE, METAL-ON-METAL BEARIN

Any metal exposed to the physiologic environment will corrode. Co

Apart from potential implant mechanical failure, the clinical signific
debris that has a very large surface area to volume ratio. This deb

Released metal ions (Al, Co, Cr, Fe, Mn, Ni, Ti, and V ions) have or

Metal sensitivity induced by metal ion release is not a common pro
however, to determine if an allergic or hypersensitivity response to

MOM bearing surfaces, on the one hand, have the potential to red

Anissian L et al: Cobalt ions influence proliferation and function of

Berzins A et al: Surface damage in machined ram-extruded and ne

Brown SR et al: Long-term survival of McKee-Farrar total hip pros

Cook SD et al: Inflammatory response in retrieved noncemented p

Cook SD et al: The effect of post-sintering heat treatments on the

Dorr LD et al: Histologic, biochemical, and ion analysis of tissue ar

Edwards SA et al: Analysis of polyethylene thickness of tibial comp

Eid K et al: Tissue reactions to particles of bone-substitute materia

Friberg L et al: *Handbook on the Toxicology of Metals.* Elsevier, 19

Frosch KH et al: Autologous osteoblasts enhance osseointegration

Georgette FS, Davidson JA: The effect of hot isostatic pressing on

Goldberg JR et al: A multicenter retrieval study of the taper interfa

Hallab NJ, Mikecz K, Jacobs JJ: A triple assay technique for the eva

Hallab NJ et al: Immune responses correlate with serum-metal in r

Hallab NJ et al: Metal sensitivity in patients with orthopaedic impla

Huang CH et al: Particle size and morphology of UHMWPE wear de

Ingrahm E, Fisher J: The role of macrophages in osteolysis of tota

Ladon D et al: Changes in metal levels and chromosome aberratio

MacDonald SJ: Can a safe level for metal ions in patients with met

Merritt K, Rodrigo JJ: Immune response to synthetic materials. Se

Muratoglu OK et al: Optical analysis of surface changes on early re

Murray DW, Rushton N: Macrophages stimulate bone resorption w

Rao AR et al: Tibial interface wear in retrieved total knee compone

Santavirta S et al: Alternative materials to improve total hip replac

Shih LY et al: The effects of sex and estrogen therapy on bone ing

Shrivastava R et al: Effects of chromium on the immune system. F

Skoglund B et al: PMMA particles and pressure—A study of the ost

Wright TM, Bartel DL: The problem of surface damage in polyethy

Wroblewski BM, Siney PD, Fleming PA: Wear of enhanced ultra-hig

Zhang H et al: The effects of patient age on human osteoblasts' re

Gait Analysis: Introduction

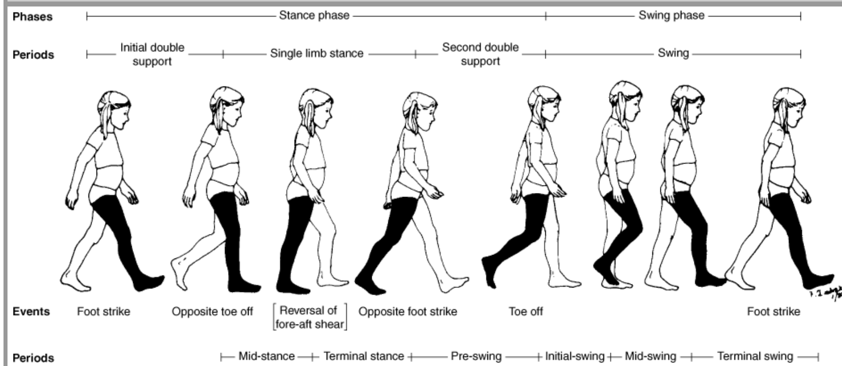
Author: Harry B. Skinner, MD, PhD

The science of studying human walking is called gait analysis. This

GAIT CYCLES, PHASES, & EVENTS

For uniformity in the reporting of gait measurements, investigator

Figure 1–26.



The typical normal gait cycle, with the phases, periods, and event
(From DH Sutherland.)

Two **gait phases** are recognized: the stance phase and the swing

The swing and stance phases are also divided into **gait events** (se

GAIT MEASUREMENTS

The quantities measured in a complete analysis of gait include thre

Movement during Gait

STRIDE CHARACTERISTICS

The fundamental data needed for almost any gait analysis are bas

Velocity of gait is the measure of forward progression of an indiv

Gait cycle is measured as the number of seconds from the initial

Step length is measured as the distance (number of meters) cove

Single-limb and double-limb support times are periods of the

Table 1–4. Gait Characteristics of Normal Men and Wo

Component (Unit of Measure)	Men (Mean ± 1SD)	Women(M
Velocity (m/min)	91 ± 12	74 ± 9

[a]Right equals left in normal individuals.

Data adapted, with permission, from Murray MP, Gore DR: Gait pa

Gait characteristics of normal men and women at free walking spe

Table 1–5. Gait Characteristics of Normal Children at

Component (Unit of Measure)	1 Year	2 Years	3 Years	4 Years
Velocity (m/min)	38.2	43.1	51.3	64.8

[a]Right equals left in normal individuals.

Data adapted, with permission, from Sutherland DH et al: The dev

Stride characteristics are sensitive indicators of diseases and disor

MOTION ANALYSIS

Motion analysis is necessary for the complete characterization of g

Motion analysis has benefits and limitations. On the one hand, it p

Motion analysis has taken on new functions with the interest in up

Energy Consumption during Gait

Energy expenditure results from muscle function and is possible as

Energy expenditure per unit of body mass can be expressed per s

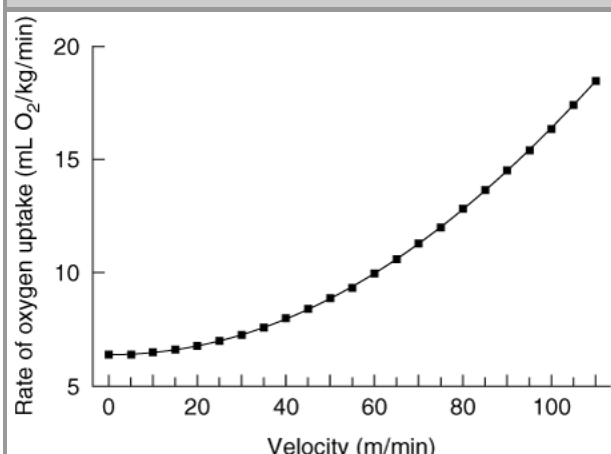
$$\text{Rate of oxygen uptake} = 0.001\,v^2 + 6.0$$

$$\text{Net oxygen cost} = \frac{6.0}{v} + 0.0011\,v$$

The rate of oxygen uptake for normal adults is 11.9 ± 2.3 mL O_2/l

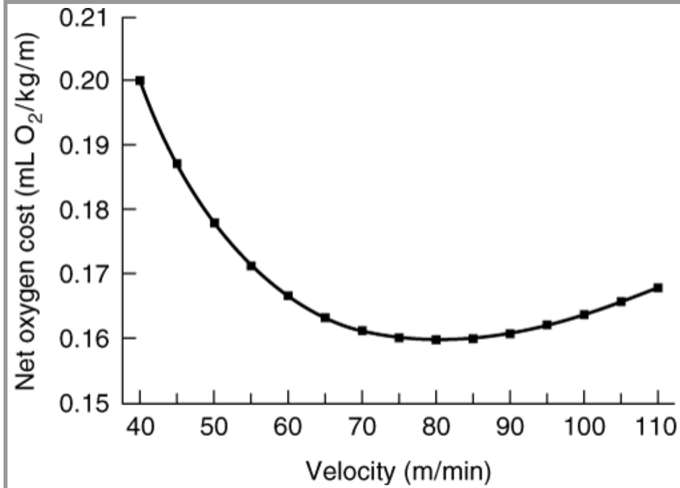
The rate of oxygen uptake increases with the square of the velocit

Figure 1–27.



Rate of oxygen uptake as a function of velocity.

Figure 1–28.



Net oxygen cost as a function of velocity.

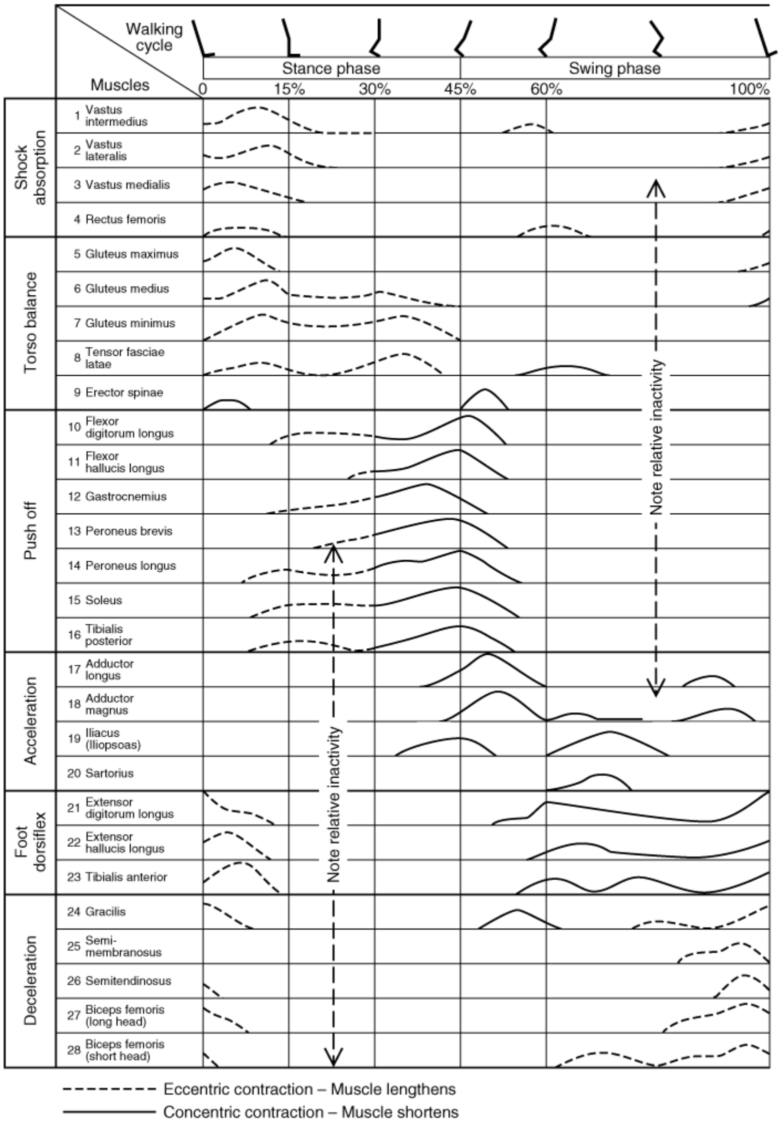
Energy expenditure in gait assumes importance when gait efficien

Muscle Function during Gait

Measurement of the function of muscles during gait is helpful in u

Normal functioning of the muscles can be presented as a function

Figure 1–29.



Tabulation of the on-off activity of the major muscles in the lower
(Reproduced, with permission, from Charles O Bechtel, Los Angele

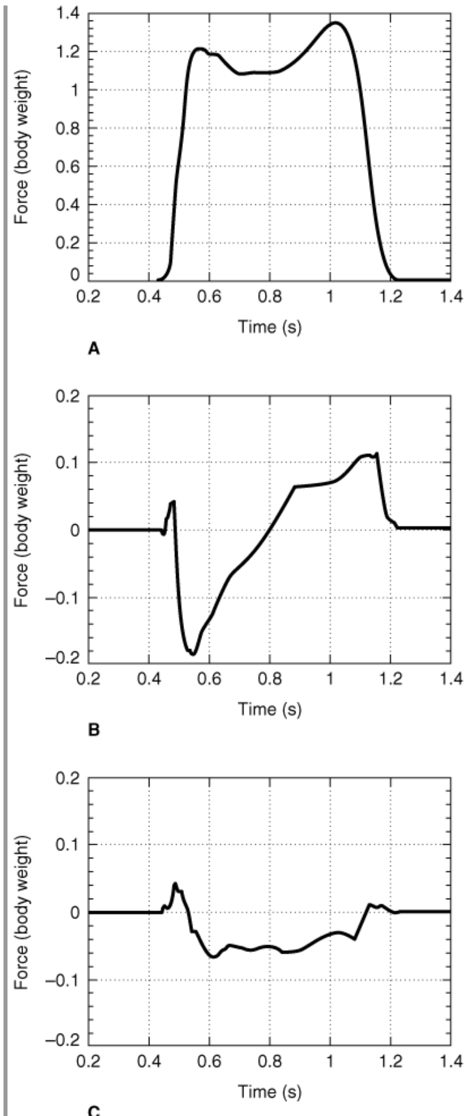
Dynamic electromyography is particularly useful in disorders assoc

Forces during Gait: Kinetics

Forces acting during ambulation arise from gravity, inertia, and gr

Typical curves for the three components of the ground reaction for

Figure 1–30.



The typical ground reaction force for the left foot, shown with its t
(Courtesy of S. Rossi.)

More sophisticated force measurement devices were developed to

Andriacchi TP, Alexander EJ: Studies of human locomotion: past, p

Anglin C, Wyss UP: Review of arm motion analysis. Proc Inst Mech

Burdett RG et al: Comparison of mechanical work and metabolic e

Chambers HG, Sutherland DH: A practical guide to gait analysis. J

Fleisig G et al: Kinematics used by world class tennis players to pr

Marshall RN, Elliott BC: Long-axis rotation: The missing link in pro

Park SS et al: The shoulder in baseball pitching: Biomechanics and

Park SS et al: The shoulder in baseball pitching: Biomechanics and

Perry J et al: Functional evaluation of the pes anserinus transfer b

Saibene F, Minetti AE: Biomechanical and physiological aspects of l

Sutherland DH et al: The development of mature gait. J Bone Join

ROLE OF GAIT ANALYSIS IN THE MANAGEMENT OF GA

Gait analysis was traditionally been a research tool and continues t

New techniques of analysis were developed as computer sophistica

Gait studies of patients with transfemoral and transtibial amputati

Table 1–6. Results of Free Walking Gait Analysis in Pa

Cause and Level of Amputation	Velocity (m/min)	Cadence (s
Traumatic TF amputation	55	86

Data adapted, with permission, from Bagley AM, Skinner HB: Prog

Techniques for gait analysis of amputees also provide the objective

Gait analysis is now a common tool in the treatment and evaluatio

Clinicians can use gait analysis to provide objective clinical data wh

Gait analysis is also improving surgical decision making. One study have pain as the primary indication for surgery, although improven

The results of surgical procedures such as total knee arthroplasty designs. As advances in prosthesis design and gait analysis continu

Table 1–7. Results of Free Walking Gait Analysis in Pa

Study[a]	Patient Diagnosis
(1) Collopy et al (1977)	OA

[a]References are as follows: (1) Collopy MC et al: Kinesiologic meas

OA = osteoarthrosis; RA = rheumatoid arthritis.

Reproduced, with permission, from Skinner HB: Pathokinesiology a

Table 1–8. Results of Free Walking Gait Analysis in Pa

Study[a]
(1) Murray, Brewer, and Zuege (1972)

[a]References are as follows: (1) Murray MP, Brewer BJ, Zuege RC:
and noncemented total hip arthroplasty. Clin Orthop 1990;254:17(

*Asterisk indicates velocity at fast walking speed; otherwise, veloc

NA = diagnostic data not available; OA = osteoarthritis; RA = rheu

Reproduced, with permission, from Skinner HB: Pathokinesiology a

Table 1–9. Results of Energy Consumption Analysis du

Study[a]	Patient Diagnosis
(1) Pugh (1973)	OA

[a]References are as follows: (1) Pugh LG: The oxygen intake and e

*Asterisk indicates velocity at fast walking speed; otherwise, veloc

OA = osteoarthritis; NA = diagnostic data not available.

Reproduced, with permission, from Skinner HB: Pathokinesiology a

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GENERAL CONSIDERATIONS IN ORTHOPEDIC SURGER

Orthopedic surgery encompasses the entire process of caring for t
period. Although the surgical procedure itself is the key step towa

DIAGNOSTIC WORK-UP

History and Physical Exam

Although it may seem obvious, the history and physical exam are
completeness of the history and physical has assumed new import
specified, and this must be clearly defined because it determines t
medical problem and to cover the subsidiary requirements for billi
affecting outcome or success of care. The physical again must cov
considerations as skin condition and blood supply must be docume
most important point here is to use the most cost-effective exami

Imaging Studies

ROENTGENOGRAPHY

Roentgenography is still the most cost-effective and most importa
sophisticated imaging study. Certain situations are obvious; for ex
views taken. If those views show normal joint spaces, consideratio
normal views usually ordered are as follows:

1. **Neck pain—**No history of trauma, more than 4 weeks' duration.

   Younger than 35 years: anteroposterior (AP) lateral, odontoid

   Older than 35 years: obliques

   History of trauma: flexion/extension laterals (obtain on first visit)

2. **Thoracic spine pain and tenderness—**

   Younger than 40 years, no reason to suspect malignancy: AP and lateral (if histo

   Consider cervical (C)-spine as a source of referred pain to thoracic (T)-spine if nc

3. **Lumbar (L)-sacral (S)-spine—**

   Younger than 40 years, no reason to suspect malignancy after 4 weeks duration

   Add obliques for chronic low back pain (ie, spondylolisthesis).

4. **Hips—**

   AP pelvis, lateral of affected hip.

   Consider lumbar-sacral (L-S) series if pain is in the buttock rather than in the gr

5. **Knees—**

   Older than 40 years or history of meniscectomy: Rosenberg, lateral, and sunrise

   For other knees: AP, lateral, and sunrise.

   In the child, up to age 16, consider a pelvis film with the complaint of knee pain a

6. **Femur, tibia, humerus, forearm—**AP and lateral are indicated for trauma, palp
7. **Ankle—**AP lateral and mortise.
8. **Foot—**AP, lateral, and oblique for routine evaluation.
9. **Shoulder—**AP, axillary, scapular Y, and outlet views.
10. **Elbow—**AP and lateral (true lateral).
11. **Hand/wrist—**

    Hand: PA and lateral.

    Wrist: PA, lateral, and oblique

    For suspected instability: clenched fist PA in radial and ulnar deviation.

Follow-up radiographs are obtained when a change in the radiogra Radiographs are obtained in view of the clinical picture. For examp weeks. However, displacement of the fracture could occur sooner. position could be considered stable, and the next films might be ol followed with radiographs at 2-week intervals, checking for displac healing.

MAGNETIC RESONANCE IMAGING

This imaging modality is very useful, but like electron beam compu Frequently in orthopedics, a bony lesion can be localized with a rad fatigue fractures, and osteomyelitis. It is also helpful in some soft- made with a less expensive test. For example, the use of the MRI arthritic knee adds little additional information because the menisc in determining soft-tissue extension of tumors or infection.

The advent of new portable MRI units that perform limited studies arthritis or osteomyelitis in a timely and cost-effective way. The po typically edema, in the bone with osteomyelitis. A bone scan usual should be treated much differently from a soft-tissue ulcer, which

COMPUTED TOMOGRAPHY

The CT scan is an extremely important imaging modality for exam provides the three-dimensional information that can only otherwise such fractures as tibial plateaus, scapular fractures, ankle fracture discerned from the plain films, the CT scan only adds expense and now the method of choice for determining whether a pulmonary em

TECHNETIUM-99M BONE SCAN

The bone scan finds many uses in orthopedic surgery. Keep in min
recorded and little or no bone resorption activity is noted. Any disc
myeloma may not show up on a bone scan because only osteoclas
even though the findings are nonspecific. It is very helpful in exam
scan is also helpful in diagnosing any disorder of unknown origin w
scan points to a region that may benefit from MRI.

Laboratory Exams

The two most important laboratory exams are for C-reactive prote
disorder are diagnostic considerations. If these tests are negative,
next most important test is the complete blood count, which provi
useful laboratory test for the orthopedic surgeon is the synovial flu
differential, protein, and glucose measurement should be perform
suggest infection. The final factor that should be considered with a
prealbumin, albumin, and serum iron transferrin.

Educating & Informing Patients & Their Families

Surgical procedures in orthopedics have varying degrees of difficul
After the decision to employ surgery as a therapeutic modality is r
the legal profession calls **informed consent,** has the more import

To comply with the requirements of the legal profession and accre
an explanation of the risks, prognosis, alternatives, and complicati
surgical procedures. The risks and the complications that occur in
example, a patient with an open fracture has a high risk of infecti
person would consent to the procedure. The choice between alter
procedures or between a particular procedure and no procedure. I
making this decision. For example, consider men, both 75 years o
play golf, a situation that is reducing his physical exercise and a n
cardiorespiratory exercise by swimming, an activity in which his kn
both men must be offered the alternatives, which include continue

Patients with an active lifestyle are becoming much more concern
when they will be fully able to take care of themselves. They are a
prepared to address these questions and also advise patients with
upper extremity, patients must be advised about when they will be
period.

The patient should also be informed about the range of expectatio
be advised that after surgery on the hip or knee, they will need a
before 6 weeks and be done with the cane before 3 months. Patie
thrombosis (DVT). In such cases, discourage (for the first 6 weeks
medication (to reduce platelet adhesion) or anticoagulants should

EXPLAINING THE PROCEDURES

An essential part of the patient's presurgical preparation and posts
the surgical procedures and their implications. For example, sched
realize that she will be unable to wear the shoes she purchased fo
choice between a unicompartmental knee replacement and a high
whether the patient is sedentary and works behind a desk most of

REVIEWING THE RISKS AND POSSIBLE COMPLICATIONS

Reviewing the perioperative risks is important for all patients and
explanations, particularly if their relatives have undergone surgery
explanations, the health care team members needs to alter their a
refuse to undergo a procedure judged to be both beneficial and ne

Risk is a poorly understood concept in our culture. Some situations
understand if these risks are put in perspective. The risks can be s
earthquake or refuse to fly commercial aircraft because of the risk
contribute to significant differences in the perception of liability as
per passenger, whereas death in an automobile accident might hav
patients can understand and accept having a myocardial infarction
understanding of a lower extremity paralysis that can result from
myocardial infarction is clearly different from the healthy 20-year-

Table 2–1. Rates of Death and Complications Associat

Death or Complication	Percentage		
Death (from MI after previous MI)	1	Major bleed (7 days, warfarin, INR 2.65)	0.0

GI = gastrointestinal; INR = international normalized ratio; MI = r

Although all procedures carry some risks, the incidence and type c
are listed and discussed here in alphabetical order.

1. Amputation—The potential problem of amputation is seldom
infection because ischemia and infection can increase the risk of

2. Anesthesia—One of the major risks in orthopedic surgery is
occurs at a rate of approximately 1 in 200,000 patients undergo
blocks; headaches from dural leaks following use of spinal anest
problems with the patient only in general terms, allowing the an

3. Arthritis—Virtually any procedure that enters a joint, other t
likely lessen the risk of arthritis. Even in these instances, the pa

4. Blood loss—Patients should be given a reasonably accurate e
safer but gives the patient who receives it a sense of security. T
postoperative homologous blood transfusion needs. Other altern
accepted by Jehovah's Witness patients, whereas the autologous
drugs (NSAIDs) should be discontinued approximately 2 weeks b
rely on these drugs. To minimize the risk, newer COX-II inhibito
drugs because they do not affect platelet function or inhibit thro

5. Blood vessel damage—Arterial and venous damage take or
disease. Patients generally understand this, but it must be emph
may damage calcified arteries.

6. Deep venous thrombosis/pulmonary embolism—Virtuall
many as 25% of patients who undergo a relatively high-risk pro
of 0.3% for fatal emboli. This rate of fatal PE is approximately a
procedures may be lower. In any case, the patient should be rea

7. Fracture—Many procedures in orthopedic surgery carry the r
virtually any orthopedic procedure could result in fracture of a b

8. Infection—The risk of infection in orthopedic surgery ranges
emphasized in proportion to risk. For example, if a diabetic patie
administration of prophylactic antibiotics, use of ultrafiltration of
occurred. These options include debridement, prosthesis remova
accompanied by the frequent problems associated with pin care
something has gone wrong. Skin problems are frequently associ
patients and individuals who are smokers, have diabetes, or hav
necrosis of the skin edges may occur.

9. Loss of reduction—Although fracture care continues to impr
individualized, based on the type of fracture. Loss of reduction r
surgeon. Poor vascular supply or smoking can be a factor leadin

10. Nerve damage—Certain procedures are associated with ne
from cutting the infrapatellar branch of the saphenous nerve. Th
surgical procedure being pursued and should also be informed o

PROGNOSIS

The prognosis of the procedure is intimately related to the procedu
and depend on the patient's occupation, age, and available sick lea
Driving is an important activity for many people, and limitations pl

The patient should be given reasonable expectations about range o
ability to use a computer keyboard, and the time to expect to be a
determined for each home situation.

KEEPING THE PATIENT AND FAMILY INFORMED

Immediately before elective surgery, the surgeon can help comfor
outcome of the surgery. Giving the family a good estimate of the s
that are detrimental to the patient. If the family members wish to
completed and the patient is no longer at risk of untoward acciden
appropriate to emphasize particular concerns to the family, such a

Johnson BF et al: Relationship between changes in the deep venou
to six-year follow-up. J Vasc Surg 1995;21:307. [PMID: 7853603]

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11128112]

Warner C: The use of the orthopaedic perioperative autotransfusic

SURGICAL MANAGEMENT

Preoperative Care

THE TEAM APPROACH

Inclusion of nurses, residents, anesthesiologists, and other membe
Good estimates of the length of the operative procedure and of th
site of the operation and assessing the need for any special suppli
be exercised by all members of the operative team to prevent "wr

PREPARING AND POSITIONING THE PATIENT

Once the patient is in the operating room, every effort should be r
and after anesthesia is induced. If the anesthesiologist indicates th
these can be put in place prior to induction. Placement of arterial l
must be adjusted to ensure good lighting, optimize the efficiency c

Positioning of the patient is the responsibility of both the surgeon
by a nerve palsy that results from the failure to pad a remote area
downside shoulder girdle must be protected. During shoulder surg

maximize the operative field. Similarly, the patient's shoulder shou
particularly necessary in treating rheumatoid patients or older oste
patients into the lateral decubitus position or prone position.

USE OF ANTIBIOTICS

Except in cases in which concern about infection requires unambig
cephalosporin antibiotic is considered appropriate for orthopedic pı

USE OF A TOURNIQUET

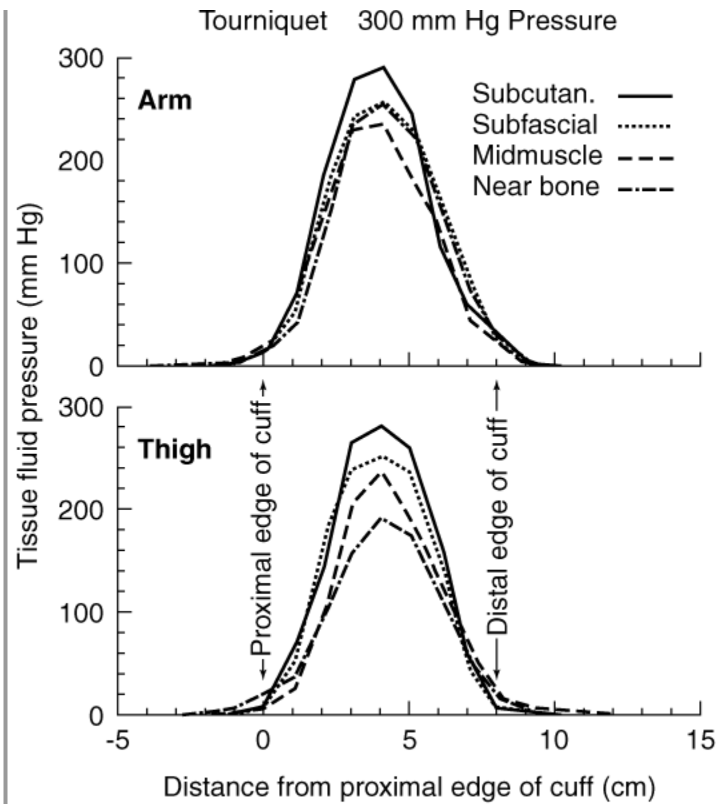
A tourniquet can be extremely helpful in some procedures and is p
tourniquet is inflated to a pressure that must be significantly highe

1. **Tourniquet size and placement—**The tourniquet should be
muscles that cross the elbow or knee, the tourniquet should be
a large extremity with a great deal of adipose tissue, care must
on the skin. Slippage can be prevented by applying 5-cm (2-inch

2. **Tourniquet time and pressure—**The effects of tourniquets
deleterious effects arising from direct pressure to structures anc

Several considerations are involved in the selection of the level of
the pressure around the arterial supply to the extremity is greater
patient with a stable blood pressure, tourniquet pressures of 75 m
the tourniquet is on an extremity with a great deal of adipose tissu
and can be tested with an independent pressure measurement dev

Figure 2–1.



Distribution of tissue fluid pressure at four depths beneath pneum
on each graph.

(Reproduced, with permission, from Hargens AR et al: Local comp

Complications will arise if tourniquets are used at high pressure fo
pressure below the tourniquet. A rule of thumb is that tourniquet
the tourniquet, investigators found that 90-minute tourniquet time
surgical procedures under tourniquet. After tourniquet release, ref
to tourniquet inflation facilitates emptying of large veins of the thi
especially when reinflation of the tourniquet is planned.

Barwell J et al: The effects of early tourniquet release during total

Classen DC et al: The timing of prophylactic administration of anti

Darmanis S, Papanikolaou A, Pavlakis D: Fatal intra-operative puln

Fernandez AH, Monge V, Garcinuno MA: Surgical antibiotic prophyl

Hargens AR et al: Local compression patterns beneath pneumatic

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[PMID: 8448950]

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Operative Care

The surgical team should make every effort to work efficiently dur
take from 10 to 30 minutes or longer. It is in the best interests of

INCISION SITES AND APPROACHES

Although the surgical wound "heals side-to-side, not end-to-end,"
the patient, slow the healing process, and lengthen the rehabilitati
intensifier should be considered in obese patients or in patients wi

The incision should be made perpendicular to the skin, generally lo
the subcutaneous fatty layer is variable and depends on the locati
upper extremity and in areas where cutaneous nerves can be trou
dissection with scissors used to spread tissue perpendicular to the
devascularize it.

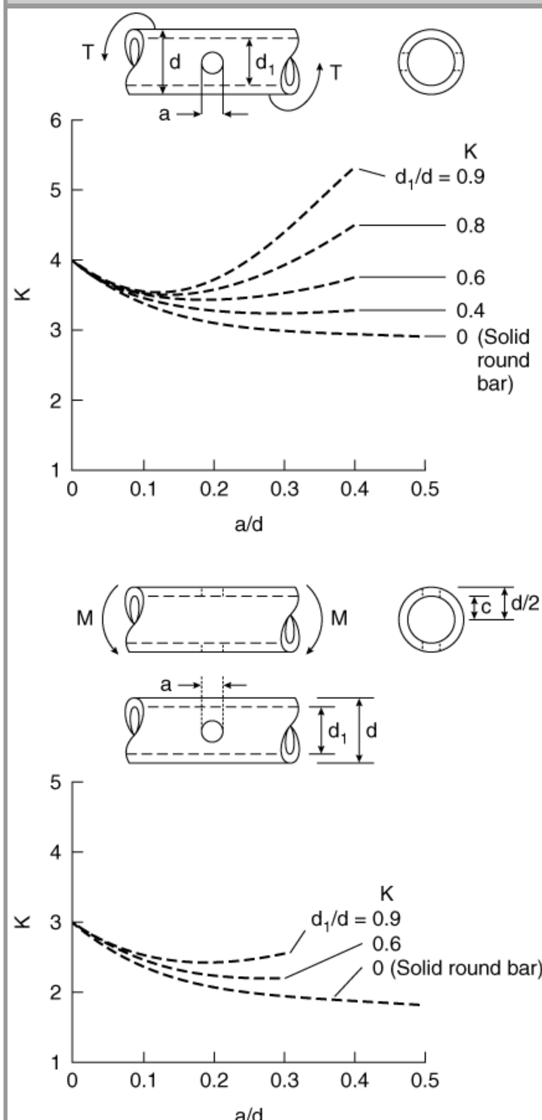
Surgeons must be extremely careful with the skin, making sure to
is much better for the skin than extreme tension. Care of the soft
suffer damage from both traction and compression. Nerve palsies
cartilage includes keeping it moist because drying has a deleteriou

Surgical approaches that go through internerve planes, such as be
approach should also be avoided because splitting is generally mor
keep tumor cells in a single compartment.

ORTHOPEDIC INSTRUMENTS AND DRAINS

It is mandatory that tools be sharp at all times because the sharpr
osteotome or elevator is needed, the concurrent use of a hammer
achieve by pushing on an osteotome. With drill points and power s
Unless using a drill guide, the surgeon should start drilling bone in
off the desired bone entry point. Holes in long bones are stress co
drill holes to terminate saw cuts (Figure 2–2). When holes were m

Figure 2–2.



Stress concentration factors for torsion (**top**) or bending (**bottom**
inside diameter of the tube; K = the stress concentration factor, d
(Modified and reproduced, with permission, from Peterson RE: *Str*
Wiley, 1974.)

Obtaining hemostasis in bone can be troublesome, and the use of
bony surfaces. Despite the traditional use of drains by surgeons, e
necessary and may lead to increased blood loss. If drains are usec
generally removed within 48 hours of surgery unless they are usec

CLOSURE AND DRESSING

Wound closure should be done quickly and efficiently to minimize t
entered, it is sometimes worthwhile to remove scar tissue from th

wound closure is necessary to avoid tension on the skin in many a
passive motion machines or early motion, which may apply repetit
adhesives and sutures for closure of incisions, although the adhesi

Dressings should be padded with cotton or gauze to discourage th
total knee arthroplasty. Tape should be avoided when possible bec
blistering and other problems.

Batra EK et al: Influence of surgeon's tying technique on knot secu

Brown MD, Brookfield KF: A randomized study of closed wound su

Coulthard P et al: Tissue adhesives for closure of surgical incisions

Kolt JD: Use of adhesive surgical tape with the absorbable continu

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Ong CC, Jacobsen AS, Joseph VT: Comparing wound closure using
Epub accessed June 14, 2002. [PMID: 12415411]

POSTOPERATIVE CARE

Inpatient Care

Postoperative care begins in the postanesthesia room and is the sa
of the postoperative patient, including pain management, blood m
Sensory and motor exam of the pertinent upper or lower extremit
diminished. The wound site should be checked for excessive draina
primarily the concern of the anesthesiologist, should be evaluated

During the subsequent postoperative period, orthopedic aspects o
and neural status of the extremities affected by the surgery, as we
setting. Hourly examinations may be necessary in the face of a po
mute or alter the pain picture in a compartment syndrome, makin

PAIN MANAGEMENT

Pain management is a major issue in the United States. There is a
concept, resulting in litigation and disciplinary action by state med
concerns that they would be disciplined by state medical boards. T
control be a factor in the total evaluation of the patient and pain e
with 0 being no pain and 10 being unbearable pain. Acceptable pa

Pain is a very subjective sensation that is an emotional response t
component, transduction to a nerve impulse. The next component

cerebral cortex (perception). Pain perception depends on culture, (
is also based on patient expectations. Studies show that preoperat

Traditional postoperative pain management included the administra
analgesia (PCA) is now a mainstay. In this system, morphine is use
administered as often as every 10 minutes. Doses can be increase
more cautious dosing can result in insufficient pain relief that can s
narcotics. Patient rehabilitation can be delayed; nausea, vomiting,

Alternative postoperative analgesic methods are proposed. These i
have the potential of providing significant pain relief but must be b
spinal or epidural anesthetic provides pain relief for a limited time,
providing pain relief for up to 48 hours. It has the additional proble
epidural or intrathecal analgesia poses the problem of inhibiting re
these patients are mandated to go to the intensive care unit. Nerv
all nerves to an area to control postoperative pain. Hence, studies
body cavity, with some designs allowing an intermittent bolus for r
mL/hour. Ropivacaine is reported to have vasoconstrictive properti

In the past, non-narcotic pharmacologic treatment of acute postop
is restricted in oral intake. Although ketorolac is an effective analg
other NSAIDs can be used for analgesics. Neither ketorolac nor oth
have on the platelets and subsequent blood loss. The availability o
without fear of bleeding problems. These drugs act to reduce the r
administered parenterally, and these drugs may be of major assist
and Drug Administration (FDA). The use of highly specific COX-2 in
increased cardiovascular events with long-term use. At this time, c
platelet function is minimal.

Other analgesics and techniques do not get sufficient recognition f
significant relief of pain. It can be tolerated in doses up to 4 g/day
reduce the requirement for narcotics. Another analgesic that shoul
through inhibition of norepinephrine reuptake as well as a weak μ-a
analgesic effect. Glucocorticoids are naturally increased in periods
increase in cortisol production of 17-fold after TKA, but no such in
prescribed for such patients. High doses (20 mg) of dexamethason
reduce postoperative nausea, swelling, and pain, as well as create
doses of glucocorticoids may be beneficial in reducing postoperativ
Hemostasis may be achieved through the use of bone wax on canc
nociceptive transduction.

A comprehensive approach to pain management can lead to benef
process. Combinations of medications can include narcotics, acetar
given to administering these medications in the preanesthesia roor
addition to pharmacological interventions, patient education can re

Bianconi M et al: Pharmacokinetics and efficacy of ropivacaine con

Cook P, Stevens J, Gaudron C: Comparing the effects of femoral n
2003;18:583. [PMID: 12934209]

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safety in 154 patients. Acta Orthop Scand 2004;75:606-9. [PMID:

Reuben SS et al: Evaluation of the safety and efficacy of the perio

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DEEP VENOUS THROMBOSIS/PULMONARY EMBOLUS

DVT, a potentially life-threatening disorder, frequently accompanie
after surgery. This is one of the expected risks after surgery. Venc
put the risks of PE into appropriate perspective because, contrary
a PE depends on a number of risk factors, including age, weight, t
the location. There is an uncertain relationship between DVT and t
become emboli, and which ones will cause problems are still unres
do. It is generally conceded, however, that DVT is a marker for PE
but this is thought to be an unlikely circumstance, and it is specula
to be a significant problem that results in incompetence of the valv
over time. However, many things are thought to cause these chan
Coast census region having the lowest fatal PE rate. The rate of fa
population older than 65 years is in the range of 0.03%, whereas
total hip or knee replacement.

Table 2–2. Rates of Complications Associated with To

Complication	Percentage			
Death (overall)	0.5	Myocardial infarction	0.5	Pul

Reproduced, with permission, from Mantilla et al: Poster presentec

Three classes of drugs can be used for chemoprophylaxis of DVT:
the platelet aggregation inhibitors (aspirin, naproxen, other NSAID
days to reach therapeutic levels, but its oral route of administratio
molecular-weight heparins do not affect the prothrombin time or t
given in standard doses. These medications are provided parenter
NSAIDs, although causing problems with bleeding at the time of su
pneumatic compression. These are efficacious as adjunctive thera

The American College of Chest Physicians regularly performs and
risk surgery, either warfarin with an international normalized ratio
compression are useful as supplemental protection against DVT. Th
situations. Table 2–3 lists the current recommendations.

Table 2–3. Recommendations for Management of DVT

Procedure	Grade	Recommendation									
THA/TKA	1A	LMWH started 12–24 h after surgery			Or		1A	Fondaparinux 2.5 mg started 6–8 h after surgery			Or

THA = total hip arthroplasty; TKA = total knee arthroplasty; LMW
ratio based on randomized trials without important limitations; 1B
studies; 1C+ Grade = same as 1C but based on indirect evidence.

Derived from Geerts WH et al: Prevention of Venous Thromboemb

The community standard in orthopedic surgery probably differs so
warfarin is the drug of choice but with lower INR values. However,
thromboembolism and bleeding problems.

Both warfarin and heparin, either low-molecular-weight or regular,
syndromes unrelated to the operative site. Heparin can induce thr
hypercoagulable state that can result in serious problems of coagu
but are not indicated for DVT prophylaxis. These drugs are related
in the presence of heparin-induced thrombocytopenia.

In addition, ximelagatran is an antithrombin drug that may soon b
a manner similar to heparin.

Diagnosis

DVT is diagnosed with ultrasound in the postsurgical patient with c
the suspicion of DVT. These include immobilization, lower extremit
of the thigh veins but less reliable for calf veins. The gold standarc
PE has evolved. In nonsurgical patients, *d*-dimer can be helpful in
period. Previously, ventilation/perfusion scans were the standard r
reported to be 70% sensitive and 91% specific. In outpatients witl
evidence from a preliminary study suggests that fibrin monomer d
not significantly until 7 days postoperatively.

Ananthasubramaniam K, Shuafra M, Prasad A: Heparin-induced th

Ballard JO: Anticoagulant-induced thrombosis. JAMA 1999;282:31(

Brookenthal KR et al: A meta-analysis of thromboembolic prophyla

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Kane RE: Neurodeficits following epidural or spinal anesthesia. Ane

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Wells PS et al: Excluding pulmonary embolism at the bedside with(

using a simple clinical model and D-dimer. Ann Intern Med 2001;1

Outpatient Care

Economic realities today mandate earlier discharge from the hospi patients must take more responsibility for their care, and surgeon the reasons for admission have narrowed. The reasons for keeping parenteral narcotics, presence of hemodynamic instability, a need therapy is not an adequate reason for an acute-care stay. Thus tin delayed recognition of a complication. In most cases, the first visit Follow-up for a total hip replacement patient might be at 2 weeks, and how much external support the patient is receiving (physical t yearly on a permanent basis. The American Academy of Orthopedi bacteremia may occur, for 2 years after joint replacement, althoug

Long-term follow-up for patients with plates, screws, pins, rods, o Antibiotic prophylaxis is not necessary for these patients. In cases generally not indicated. In younger (less than 50 years), active pa prevent fracture prophylactically. An adequate period (12 weeks o induced in the bone during removal of hardware. For a detailed dis

Harrington P et al: Acute compartment syndrome masked by intra

Pacheco RJ et al: Gluteal compartment syndrome after total knee

Richards H et al: Does patient controlled analgesia delay the diagr

Blood Loss & Replacement

Because blood replacement is now a complicated issue, it is fortun brochure from the state that describes the blood management opt form for the patient to sign, verifying receipt of this information. F conflicting, however, and generally the decision is based on the ph approximately 5 L in a 70-kg individual. Normal individuals can be state is maintained, but transfusion should be considered. The sta postoperative subacute phase can be managed with volume replac myocardial infarction, or those with decreased cardiac output may unless they have postural hypotension, tachycardia, dizziness, or f

CRITERIA FOR BLOOD TRANSFUSION

The decision to transfuse in the immediate postoperative period is availability of blood (autologous, designated donor, or bank), and t healthier patient until the patient has a hematocrit level of 20–22% patients at risk of stroke or myocardial infarction would be candida

STRATEGIES FOR MINIMIZING THE RISKS ASSOCIATED WIT

Blood loss is an inevitable part of surgery. With the realization tha transmission were developed.

An obvious method of accomplishing this goal is to reduce blood lo the actual blood loss. The patient has to be counseled to avoid ant over-the-counter analgesics, cough and cold remedies, and arthrit tranexamic acid and aminocaproic acid (antifibrinolytic), and fibrin efficient and meticulous to reduce time and therefore blood loss. T to reduce blood loss.

Presurgical banking of autologous blood by the patient (with or wit intraoperative and postoperatively lost blood with infusion of eithe blood. The problems with autologous blood begin with the cost, bu greatest risks are bacterial contamination and clerical error, in whi and not put into the general blood bank pool.

Preoperative hemodilution has the cost associated with the operati boosted through parenteral erythropoietin, which can minimize the autologous blood at $300–400/unit. Furthermore, there may be ris Witnesses who refuse transfusions.

Despite initial resistance and continued questions about cost effect blood bank administrators. There are disadvantages of autologous possible bacterial contamination of the blood, perioperative anemia wastage of autologous blood that is not used. Blood can be stored methods. Use of autologous blood can eliminate the need for bank of 10 g/dL and hematocrit level of 30%) that preclude their predor use of recombinant human erythropoietin therapy. Injections can b admission. Although expensive, this therapy can be of benefit to p receiving blood from others.

Red blood cells can be salvaged by suction in the operating room c effective. The salvaged blood is generally washed to remove cell d process.

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Ethics in Orthopedic Surgery

Ethics in medicine started with Hippocrates and was codified by Th
1847 and has undergone several revisions over time. Ethics basica
or artificial insemination, have little to do with orthopedics. Althou
which orthopedists have to abide, with tighter constraints than eth
orthopedics are addressed here.

Clinical Trials

A particularly difficult ethical area is the clinical research study. Alt
for Human Research Protections, and sponsors of research, the sir
controls. The three main areas for concern are the use of ionizing
indicated, and the use of patient data in a manner that does not m
patient/subject consent is obtained. This must be done in a formal
unindicated studies (laboratory, radiographs) at patient expense is
and Accountability Act changed the way physicians have to look at
closely controlled with care taken regarding personal data assistan
domain may be acceptable for presentation, although in some situ
publications cannot be used without written patient permission. Th
(HIPAA) regulations, especially with local area networks that perm

The typical orthopedic clinical research study is a retrospective rev
controlled, double-blind studies, but until the funding is found to d
decision making. This is especially be true for low-volume procedu
maintaining patient confidentiality, and conflict of interest. The firs
of interest has at least two aspects. Physicians may be consultants
their surgery, that is, they do not want to look like "bad" surgeons
publications as part of promotion requirements or simply want to '
financial conflict. The potential financial conflict should be disclosed
share medical advances, and presenting surgeons' results with a p

Gifts from Industry

The concept that gifts from industry may affect the choice of medi
other remuneration, subsidies for meetings, and so on, if the prim
pharmaceutical and orthopedic manufacturers are now self-regulat
only allowed to discuss "label" applications of the drug or device, w
label" uses of products. Payment for travel costs, lodging, and hor
consulting. Although it seems unlikely that a physician would chan

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THE HIGH COST OF MUSCULOSKELETAL TRAUMA

Trauma is the "neglected disease." It is the leading cause of death
caused by morbidity and premature mortality, and pain and suffer
costs from the 2000 Medical Expenditure Panel Survey (MEPS) anc
unintentional trauma, half of which were caused by motor vehicle
million emergency department visits annually. The economic burde
population, 10,000 deaths associated with trauma are recorded an

Musculoskeletal disorders generated 3.5 million admissions to acut

1. physical and psychologic effects of pain, limitation of daily activities, loss of indep
2. direct expenditures for diagnosis and treatment; and
3. indirect economic costs associated with lost labor and diminished productivity.

Musculoskeletal injuries occur frequently, result in significant disab
nursing home care $1.6 billion. More recent estimates show an inc

Mass casualty situations as a result of terrorism are the challenge
great number of victims. The terrorist attacks in Oklahoma City (1

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THE HEALING PROCESS

Bone Healing

Bone is a unique tissue because it heals by the formation of norma
from the diaphysis, epiphysis, or metaphysis. Bone will, therefore,

Fracture healing can be divided into primary and secondary healin
Secondary fracture healing results in the formation of callus and ir

Fracture healing can be conveniently divided, based on the biologi

1. Hematoma formation (inflammation) and angiogenesis.
2. Cartilage formation with subsequent calcification
3. Cartilage removal and bone formation
4. Bone remodeling

HEMATOMA FORMATION AND ANGIOGENESIS

Initially, there is an inflammatory phase characterized by an accum
cells and osteoblasts to produce type II collagen and proteoglycans
where the periosteum is intact, these cells probably come from the
derived from the pericytes found around capillaries, arterioles, and

Whatever their origin, these cells ensheathe the fracture and diffe
present during cartilage formation. This initial callus acts as an int
peripheral distribution adds to rigidity. Clinically, the fracture beco

CARTILAGE FORMATION WITH SUBSEQUENT CALCIFICATIO

Radiologic evidence of mineral formation signals the onset of this p
supersaturated solution. Mineralization causes the chondrocytes th
bone on the exposed surface of the bone, if conditions are favorab

The phase of mineralized callus leads to a state in which the fractu

CARTILAGE REMOVAL AND BONE FORMATION

The woven-bone mineralized callus has to be replaced by lamellar
phase between the ends of the bone; it is also called **gap-healing**

1. It forms only under conditions of mechanical stability;
2. It has the ability to replace fibrous or muscle tissue; and
3. It forms within the confines of the bone defect

Gap-healing bone is essentially coarse fibroid bone and, therefore,

REMODELING

This final phase involves the replacement of woven bone by lamell

Two lines of cells, osteoclasts and osteoblasts, are responsible for

Cartilage Healing

Articular cartilage consists of extracellular matrix (ECM) and chond
endurance.

Chondrocytes are sparse in the adult cartilage, which is not a vasc
rationale behind rigid internal fixation of fractures is to allow early

Rapidly applied forces to the articular cartilage prevent adequate f

1. Injuries to the cartilage matrix and cells.

Caused by acute or repetitive blunt trauma. Evidence of alterations in ECM (decrea

2. Chondral fissures, flap tears, or chondral defects.

Limited, short chondrocytic reparative response. Loss of segmental cartilage.

3. Osteochondral injuries.

Hemorrhage, fibrin clot formation and inflammatory response. Fibrocartilage format

Articular cartilage has limited reparative capacities because chondr
smallest defects. If the calcified plate is violated, the subchondral
matrices, growth factors, perichondrium, periosteum and transplar

Tendon Healing

Tendons are specialized structures that allow muscles to concentra
fibrocytes. These cells are nourished by the synovial fluid secreted

Muscle Healing

Human skeletal muscle is divided into fiber types depending on the
as **fast twitch** or **white** muscle, is subdivided into two types, acco
contraction. Fiber type interconversion can occur, but this is gener
Interconversion between type 2A and 2B fibers is much more likely

Traumatic injury to muscle can occur from a variety of mechanism
resulting from excessive stretching. In addition to muscle regenera
myositis ossificans and may cause decreased function. Muscle stra

Of particular concern to the traumatologist is the effect of immobil
are minimized if immobilization occurs with some stretching of the

Nerve Healing

Peripheral nerves have a distinct anatomic structure, with multiple
length, reflecting greater or lesser nerve fibers in each fascicle. Ar
extension cycles. Nerve damage may occur through direct compre
is reversible. Second-degree injury is equivalent to axonotmesis, w
endoneurial tube. The perineurium is preserved, however. Because
degeneration of the fascicles. Despite the continuity of the nerve t
restoration of function.

Functional recovery after nerve injury depends on a number of var
the nerve, the technical ability of the surgeon, and the length of ti

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ORTHOPEDIC ASSESSMENT & MANAGEMENT OF POLYT

A thorough understanding of the pathophysiology of trauma is ess

Life-Threatening Conditions: The ABCs of Trauma Care

A systematic approach is required in all cases. The patient is asses
the major functions of the body. Assessment consists of four overl

1. Primary survey (ABCDE)
2. Resuscitation
3. Secondary survey (head-to-toe evaluation and history) and
4. Definitive care

This process, identifies and treats life-threatening conditions, and

*A*irway maintenance (with cervical spine protection);

*B*reathing and ventilation;

*C*irculation (with hemorrhage control);

*D*isability (neurologic status);

*E*xposure and environmental control (undress the patient but prev

A brief overview of the treatment of polytrauma patients, with spe

AIRWAY

Great care should be taken while assessing the airway. The cervica
or jaw thrust maneuver should be used to establish an airway. A G
cervical spine, including the C7-T1 disk space, does not rule out ce

BREATHING

The trauma surgeon should evaluate the patient's chest. Adequate

1. Tension pneumothorax
2. Flail chest with pulmonary contusion
3. Open pneumothorax and
4. Massive hemothorax

CIRCULATION

Hemorrhage is the principal cause of postinjury deaths that are pr
or the pelvis can cause major blood loss, which can severely comp

DISABILITY (NEUROLOGIC STATUS)

The Glasgow Coma Scale (see Chapter 13) should be used to asse

*A*lert and oriented,

or responds to *V*ocal stimuli,

or responds only to *P*ainful stimuli,

or is *U*nresponsive.

EXPOSURE AND ENVIRONMENTAL CONTROL

Recognition of lacerations, contusions, abrasions, swelling and def
problems. Hypothermia must be avoided, as cardiac function may

CARE OF PATIENT BEFORE HOSPITALIZATION

The diagnosis and treatment of musculoskeletal injuries in polytra
elements and limit hemorrhage. In many cases, proper care at thi

The old saying "splint them where they lie" remains especially true

1. The joints above and below the fracture should be immobilized.
2. Splints can be improvised with pillows, blankets, or clothing.
3. Immobilization does not need to be absolutely rigid.
4. Apply gentle in-line traction to realign the extremity in severe angulation.
5. Overt bleeding should be tamponaded with available dressings and firm pressure
6. Tourniquets should be avoided, unless it is obvious that the patient's life is in dan

Orthopedic Examination

HISTORY

Injury mechanism: an adequate assessment of the conditions in w

1. MVA: speed; direction (T bone, rollover etc.); patient location in the vehicle, imp
2. Falls: distance of the fall; landing position.
3. Crush: weight of the object, site of the injury, duration of weight application.
4. Explosion: blast magnitude; patient distance from the blast: primary blast injury
5. Vehicle-pedestrian: type of vehicle, site of collision, speed.

Environmental exposure, comorbidity, pre-hospital care and obser

GENERAL EXAMINATION

The clinical orthopedic examination requires assessment of the axi
each joint. Examination soon after trauma may precede telltale sw
of the iliac wings in a mediolateral, anterior-posterior direction an

NEUROLOGIC EXAMINATION

The neurologic examination of the extremities should be documen
also important. Thus, in the upper extremity, dermatomes from C

MUSCLE EXAMINATION

Motor examination can be difficult because of pain or impaired me
opponens pollicis muscles) must be examined. A more complete ex
desirable, but demonstration of a minimum of volitional control (ev

Particularly important in the face of spinal cord injury or suspectec
in Chapter 5, "Disorders, Disease, & Injuries of the Spine.")

Imaging Studies

Radiologic assessment follows the same general hierarchy as the c
information obtained from this film dictates treatment and the nee

Subsequent evaluation is dependent on clinical findings. Any long b
usually the anteroposterior and lateral views. Coordination of more
scanning should be performed with the fewest changes of position

"Clearing" the Cervical Spine

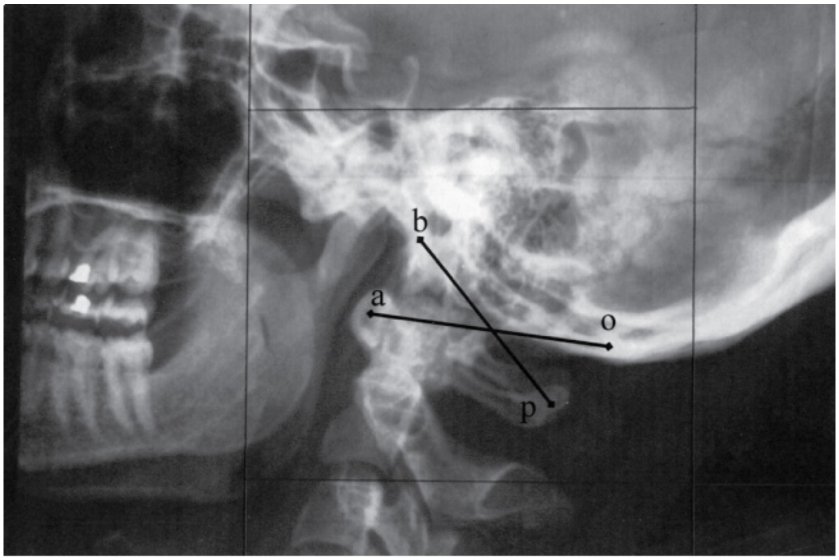
In the evaluation of the trauma patient, an important consideratio
force and suffer injury. In the conscious and responsive patient, sv

The essential radiographs for evaluation of the cervical spine incluc
abducted and elevated, should be obtained.

After the cervical spine x-ray films have been reviewed, the ligame
patient who can safely sit upright. These films are often delayed fo

In the obtunded patient, CT and/or MRI scan is necessary to delin
should describe an arc. The distance from the basion to the poster
injury. The posterior border of the anterior arc of C1 should be wit
dislocation should be suspected. Suspected cervical spine fracture
soft tissues and reduction maneuvers. In the case of neurologic de

Figure 3–1.



Powers ratio: a – anterior arch of atlas, b – basion, p – posterior a

IMMEDIATE MANAGEMENT OF MUSCULOSKELETAL TRA

The orthopedic injuries in the polytrauma patient are seldom truly

For example, fracture-dislocation of the ankle or knee resulting in open fracture should be treated immediately with pressure to mini

Orthopedic management of traumatic injuries requires consideratio damage is clearly important in achieving satisfactory function afte

Complications

From the orthopedist's viewpoint, the major complications associat formation. The first five disorders involve pulmonary complications however, and constant vigilance is necessary to prevent serious co

ACUTE RESPIRATORY DISTRESS SYNDROME

Acute respiratory distress syndrome (ARDS) can be a sequela of tr activate the immune system. Pulmonary endothelial damage result saturation if appropriate treatment is not instituted.

Fat embolism syndrome is a unique orthopedic manifestation of nonfracture situations, as when the medullary canal of a long bone

The clinical diagnosis of ARDS is confirmed by a decrease in arteria hypoxemia with ventilatory support as needed. Prevention is enha

ATELECTASIS

Atelectasis, or localized collapse of alveoli, is a frequent postopera Occasionally, radiograph examination, showing platelike collapse o

PULMONARY EMBOLISM AND DEEP VENOUS THROMBOSIS

Although ARDS and atelectasis are seen in the early postoperative
associated with a 13-fold increased risk of venous thromboembolis
history of prior venous thromboembolism, major surgery of the ab
the legs are dependent. Oral contraceptive and smoking use may

Geerts and colleagues examined the incidence of DVT and PE in tr
Severity Score (ISS) greater than 8. Overall, they reported an inci

Patients at high risk for PE are those with DVT in the lower extrem
molecular-weight heparin, pentasaccharide, or sodium warfarin; ar

Clinical diagnosis of DVT is unreliable. Definitive diagnosis is made
rate of PE.

Pulmonary embolism is suspected in the orthopedic patient sufferi
rub can be noted.

Arterial blood gas studies demonstrate hypoxemia, although this is
there is a high or low probability of pulmonary embolus. Spiral CT

Treatment involves pulmonary support and heparin therapy. The n
characterized by chronically painful swelling in the extremity.

COMPARTMENT SYNDROME

The term **compartment syndrome** refers to pathologic developm
contents of the compartment over a period, and can result in necr

Compartment syndrome may result from a fracture; a soft-tissue
results in ischemia of the area under pressure because of collapse

The diagnosis of compartment syndrome must be considered in th
extremity.

The five P's (pulselessness, paresthesia, paresis, pain, and pressur
This points to the importance of careful documentation of sensory
compartment syndrome is unlikely unless it is early. Pain with pass
but palpation of a soft compartment does not rule out the diagnos
measurements. Intracompartmental pressure readings within 30 n
fasciotomy even despite normal pressures. Late fasciotomy may re

Although compartment syndrome can occur in almost any portion
calf, two incisions are used to release the four compartments of th
limited incision approaches have been described, these may be un

HETEROTOPIC BONE FORMATION

Clinically significant heterotopic ossification occurs as a consequen
significant, resection may be indicated when the bone has matured

Resection is accomplished by removing the entire piece of heteroto
This is believed to result from release of humeral modulators that

Classification of Open Fractures

GUSTILO AND ANDERSON CLASSIFICATION

Gustilo and Anderson made a significant contribution to trauma ca
uses three grades and divides the third most severe grade into thr

Grade I fracture is a low-energy injury with a wound less than 1 cr

Grade II fracture involves a wound more than 1 cm long and signi

Grade III open fracture has extensive wounds more than 10 cm in
from outdoor sites such as with tornado disasters or farming accid

Grade III injuries are divided into subtypes A, B, and C. Grade III
IIIB fractures, in contrast, have extensive soft-tissue injury with p
The soft-tissue and bony damage may be as severe for closed frac

Severe soft-tissue and bony injuries, especially when open, raise t
reconstruction may be necessary to achieve a united tibia fracture
particularly in the trauma patient at the below-knee level, may we

Early Total Care

The desirability of early total and appropriate orthopedic care in m
fractures were entered into an early fixation group (treatment witl
fixation was delayed. Bone and collaborators did a follow-up retros
compared with historical records of 906 patients from the America

In a study by Reynolds, Richards, and Spain, records of 424 conse
authors noticed that progressive surgical delays caused by decline
authors concluded that the severity of injuries, not the timing of fr

Damage Control Orthopaedics

Controversy exists, however, regarding the appropriate timing of c
inflammatory mediators with deleterious results in specific patients

The multiply injured patient's immunological system is stimulated
neutrophils are the principal effector of the inflammatory response
trauma. Damage control Orthopaedics aims to decrease the additi

Alternatives to modify the inflammatory response are currently un

Soft-Tissue Injuries & Traumatic Arthrotomies

Lacerations of the extremities can result in neural or vascular com
Other soft-tissue lacerations may require neural or vascular repair.
prevent late imbalance or loss of function. Muscle belly injuries ge
tendon of the muscle. In this case, optimal function is obtained by
blood clot inside.

In most cases, immediate treatment of open fractures and lacerat
Tetanus prophylaxis is administered if needed. Antibiotic therapy is

Irrigation and debridement are intended to convert a clean contam
debrided, as should dead muscle, and the surface of any contamin

After debridement, bone surfaces and exposed tendons should be
be left open, closed fractures should be left closed" was suitable m
debridement may be closed, leaving the original débrided laceratic
Adequate closure to cover bone and other structures that may be
wounds that are left open may be closed safely at 3–5 days.

Flaps and Soft-Tissue Coverage for Open Trauma

Soft-tissue wounds in association with skeletal trauma (Gustilo gra
treated best by large regional soft-tissue flap reconstruction. Befo
microsurgical techniques for skin, muscle, and fascia transplantatic
requirement for this procedure is radical debridement of the zone

If radical debridement is not performed, then flap reconstruction s
compromised extremity, preventing infection and simultaneously p

There are many sites that can be harvested for flaps. The most co
host of smaller tissue transfers designed for more specific uses tha

A recent innovation in wound management is the Vacuum Assisted
stimulation, and local increase of growth factors. Also, edema fluid
with large traumatic wounds. Additional orthopaedic indications inc

Gun-Shot Wounds

Optimum treatment of fractures caused by gun-shots relies upon a
Gun-shot wounds to the musculoskeletal system result in complex
important. Additional characteristics are the efficiency of energy tr

$$KE = \frac{M}{2} \times v^2$$

where *M* equals mass and *V* equals velocity. Thus velocity and mis
kinetic energy, resulting in a more severe injury. Additionally, shot

In gun-shot wounds and high-velocity missiles, shock waves, lacer
pressure in the cavity sucks contaminants in from both ends. Seco
is suspected.

Low-velocity civilian gun-shot wounds and fractures are relatively s
or external fixator means is somewhat controversial. On the one h
gun-shot wounds in ballistic injuries can be significant. In a study
surgery service was consulted were evaluated. These 284 patients
patients were privately insured. The authors concluded that during
drainage. If the fracture requires surgical treatment, antibiotic pro

Multiple Trauma Treatments—Strategies and Traumati

The surgeon who has to provide fracture care to patients who hav
orthopedic injuries and multisystem organ injuries.

Within these categories, orthopedic injuries are either life- or limb-

Several classification systems have been used to try to stratify the
separated into five domains with each assigned a point value from

The Abbreviated Injury Scale (AIS) divides injuries into nine body

The Injury Severity Score (ISS) is the sum of the squares of the h
is associated with an ISS of less than 30, whereas an ISS greater

Factors at the time of injury, which have a bearing on the decision
previously used as a predictor of eventual amputation; however, re

Table 3–1. Factors in Evaluation of the Mangled Extre

	Points			
A. Skeletal and soft-tissue injury		Low energy (stab; simple fracture; "civilian" gunshot wound)	1	Medium multiple f dislocatio

[a]Score doubled for ischemia more than 6 hours.

Adapted and reproduced, with permission, from Johansen K et al:

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FAILURE OF FRACTURE HEALING

Fracture union is a gradual, continuous process where the mechan
osteonal remodeling. The speed of healing by periosteal callus dep

Generally, a fracture has united when there is radiographic eviden

Many variables have an effect on the fracture healing process, incl
ends are in close apposition and the affected area has been adequ

Nonunion of Fracture

Despite the best efforts and treatment, a certain percentage of fra
6 months. Delayed union is represented by evident cessation of pe

Nonunion is less well defined. Clearly, a fracture that fails to show
simply left immobilized.

Nonunion corresponds to scar formation in which the rate of endos
bone formation is taking place, the morphology will be atrophic.

REASONS FOR NONUNION

There are many reasons why a fracture might not heal. The two m
abnormalities, and infection. Infection at the fracture site does not

Table 3–2. Causes of Nonunion.

1. Excessive motion: inadequate immobilization	2. Diastasis of fracture fragments	a. Soft-tissue interposition	b. Dis traction fixation

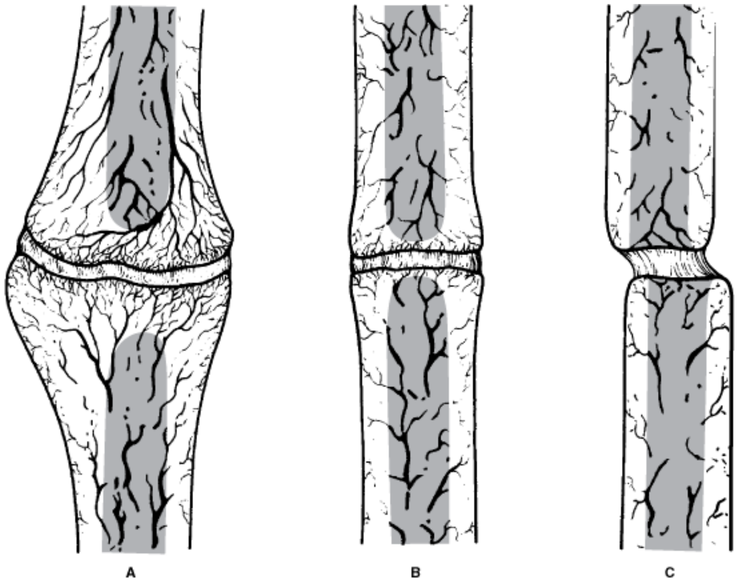
Adapted and reproduced, with permission, from Rosen H: Treatme

The location of the fracture is also an important factor in healing. (
the body. Fracture pattern also plays a role in the development of

CLASSIFICATION OF NONUNIONS

Nonunions have been classified according to their radiologic charac
Hypertrophic nonunions have viable bone ends, whereas **atrop**
3–2). It is somewhat confusing as to what actually causes a viable
those with either no motion, excess motion, or distraction and a le

Figure 3–2.



Weber and Cech's subclassification of hypertrophic nonunions: ele
(Reprinted, with permission, from Browner BD et al, eds: *Skeletal*

COMPLICATIONS OF NONUNION

Grossly mobile hypertrophic or atrophic nonunions that are left un
intervention is the only treatment option available.

Figure 3–3.

Fourteen-year-old distal humeral pseudarthrosis left untreated in

TREATMENT

Once nonunion has been established, the physician must establish
as the degree of functional impairment the patient is actually expe

Stimulation of Osteogenesis by External Forces

It is now known that several pathways exist to stimulate healing o

MECHANICAL FORCES

Application of mechanical forces to achieve bony union has remain
method. Cyclic mechanical force of ambulation while the fracture r

Mechanical forces can also be generated by surgical means. Mecha
caused by weight bearing. The compression plate provides stability

ELECTRICAL STIMULATION

Electrical fields have also been shown to stimulate the dormant ch
devices that are incorporated in a cast or functional brace around
to a statistically significant increase in healing of documented dela
these fractures are usually immobilized and weight bearing is ofte

BIOLOGICAL ENHANCEMENT

Chemical modulators also play an important role in promoting non
modulators from the grafted cancellous bone are responsible for st
bore needle from the iliac crest and injecting this into the nonunio

PATHWAYS OF SIMULATION

It is interesting to note that although three separate forces exist t

Atrophic Nonunions

Atrophic nonunions are not as easily treated as hypertrophic nonu
fixation and autogenous bone grafting. This same procedure is use

The Ilizarov method has also shown great success in the treatmen
be present.

Malunion of Fracture

A fracture that has healed with an unacceptable amount of angula
Hence, no absolute guidelines can be given as to an acceptable ve
caused by walking on the side of the foot secondary to varus malu

When correction of malunion is undertaken, proper preoperative p
(where a wedge of autogenous or allograft bone is added). This is
malunion to a nonunion is only worsening an already bad situation

Determination of the true plane of deformity is essential in plannin
lateral radiographs, as the axis is usually in a plane somewhere be

Ilizarov Method

The Ilizarov apparatus and the concepts of distraction osteogenesi
throughout the world have employed this method to pioneer mode
Accordingly, leg length discrepancy, deformity, nonunions, and infe

The basic premise of the Ilizarov technique is that osteogenesis ca
either controlled distraction or compression. This dogma is a funct
permits axial micromotion with postoperative weight bearing, whic
termination of distraction, neutral fixation is required to allow mat

Clinical principles such as the geometry of the apparatus once it is
comfortable as possible because for an extended period of time. P

From a technical viewpoint, Ilizarov methodology relies on the use
possible the limb lengthening or osteogenesis required in bone tra
healing.

During distraction osteogenesis, the new tissues are aligned parall
distraction gap and soon differentiate into osteoblasts. A hyperemi

As noted earlier, the circular external fixator is attached to the lim
well as to provide for rigidity of fixation, to prevent unwanted tran
essential to achieve good bone regeneration and union. This cyclic

With the incorporation of hinges, plates, rods, and other elements
unique is that all problems affecting a limb can be managed with t
angulatory deformity or gradual correction via application of hinge
the same time that the nonunion is being compressed. Ilizarov als
some of the limb length at the nonunion site. In essence, Ilizarov f
differentiate into functioning osteoblasts and allow for bone synthe

The Ilizarov method has revolutionized thinking about fracture hea
stress effect have changed Western thinking regarding limb length
method will continue to grow.

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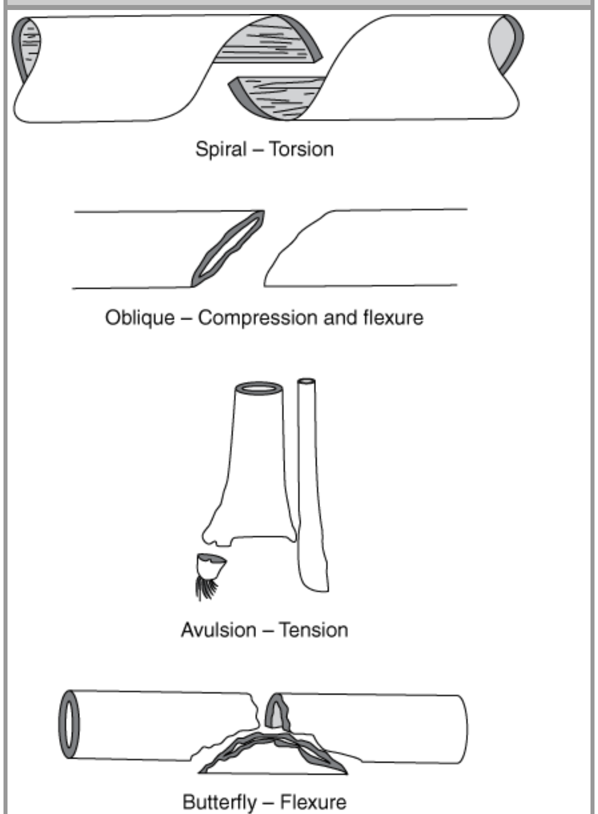
Weresh MJ et al: Failure of exchange reamed intramedullary nails

PRINCIPLES OF OPERATIVE FRACTURE FIXATION

Fractures occur when one or more types of stress, in excess of fai
order to treat the fracture. Examples of these mechanisms are sh

Figure 3–4.



Mechanisms of failure of bones.

Biomaterials Used in Fracture Fixation

Operative fracture fixation requires strength and flexibility of the f
healing to occur. The elastic modulus of titanium is half that of sta
materials, including composites, cannot be contoured in the operat

Biomechanical Principles of Fracture Fixation

The principles of operative fracture fixation are demonstrated by s
the load sharing that goes on between bone plates in bone. In adc

BONE PLATE THICKNESS

One approach to solving the problem of bone plate fractures is to
half the thickness of the plate, and the area moment of inertia, *I,*

$$\frac{bh^3}{12}$$

where h is the thickness of plate and b is the width of the plate. T

$$s_{max} = \frac{6M}{bh^2}$$

because c is equal to one-half of h. Doubling the thickness decreas

$$\frac{6M}{4bh^2}$$

Thus, increasing the thickness of the plate by a factor of 2 reduce
h, which would mean that the plate is eight times stiffer (but only

TITANIUM AND STAINLESS STEEL RODS

The second consideration is the difference in the stress carried by
modulus. A higher flexural rigidity indicates a greater resistance to

$$p^3 r_{ave}^3 t$$

where r is the average radius and t is thickness. Assuming this equ

$$\frac{E_m I_m}{E_b I_b} = \frac{r_m^3 t_m E_m}{r_b^3 t_b E_b}$$

The r_{ave} for the metal is 5 mm and for the bone 7.5 mm; t_m is 1 m

$$\frac{E_m I_m}{E_b I_b} \begin{array}{l} = 0.60 \text{ for stainless steel} \\ = 0.30 \text{ for titanium alloy} \end{array}$$

This indicates that the geometric contribution to stiffness of the co
steel alloy rods. The difference between the two metals is probably

BONE PLATE

The placement of a plate on a bone has a significant bearing on its
Conversely, placement of a plate posteriorly tends to cause the fra
of bending bisects the broad aspect of the plate, and thus the bon
the bone will be placed in compressive loading as a result of muscl

The conventional plate and screw system requires substantial bone
blood supply and hence the healing process. The Low Contact Dyn

The recently developed locking plates or internal fixators use a sys
unicortical screws can be used. This achieves relative stability and

EXTERNAL FIXATION

External fixation is an important treatment modality for musculosk
fractures. These devices can be useful as temporary treatment for
stabilization for healing as well as provisional treatment for grade

For the pelvis, rapidly applied external fixation with compression fo
fractures, and in the treatment of open forefoot injuries and femu

These specific uses of external fixation will be discussed in the indi

Bone Substitutes Used in Fracture Fixation

AUTOGENOUS BONE GRAFTING

The gold standard for bone grafting material to stimulate bone gro

OSTEOCONDUCTIVE GRAFT SUBSTITUTES

Hydroxyapatite and tricalcium phosphate, are inorganic structural
testing. The common denominator is that these are osteoconductiv

DONOR BONE ALLOGRAFTS

The third alternative bone substitute is allograft derived from living
same. Immunogenicity, sterility, mechanical properties, and bone s
delivered in a sterile manner without further sterilization or proces
ethylene oxide perhaps being worse than irradiation. Freeze-dried
accepted dosage of gamma radiation is 2.5 mrad, but even this do

OSTEO-INDUCTIVE AGENTS

Initially, bone substitutes consisted either of autogenous bone graf
The identification of such specially purified BMPs, which had been s
human trials. These proteins can potentially be coupled with a colla

Demineralized bone matrix (DBM) is another osteo-inductive agent
effect than standard allograft, as the growth factors have not been

Cobos JA, Lindsey RW, Gugala Z: The cylindrical titanium mesh cag

El Maraghy AW et al: Influence of the number of cortices on the st

Kurdy NG: Serology of abnormal fracture healing: The role of PIIII

Laurencin C, Khan Y, El-Amin SF: Bone graft substitutes. Expert R

MMWR 2002;51:207–210: Update: Allograft-associated bacterial in

Radomisli TE et al: Weight-bearing alters the expression of collage

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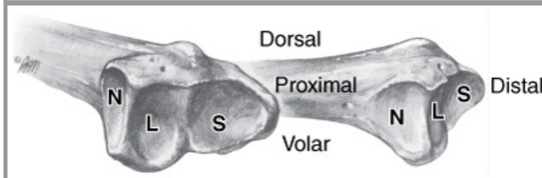
Zlotolow DA et al: The role of human bone morphogenetic protein

Fractures & Dislocations of the Distal and I

Anatomy & Biomechanical Principles

The articular surfaces of the radius, ulna, scaphoid, lunate and tri
which allows articulation with the ulna medially. Between the scap
the radial scapholunate and radial lunocapitate ligaments.

Figure 3–5.



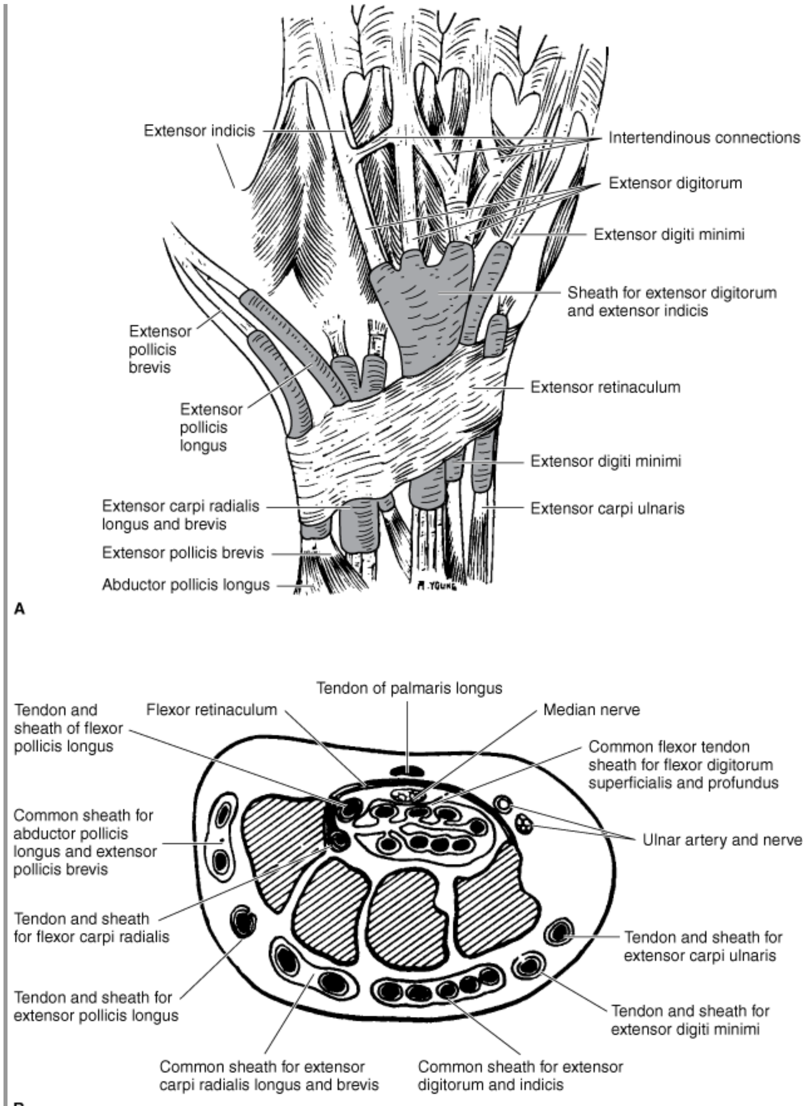
Articular components of the distal radius. L = lunate articular surf

(Reproduced, with permission, from Green DP, Hotchkiss RN, Pede

The third articular component of the distal radius is the sigmoid no
the ulnar collateral ligament at the wrist. The concave elliptical dis

In addition to the bony surfaces, the articular cartilage, joint caps
tendons and the median nerve. On the ulnar surface, the flexor ca
ulnar artery and nerve. In the most superficial soft tissue layer of

Figure 3–6.



A: Dorsal section of the wrist, showing the six dorsal compartmen

(Reproduced, with permission, from Jenkins DB: *Hollinshead's Fur*

The radius and the ulna structurally support the forearm. The dist
pronation and supination. The radius has a lateral bow that is cruc

The interosseus membrane in the interosseous space connects the
interosseus membrane.

Berger RA: The anatomy of the ligaments of the wrist and distal r

Blazar PE et al: The effect of observer experience on magnetic res

Cober SR, Trumble TE: Arthroscopic repair of triangular fibrocartil

Freeland AE, Geissler WB: The arthroscopic management of intraa

Gupta R, Bozenthka DJ, Osterman AL: Wrist arthroscopy: Principle

Lindau T, Adlercreutz C, Aspenberg P: Peripheral tears of the trian

McGinley JC et al: Mechanics of the antebrachial interosseous men

Nakamura T et al: Origins and insertions of the triangular fibrocart

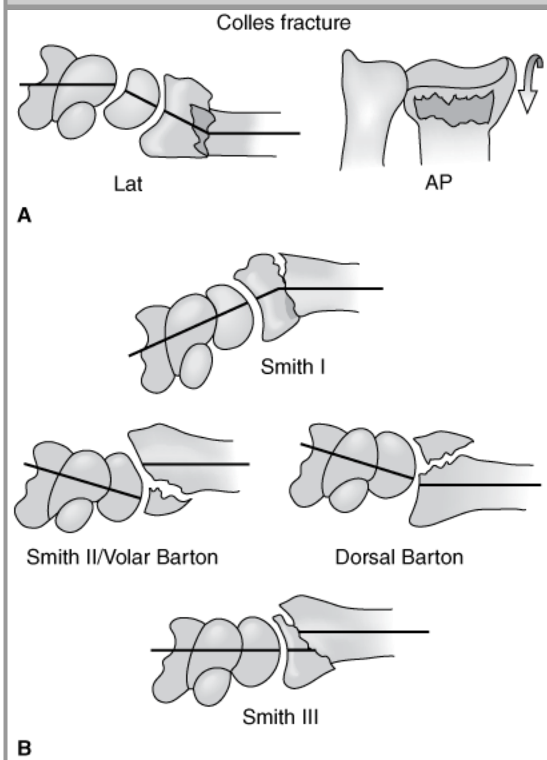
Poitevin LA: Anatomy and biomechanics of the interosseous memb

DISTAL RADIUS & ULNA INJURIES

Distal Radius & Ulna Fracture

Fractures of the distal radius account for approximately 14% of all
displacement, loss of radial inclination and resultant radial shorten
a part of a fracture-dislocation involving the wrist. **Barton's fractu**
hand cranking to start. When the engine engaged, the crank woul

Figure 3–7.



Schematic drawings of Colles fracture (**A**) and Smith and Barton f
(Reproduced, with permission, from Green DP, Hotchkiss RN, Pede

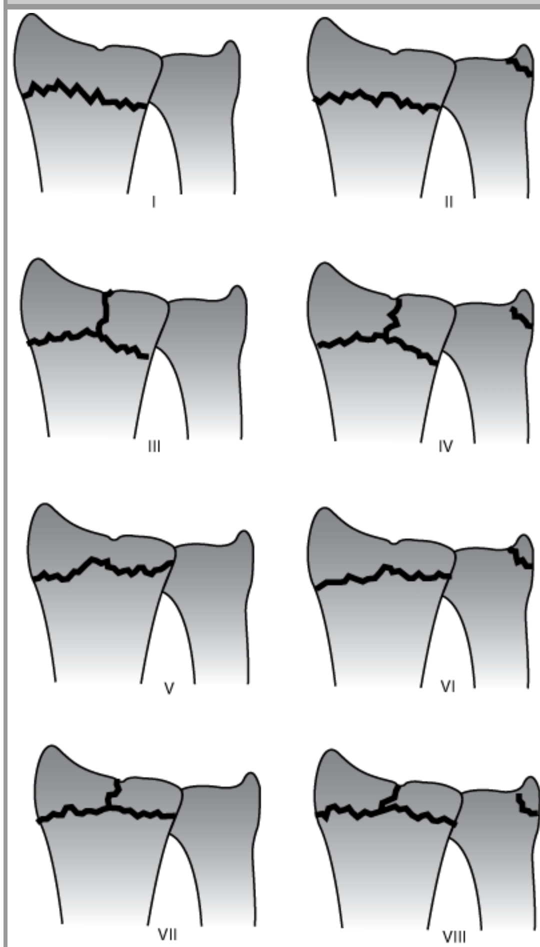
Fracture Classification

In modern day fracture care, the emphasis has shifted from "nam

No one fracture classification system is comprehensive in describin

The Frykman classification categorizes fractures by the presence o

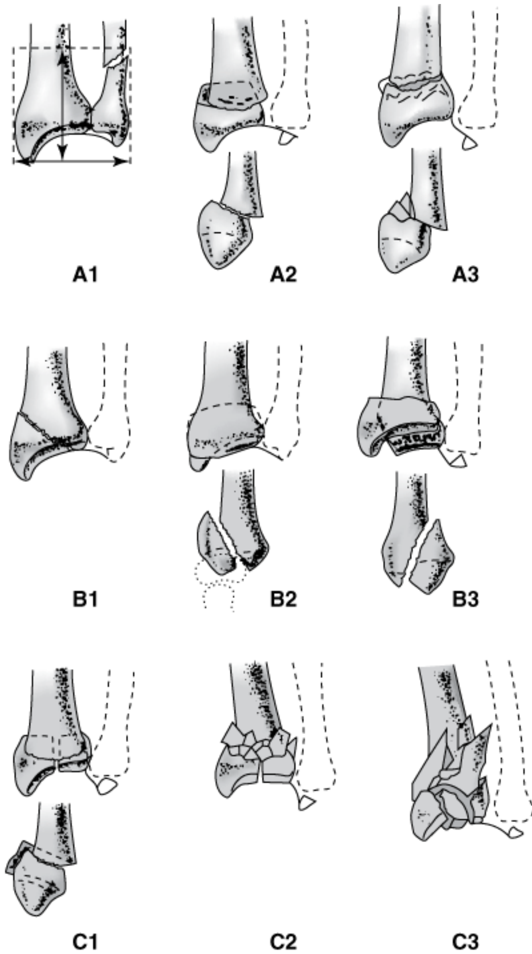
Figure 3–8.



Classification of distal radius fractures according to Frykman.
(Reproduced, with permission, from Green DP, Hotchkiss RN, Pede

The AO classification and its derivative, the OTA fracture classificat
classifications that relate to the particular amount of displacement

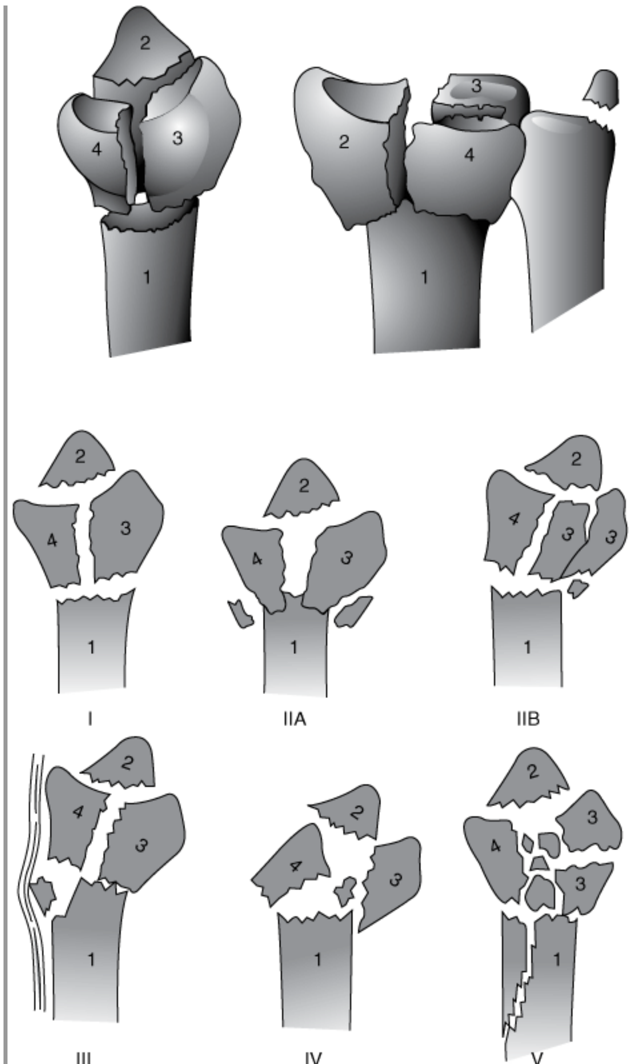
Figure 3–9.



AO classification of distal radius fractures. **A:** Extraarticular metap
impaction. **B:** intraarticular rim fracture (preserving the continuity
and metaphysis). **C1:** Radiocarpal joint congruity preserved, meta
(Reproduced, with permission, from Green DP, Hotchkiss RN, Pede

Another useful classification that addresses intraarticular fractures
scaphoid fossa a separate component. Four-part articular fracture

Figure 3–10.



Intraarticular fracture classification of Melone.

(Reproduced, with permission, from Green DP, Hotchkiss RN, Pede

Treatment

Treatment of distal radius fractures should be influenced by fractu
mm. Additional factors to consider are fracture displacement, intra
injuries to the carpal ligaments or to the triangular fibrocartilage c

CLOSED PROCEDURES

Closed Reduction with Splinting and Casting

Extraarticular distal radius fractures in certain individuals (classic C
lead to increased load in the lunate fossa, distal ulna, and triangula
abutment, which may necessitate later reconstruction. In minimall

Percutaneous Pin Fixation

Percutaneous pins can be an effective adjunct to cast treatment o
preventing loss of reduction. The pins can be removed after 4 wee
formation around the pin can be seen.

External Fixation

External fixation is an effective way to handle distal radius fractur
effective. There is the additional advantage of not devascularizing
external fixation can be used but reductions are difficult to mainta

OPEN REDUCTION AND INTERNAL FIXATION

Plate and Screws

Plate and screws can be extremely effective in achieving and main
achieve. Other drawbacks to this technique include creation of an

Recently, distal radius plates with fixed-angle screws have been de
plates and early postoperative range of motion may provide impro

Arthroscopically Assisted Reduction

Arthroscopically assisted reduction can address the associated liga
intraarticular distal radius fractures.

TREATMENT DECISIONS

Besides fracture type and comminution, additional factors that mo
cast application is the appropriate treatment. In contrast, intraarti
pinning and external fixator can be the most suitable treatment.

Extraarticular Nondisplaced Fractures

Extraarticular nondisplaced fractures can be treated with cast imm

Extraarticular Displaced Fractures

Closed reduction should be attempted on extraarticular displaced f
fracture) may be necessary. Current trends toward plating via a v

Intraarticular Fractures

The treatment of intraarticular fractures aims to restore the congr
contraindications to this treatment are cases with excessive comm
ascertain that both articular alignment and overall radial length ha
the displacement is severe. In this case, open reduction and interr
degrees and loss of radial inclination <10 degrees. Arthroscopicall
grafting in the acute treatment of comminuted fractures.

Distal Radioulnar Joint Dislocation

The distal ulna transmits significant loads to the forearm through t
mechanisms, including low- and high-energy trauma. These are as
orientation will tend to look relatively normal. A displaced fracture

Clinical Findings

The clinical examination is key, with identification of the distal radi
displace the ulnar head applying a dorsal to volar load 4 cm proxir
associated with such motion, would be expected in such a situatior

Treatment

Dorsal dislocation, or subluxation, should be treated by reduction (
dislocation or subluxation of the distal ulna cannot be reduced witl
more dorsal position to stabilize the distal ulna, as has been descri

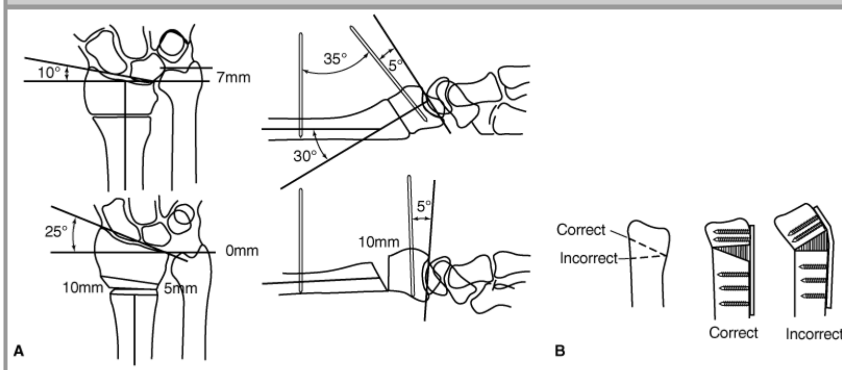
Malunion of Distal Radius

Malunion of the distal radius can have a variety of negative consec
angulated malunions. CT of both wrists can be used to identify and

Treatment

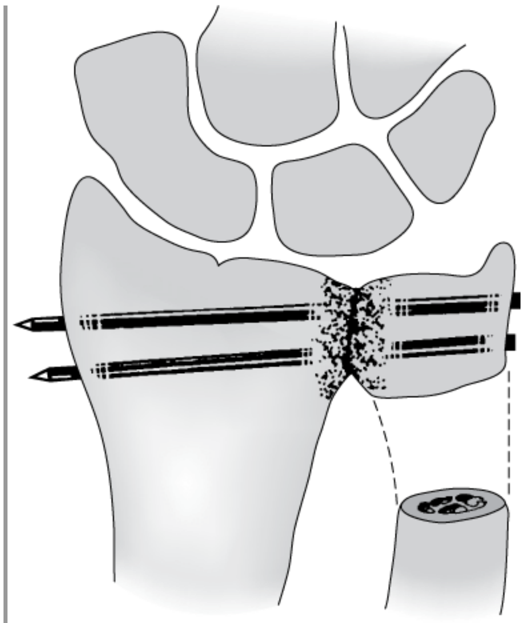
The treatment of choice in such a situation, if conservative treatm
subluxation or arthrosis, may require closed reduction, open reduc
distal ulna to the radius, using the resected bone as grafting mate
of laminar spreaders to distract the proximal and distal fragments

Figure 3–11.



Wedge osteotomy of the distal radius with iliac crest bone graft ar
(Reproduced, with permission, from Green DP, Hotchkiss RN, Pede

Figure 3–12.



Suave-Kapandji reconstruction of the distal radioulnar joint.

(Reproduced, with permission, from Green DP, Hotchkiss RN, Pede

If the distal radius has settled into a position of shortening and sig
to better long-term results. Additionally, the distal radioulnar joint
arthroplasty.

Abboudi J, Culp RW: Treating fractures of the distal radius with art

Carter PB, Stuart PR: The Sauve-Kapandji procedure for post-trau

Chhabra A et al: Biomechanical efficacy of an internal fixator for tr

Jakob M, Rikli A, Regazzoni P: Fractures of the distal radius treate

Katz MA et al: Computed tomography scanning of intraarticular dis

Ladd AL, Pliam NB: The role of bone graft and alternatives in unst

Margaliot Z et al: A meta-analysis of outcomes of external fixation

May MM, Lawton JN, Blazar PE. Ulnar styloid fractures associated w

Mehta JA, Bain GI, Heptinstall RJ: Anatomical reduction of intraart

Orbay JL, Fernandez DL. Volar fixed-angle plate fixation for unstab

Rogachefsky RA et al: Treatment of severely comminuted intraarti

Schneeberger AG et al: Open reduction and plate fixation of displa

Viso R, Wegener EE, Freeland AE: Use of a closing wedge osteotor

DISLOCATION OF THE RADIOCARPAL JOINT

Dislocation of the radiocarpal joint is usually accompanied by signi
Associated fractures, such as transscaphoid perilunate or distal rac
dense neuropathy is present.

FOREARM SHAFT FRACTURES

In general, any fracture requires evaluation both clinically and rad

Isolated Fracture of the Ulna (Nightstick Fracture)

Nondisplaced or minimally displaced fractures of the ulnar shaft ar

Treatment

A variety of treatment options are possible for managing minimally
achieved excellent results using a functional brace for isolated ulna
excellent results with minimal or no immobilization. In general, sor
in the adult with displacement >50% or angulation >10 degrees (
seems to provide comparable results to plate fixation, but further

Isolated Radial Shaft Fractures

A fracture anywhere along the length of the radius with or without

Treatment

Open reduction and internal fixation with plate fixation is recomme
approach using compression plating, the distal radioulnar joint sho
ligaments or removal of interposed soft tissue is mandatory.

Monteggia Fracture

Classification of Fractures

In 1814, Monteggia of Milan described an injury involving fracture
following ways:

Type 1: Fracture of the ulnar diaphysis with anterior angulation an

Type 2: Fracture of the ulnar diaphysis with posterior angulation o

Type 3: Fracture of the ulnar metaphysis, with lateral or anterolat

Type 4: Fracture of the ulna and radius at the proximal third, with

Other authors have noted that type 3 fractures may be more com

Associated lesions include injury to the radial nerve; palsies of bot
head dislocation may be missed if appropriate radiographs are not

Treatment

Closed treatment is usually satisfactory for children, but open redu
allow healing with sufficient stability. Internal fixation is best perfo
annular ligament, the lateral epicondyle, and the radial head. Entr

Fractures of Both the Radius & Ulna

Fractures of both the radius and ulna (both-bones fractures) usual

Treatment

Treatment of choice for both-bones fractures is open reduction an
the radius and ulna, which is critical to forearm function and in pa
subperiosteal stripping only of the fracture site. The plates can be
significant bone loss. Only the skin is closed so as not to cause co

Many authors recommend plate fixation for Gustilo type I, II, and
than one third the cortical circumference and comminution that co

Catalano LW 3rd, Barron OA, Glickel SZ. Assessment of articular di

Chung KC, Spilson SV: The frequency and epidemiology of hand a

Dell'Oca AA et al: Treating forearm fractures using an internal fixa

Iqbal MJ, Abbas D: Distal radioulnar synostosis following K-wire fi

Qidwai SA: Treatment of diaphyseal forearm fractures in children

Sarmiento A, et al: Isolated ulnar shaft fractures treated with fun

Wei SY, et al: Diaphyseal forearm fractures treated with and with

Ruch DS, Vallee J, Poehling GG, Smith BP, Kuzma GR. Arthroscopi

Injuries Around the Elbow

Anatomy & Biomechanical Principles

The elbow is one of the most confined articulations in humans. The
palpated include the medial and lateral condyles and the olecranor
when clinically assessing the elbow for fractures, dislocations, or e
diameter of the distal humerus in the mediolateral plane. Each cor
the ulnotrochlear joint, the radiocapitellar joint, and the proximal r
coronoid and radial fossa, which receive the coronoid process of th
insertion into the olecranon posteriorly; anteriorly, the brachialis ir
important portion being the anterior band of the medial or ulnar co
fan-shaped lateral collateral ligament, whose origin is the lateral e

DISTAL HUMERUS FRACTURES

Intercondylar-T or -Y Fractures

Intercondylar humerus fractures are among the most challenging f
medial and lateral column for reconstructible bone fragments and

Classification

Jupiter and Mehne classified distal humerus fractures into intraarti

1. Single column: Divided into medial or lateral
2. Bicolumn: Divided into TT, TY, TH, lambda, or multiplane pattern
3. Capitellum fractures
4. Trochlea fractures

Extraarticular fractures are classified into intracapsular and extrac

Table 3–3. The Jupiter and Mehne Classification of Dis

I. Intraarticular fracture	A. Single-column fractures	1. Medial	a. High	b. Low	2. Lateral	a. High	Lo

Reproduced, with permission, from Browner BD et al, eds: *Skeleta*

Treatment

Traditional treatment favored closed techniques because of the dif
fixation (ORIF) in even the elderly (>70 years) population. Total el

Early operative methods consisted of pins and plaster or limited op
approach have also been described.

Intercondylar T fractures have two distinct components: the intraa
the medial or lateral column is required to complete the operative
helpful for achieving stable fracture fixation in patients with osteo

In summary, intraarticular distal humerus fractures should in gene

Fracture of the Humeral Condyles

Both medial and lateral condyles can be disrupted. These fracture

Lateral Condylar Fracture

Lateral column fractures are single-column injuries and are dividec
injuries, respectively. Stable internal fixation with early range of m

Medial Condylar Fracture

Medial condyle fractures are similarly single-column injuries with lo

Both fractures, if displaced, should be treated with ORIF and early

Fracture of the Epicondyles

Although lateral epicondylar fractures are rare, medial epicondylar
percutaneous pinning or open reduction. Elbow instability is not ge

OLECRANON FRACTURES

The olecranon is the most proximal posterior eminence of the ulna
epicondyle at the posterior medial aspect of the elbow and then pi

Fracture of the olecranon commonly occur with a direct blow or as

Clinical Findings

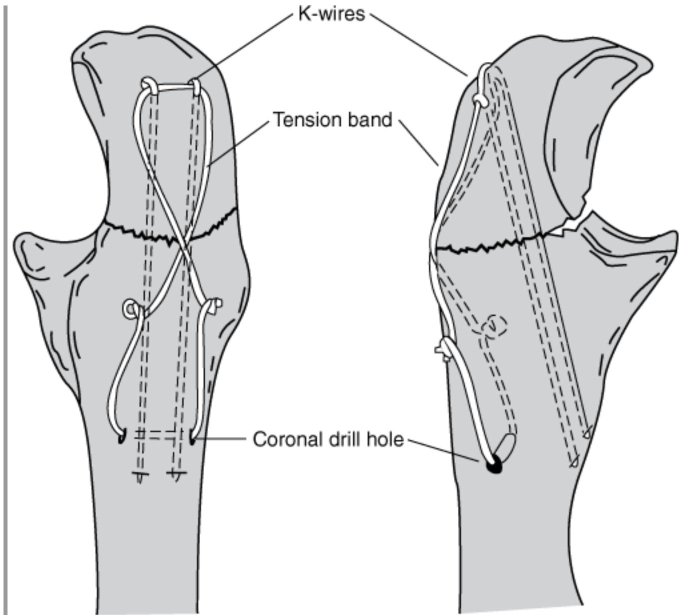
Radiographic evaluation consists of a true lateral radiograph of the
displacement, are all critical in evaluating the injury and selecting

Treatment

Methods of treatment vary from closed treatment to ORIF. Nondis

Displaced transverse or short oblique fractures generally are best
with a neutralization plate. Wire protrusion and pain frequently res

Figure 3–13.



Tension band technique for fixation of olecranon fractures.

(Reproduced, with permission, from Browner BD et al, eds: *Skele*

If the articular surface is significantly comminuted, a low-profile, li
accompanied with early protected range-of-motion exercises.

FRACTURE OF THE RADIAL HEAD

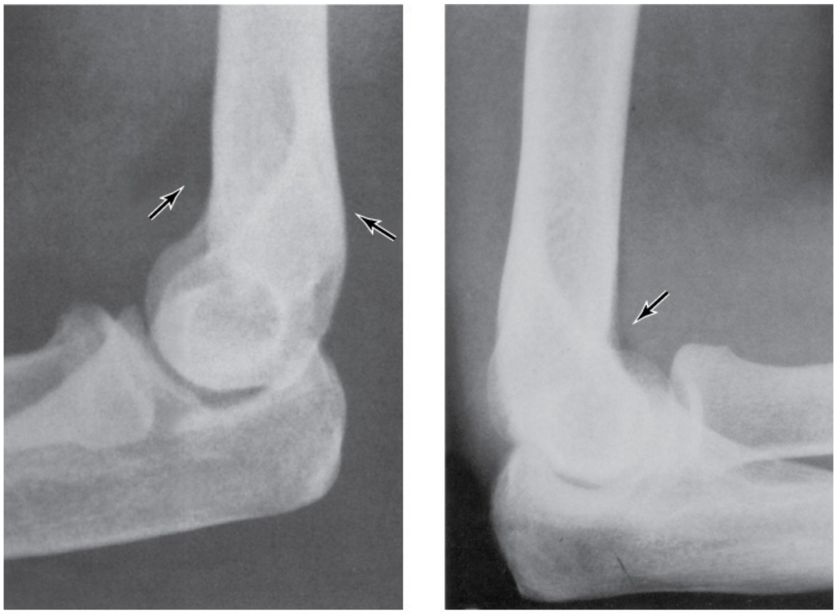
The incidence of fractures of the radial head is between 15% and
through the interosseous membrane from the radius proximally to

Radial head fractures are generally caused by longitudinal loading

Clinical Findings

One generally describes these fractures based on their location, pe

Figure 3–14.



A

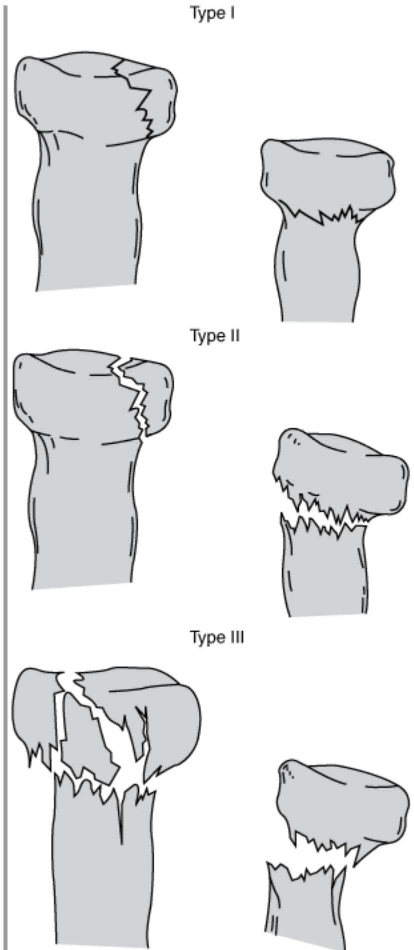
B

Positive fat pad sign on lateral radiograph of elbow. This finding in

Classification

Mason proposed a classification scheme for radial head fractures:

Figure 3–15.



Mason classification of radial head fractures.

(Reproduced, with permission, from Browner BD et al, eds: *Skele*

Treatment

For type I fractures, nonoperative treatment with early motion car

The treatment of type II fractures is controversial. For fractures w

Type II fractures with associated injuries that may compromise elb
the nonarticular safe zone to avoid impingement on the sigmoid fo

The result of ORIF is less predictable when there is more than one

Early excision with immediate motion is recommended for type III
material failure and particulate synovitis that preclude permanent
radiographic evidence will show proximal migration of the radius a
and Morrey noticed a 92% incidence of arthrosis ten years after fr

Capitellar Fractures

Capitellar fractures frequently accompany and result from the sam
impaction of the radius against the capitellum. Shearing forces car
Steinthal II). CT reconstructions are useful to further delineate the

Treatment

Today, anatomic reduction and early motion is the standard treatm

ELBOW DISLOCATION

Dislocations of the elbow occur when loads are placed on the struc
goal of treatment.

Although diagnosis of elbow dislocation can be made easily prior to
direction of displacement of the radius and ulna. Because two bon
ulna has been observed to dislocate anteriorly or posteriorly. The r
fractures occur, treatment of the combined injury is usually dictate

Posterior Elbow Dislocations

Posterior dislocations are the most common type (80%) of elbow d

Diagnosis is made by clinical examination and verified by radiograp

Treatment is initiated after documenting the neurovascular examir
ensure that reduction has been obtained and that there is no soft-

Anterior Elbow Dislocations

Anterior dislocations are relatively rare. Soft-tissue damage is typi

Medial & Lateral Elbow Dislocations

The radius and ulna may be displaced medially or laterally. Some s
surfaces, to reduce these dislocations.

Isolated Ulnar Dislocations

Isolated ulnar dislocations occur when the humerus pivots around
reduces the ulna.

General Treatment Procedures

EARLY TREATMENT

The elbow is tested for stability to varus and valgus stress and to
Immobilization does not guarantee maintenance of reduction. Unst

Uncomplicated elbow dislocations have a favorable long-term prog

DELAYED TREATMENT

It would seem impossible for a patient not to seek immediate care
weeks from the time of injury. Dislocations left untreated for longe

ELBOW DISLOCATION AND CORONOID FRACTURE

An elbow dislocation and associated fracture of the coronoid proce
ligament (Reagan-Morrey Type III). The decision to fix a coronoid

ELBOW DISLOCATION WITH RADIAL HEAD AND CORONOID

Denominated the terrible triad of the elbow, these injuries are diff
coronoid fracture and/or repair of the anterior capsule, ORIF or re

Bailey CS et al: Outcome of plate fixation of olecranon fractures. J

Eygendaal D et al: Posterolateral dislocation of the elbow joint. J E

Hak DJ, Golladay GJ: Olecranon fractures: Treatment options. J Ar

Mckee MD et al: Functional outcome following surgical treatment c

Paramasivan ON, Younge DA, Pant R: Treatment of nonunion arou

Popovic N, Rodriguez A, Lemaire R: Fracture of the radial head wit

Pugh DMW et al: Standard surgical protocol to treat elbow disloca

Sanchez-Sotelo J, Romanillos O, Garay EG: Results of acute excisi

Wainwright AM, Williams JR, Carr AJ: Interobserver and intraobse

SHOULDER & ARM INJURIES

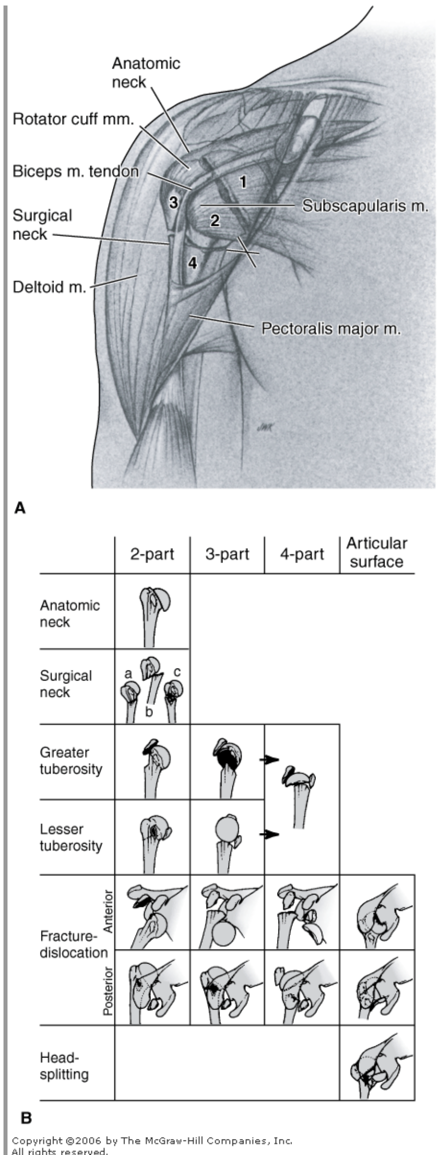
Anatomy & Biomechanical Principles

BONY ANATOMY

Humeral Shaft

The humeral shaft extends from the level of the insertion of the pe
and posterior compartments. In the anterior compartment reside t
triceps brachii muscle and the radial nerve. Understanding the ins

Figure 3–16.



A: Muscle insertions on humerus and fracture displacement. **B:** Ne
(Reproduced, with permission, from Rockwood CA et al, eds: *Frac*

Shoulder Girdle

The shoulder girdle is a complex arrangement of bony and soft-tis
allows for motion; the rotator cuff controls the joint itself.

Proximal Humerus

The proximal humerus contains the humeral head, lesser and grea
branch of the anterior humeral circumflex artery, which penetrates
muscles around the shoulder include the axillary, suprascapular, su
the bicipital groove lies the biceps tendon, which is covered by the
145 degrees, and the humeral head is retroverted an average of 3
aspect of the glenohumeral joint, provides origin for the deltoid mu

humeral head to allow the deltoid to efficiently abduct the humeru
predictable displacement of fractures around the proximal humeru

NERVE SUPPLY

Injuries to the nerves around the shoulders occur with fractures ar

The most important evaluation consists of a neurovascular examin critical. Evaluation should include sensation of the dorsal web spac

Around the shoulder girdle, fractures of the proximal humerus anc arm. Axillary artery injuries, although uncommon, generally result appearance. Pulses should be palpated and evaluated by Doppler s the neurological morbidity, even though the results of vascular rec

More subtle associated injuries involve the rotator cuff. This can ge externally rotate the shoulder against resistance. Evaluation of the

HUMERAL SHAFT FRACTURE

Fractures of the shaft of the humerus usually result from a direct midshaft fractures.

Classification

Fractures are classified according to whether they are open or clos

Clinical Findings

Clinical signs and symptoms include a shortened extremity with cr

Treatment

CLOSED TREATMENT

The recommended treatment in isolated diaphyseal humeral fractu appears to be the most effective closed treatment.

Hanging Cast

Treatment with a hanging cast involves placement of the arm in a length of the sling or suspension apparatus. This treatment requir

Patients with a large body habitus may develop more significant ar fractures may have more difficulty in healing. The musculature of

Coaptation Splint

A TU-shaped coaptation splint with cuff and collar is another meth appropriate level of compression. Stand-alone slings or cuffs are u diaphyseal fractures.

Abduction Humeral Splinting and Shoulder Casting

Spica casting may be useful in certain unstable fractures, though i

Skeletal Traction

In special circumstances, skeletal traction has been used for hume
traction pin is inserted through the olecranon, going from a media
suspended overhead help to correct angulation. Positioning is chec

Sling and Swathe

Elderly patients may be best treated by reducing fracture motion i

External Fixation

External fixation is applicable to the humerus in the case of burns,
management are not applicable or appropriate. Half pins are gene

OPEN TREATMENT

Special circumstances may merit open reduction and internal fixat
are two general forms of internal fixation: (1) Compression plate a
permitting mobilization, pulmonary toilet, and pain control, may be

FRACTURES & DISLOCATIONS AROUND THE SHOULDE

Classification

The classification of shoulder fractures and dislocations developed
useful, this system has been demonstrated to have significant inte
head-splitting injuries. The relationship of the humeral head to the
years), especially with concomitant osteoporosis. The incidence of

Clinical Findings

Clinical presentation is usually with pain, swelling, and ecchymosis

Radiographic evaluation is a cornerstone for diagnosis and plannin
tangential Y-view of the scapula. The combination of three of these
patient, with gentle abduction of the arm, with the x-ray beam ain

Treatment

CLOSED TREATMENT

Approximately 85% of proximal humerus fractures are minimally c
physician-directed exercises are essential and should be started at

SURGICAL TREATMENT

Techniques useful for the smaller percentage of fractures include c
pinning method. For severe fractures, especially four-part fracture
fractures.

TWO-PART ANATOMIC NECK FRACTURES

Two-part anatomic neck fractures are rare. No single optimal meth
or interfragmentary screws. It may be difficult to obtain adequate

TWO-PART GREATER TUBEROSITY FRACTURES

Greater tuberosity fractures generally displace posteriorly and sup
displacement of the fragment by more than 1 cm is pathognomoni
disability, whereas those with less than 0.5 cm of displacement dic
displacement in the high-performance athlete as impingement syn
of this condition should be directed at rotator cuff repair as well as

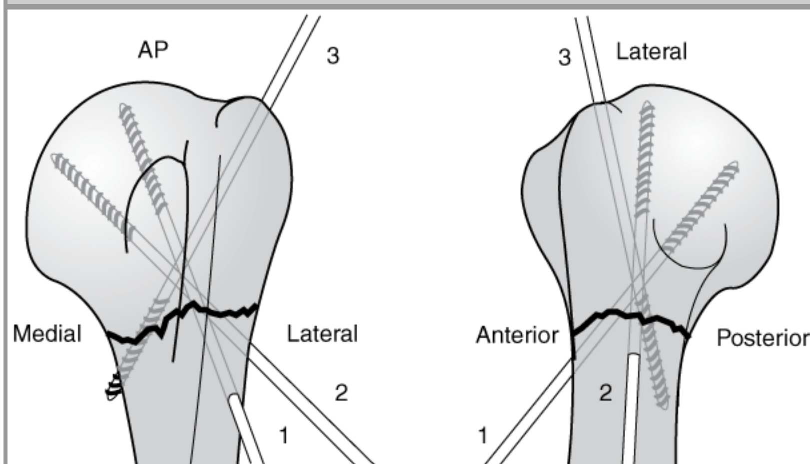
TWO-PART LESSER TUBEROSITY FRACTURES

If the displaced fragment (usually medially by subscapularis) is sm
Larger fragments may require internal fixation.

TWO-PART SURGICAL NECK FRACTURES

In these conditions, both tuberosities remain attached to the head
deltoid, pectoralis major, or fascial elements. One attempt at close
reduction is required to remove displaced soft tissues, internal fixa
patients), retention of the plate, persistent varus, and interference

Figure 3–17.



Pinning of the unstable surgical neck fracture.

(Reproduced, with permission, from Fu FH, Smith WR, eds: Percu

Another technique for internal fixation utilizes intramedullary devic
debilitated patients, this may be the best solution to achieve overa

THREE-PART FRACTURES

Avascular necrosis in three-part fractures has been reported to be
necrosis related in part to extension of soft-tissue displacement ar
Ender nails combined with tension banding are good alternatives ir
hemiarthroplasty should be considered in the elderly.

FOUR-PART FRACTURES

Open reduction and internal fixation of four-part fractures (as with
patient, the accepted method of treatment is hemiarthroplasty, pa
any rotator cuff defects is necessary to prevent proximal migratior

FRACTURE-DISLOCATIONS

Fracture-dislocations require reduction of the humeral head, and t
locked dislocation. Fractures of less than 20% will generally be sta
With impression fractures of greater than 50% or chronic dislocati

Complex Regional Pain Syndrome (CRPS)

This is defined as an abnormal reaction to injury characterized by
hyperesthesia, restricted mobility and movement disorder, skin ch
surgery, spinal cord disorders, and sometimes, without obvious ca
and can be made based on history and examination. Investigation
surgical) can be useful.

Clinically, reflex sympathetic dystrophy has three stages, which ar
develops at approximately 3 months and is characterized by signif

Sudeck's atrophy is a radiographic term that is extended to a cli
is characteristic, both at the shoulder and at the wrist and hand le

Because the cause is unclear, the recommended treatment is an a
evaluation of orthopedic musculoskeletal neurologic problems, and
benefit in the appropriate setting.

Blum J et al: Clinical performance of a new medullary humeral nai

Chapman JR et al: Randomized prospective study of humeral shaf

Cox MA et al: Closed interlocking nailing of humeral shaft fracture

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Helmy N, Hintermann B: New trends in the treatment of proximal

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Foot & Ankle Injuries

The appropriate investigation of any foot injury requires obtaining, different joints when indicated, and assessing the neurovascular st requested according to clinical suspicion. Although some fracture p display is useful for obtaining disarticulated views in intraarticular

Anatomy & Biomechanical Principles

The foot is a complex, highly specialized structure that permits we injuries, generally have a poorer prognosis, even if the bones are

Embryologically, the foot develops from proximal to distal into thre nerves, the soft tissues include extrinsic tendons, intrinsic musculo

The bones, ligaments and muscles of the foot actively maintain the

Classically, the plantar aspect of the foot is divided into four layers plantae and lumbricales muscles. In the third layer are the flexor h

These 28 bones, 57 articulations, and extrinsic and intrinsic soft tis

Energy-effective gait requires optimal integration of all segments i midtarsal joint. Increasing the flexibility of the foot allows for bette

This superficial overview of the anatomy and biomechanical princip

FRACTURES COMMON TO ALL PARTS OF THE FOOT

Fatigue Fractures

Also known as **stress, march,** or **insufficiency** fractures, fatigue for the deposition of new stronger bone. Continued loading can lea

This disorder is commonly seen in young active adults involved in

Clinical Findings

Incipient pain of varying intensity at rest is then accentuated by w
Radionuclide imaging, CT and MRI can be helpful for occult fractur

Treatment

Treatment is by protection in either a short leg cast, walking boot

Multiple High-Energy Injuries

Violent forces applied to the foot may cause more extensive dama

Treatment

High-energy fractures are often open, and the basic principles of c
the different joints (both actively and passively), achieve bone uni

Early stabilization of multiple fractures and dislocations will simplif

Neuropathic Joint Injuries & Fractures

Fractures and other foot disorders often present in the patient wit

The potential for bone healing is normal if no other comorbidities e
the rate of nonunion is higher than for normal joints.

FOREFOOT FRACTURES & DISLOCATIONS

Metatarsal Fractures & Dislocations

Fracture of the metatarsals and dislocation of the tarsometatarsals
which passes between the first and second metatarsals.

Metatarsal Shaft Fractures

Undisplaced fractures of the metatarsal shafts cause only tempora

These fractures can be treated with a hard-soled shoe with partial

For displaced fractures of the shaft, it is of paramount importance
will transfer weight to the heads of the second and third metatars
and internal fixation should be considered.

Metatarsal Neck & Head Fractures

Fractures of the metatarsal "neck" are close to the head but rema
and the functional outcome is surprisingly good. The indications fo

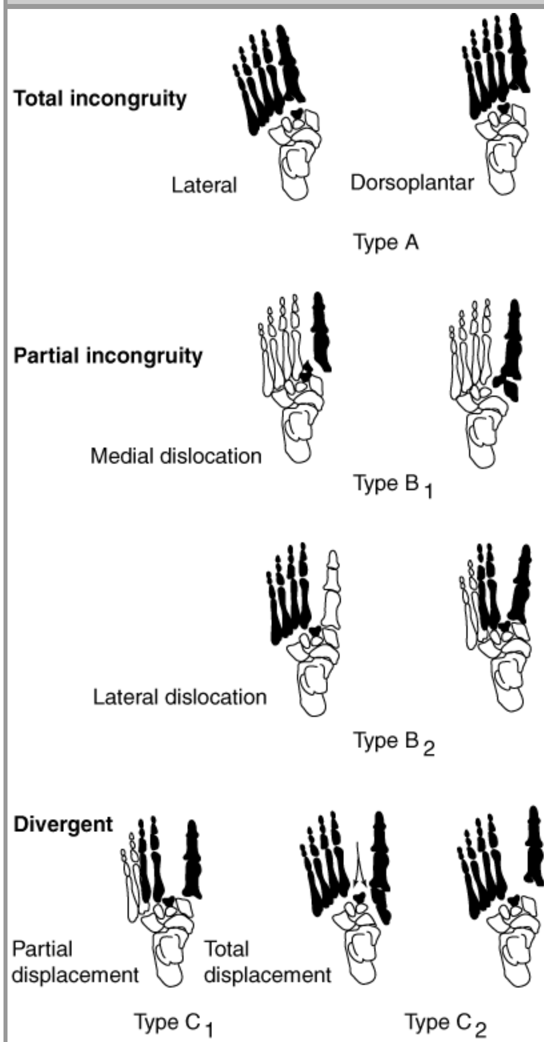
Closed reduction of metatarsal fractures is best achieved by apply
fluoroscopic imaging.

Tarsometatarsal (Lisfranc) Dislocations

The stability of the tarsometatarsal joint complex relies in part on
should alert the clinician to the possibility of other injuries along th

The original injury, described by Napoleon's field surgeon Lisfranc,
and divergent (Figure 3–18). The medial border of the second and

Figure 3–18.



Classification of Lisfranc injuries.

(Reproduced, with permission, from Coughlin MJ, Mann RA, eds: S

An attempt at closed reduction should be made as soon as possibl
preserve mobility and screws on the medial side of the foot is indic
that even in cases where anatomic reduction, normal walking patt

Some tarsometatarsal injuries present late (>3–4 weeks), when th
and direct treatment toward functional recovery. Reconstructive o

Complications of this injury include chronic foot swelling, residual c

Fracture of the Base of the Fifth Metatarsal

Three distinct patterns occur: (1) avulsion fracture of a variably si
fracture of the proximal metatarsal diaphysis.

Avulsion fractures usually occur after adduction injury to the forefo

Symptomatic treatment is most often successful in a hard-soled sh

Acute Jones fractures are best treated in a non-weight bearing cas short leg cast for 6 weeks will usually bring healing of the fracture

Fractures & Dislocations of the Phalanges of the Toes

Fractures of the phalanges of the toes are most commonly caused and radiographically.

Treatment

Comminuted fracture of the proximal phalanx of the great toe, alo arising from associated soft-tissue injury. Spiral or oblique fracture

Dislocation of the metatarsophalangeal joints and dislocation of the

Fracture of the Sesamoids of the Great Toe

Fractures of the sesamoid bones of the great toe are rare but may

Treatment

Undisplaced fractures require no treatment other than a hard-sole the first metatarsal. If conservative modalities have been exhauste

Calder JD, Whitehouse SL, Saxby TS: Results of isolated LisFranc i

Haapamaki V, Kiuru M, Koskinen S: Lisfranc fracture-dislocation in

Kelly IP et al: Intramedullary screw fixation of Jones fractures. Foo

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Richter M et al: Fractures and fracture dislocations of the midfoot:

Rosenberg GA, Sferra JJ: Treatment strategies for acute fractures

MIDFOOT FRACTURES & DISLOCATIONS

Navicular Fractures

Avulsion Fractures

Avulsion fractures of the tarsal navicular may occur as a result of s
the supernumerary sesamoid bone, or os tibiale externum. Dorsal

Body Fractures

Body fractures occur either centrally in a horizontal plane or, more
fragment can restore normal position. If a tendency to re-displace
a closed manner. Where fragments involve >25% of the bone, OR
been achieved, posttraumatic arthritis supervenes, and that arthro

Stress Fractures

The navicular is also a frequent site of fatigue fracture in runners.

Cuneiform & Cuboid Bone Fractures

Because of their relatively protected position in the midtarsus, isol
"nutcracker" fracture is a compression fracture of the cuboid and,

Midtarsal Dislocations

Midtarsal dislocation through the naviculocuneiform and calcaneocu

When acute treatment is administered, closed reduction by tractio

HINDFOOT FRACTURES & DISLOCATIONS

Talus Fractures

Three fifths of the talus is covered with articular cartilage. The blo

Major fractures of the talus commonly occur either through the bo
may occur later in association with complicating avascular necrosis

Fractures of the Neck of the Talus

The most common mechanism of talar neck fracture is hyperdorsif

Type 1: Nondisplaced vertical fracture

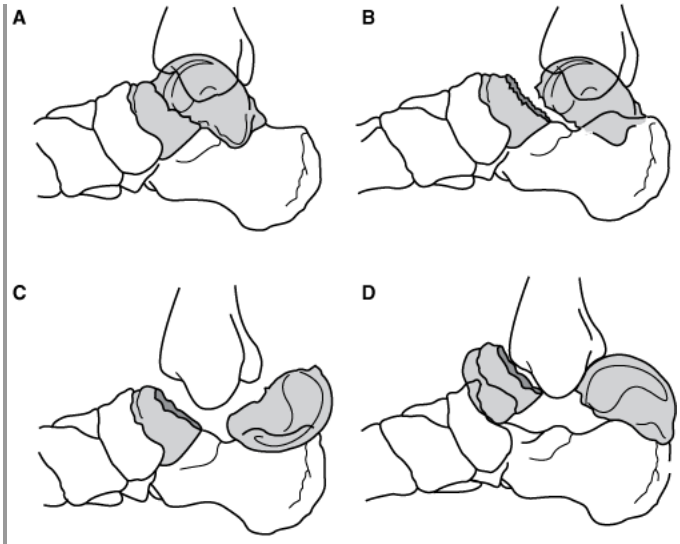
Type 2: Displaced fracture of the talar neck with subluxation or dis

Type 3: Displaced fracture of the talar neck with dislocation of the

Type 4: Later, a type 4 fracture was described by Canale and Kelly

This classification is of prognostic value for avascular necrosis of th

Figure 3–19.



Hawkins classification of talar neck fractures.

(Reproduced, with permission, from Coughlin MJ, Mann RA, eds: S

Less frequent complications of talar neck fractures include infectio

Treatment is aimed at minimizing the occurrence of these complica treatment is as for a type 1 fracture. In about 50% of cases, close bearing will be allowed after fracture union if there is no avascular most sensitive method, however, appears to be MRI, which can, as also remember that there is not a direct correlation between avasc

Fractures of the Body of the Talus

Talus body fractures occur mainly due to shear and axial compress

Type 1: Osteochondral fracture

Type 2: Coronal, sagittal or horizontal fracture

Type 3: Posterior process fracture

Type 4: Lateral process fracture

Type 5: Crush fracture of the body

Minimally displaced fractures of the talar body are not likely to cau posterior, mortise, lateral and Broden (45 degrees internal oblique

Reduction by closed manipulation is often difficult but is best achie present on serial radiographs. Even though prompt adequate redu sequela. If this occurs, arthrodesis of the ankle or subtalar joints r

Osteochondral Fractures of the Talar Dome

These can occur with any type of injury to the ankle area, includin
and symptomatic.

Initial radiograph evaluation often does not demonstrate these lesi

The Berndt and Harty classification is generally used:

Stage 1: Localized compression

Stage 2: Incomplete separation of the fragment

Stage 3: Completely detached but nondisplaced fragment

Stage 4: Completely detached, displaced fracture

A modified version of this classification to include MRI findings can

Symptomatic stage 1, 2, and 3 lesions are usually initially treated
with screws and excision with or without drilling have been recomr

Compression fractures of the talar dome are rare injuries. They ca

Other Talar Fractures

Other rare fractures include those of the lateral (snowboarders' fra

Conservative treatment usually gives excellent results; however, c

Subtalar Dislocation

Subtalar dislocation, also called **peritalar** dislocation, is the simult

Prompt gentle closed reduction is usually successful. Immobilizatio

Total Dislocation of the Talus

This injury usually results from high-energy trauma, and most are

Calcaneus Fractures

The calcaneus (os calcis) functions to provide support for body we
driving the talus downwards (e.g. a fall from a height). Ten percer

Clinical Findings

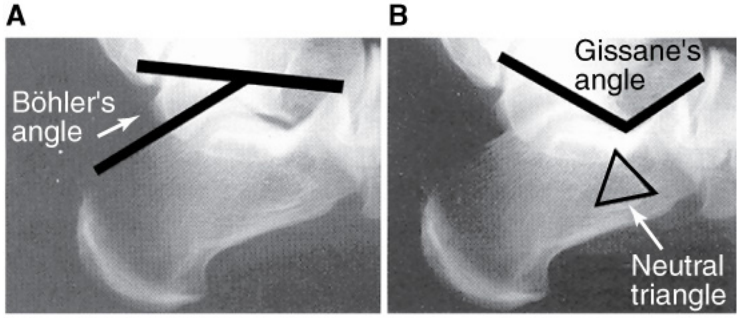
SYMPTOMS AND SIGNS

Pain is usually significant but may be masked by associated injurie
the heel pad lead to persistent pain and deformity and can produc

IMAGING STUDIES

Initial radiographs include three views: anteroposterior, lateral, an
will further delineate fracture patterns and occult injuries. Bone sc

Figure 3–20.

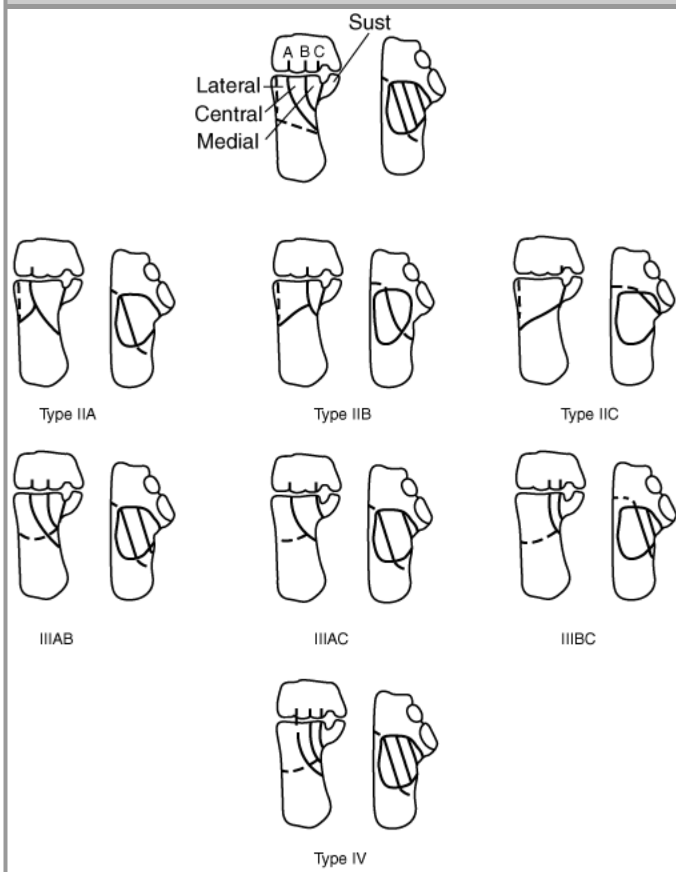


Böhler's angle (**A**) and Gissane's angle (**B**), indicating normal anat
(Reproduced, with permission, from Coughlin MJ, Mann RA, eds: S

CLASSIFICATION

Various classifications have been advocated. Sanders has develope are divided into A, B, and C based upon the location of the fractur intraarticular and extraarticular fractures. Intraarticular fractures (

Figure 3–21.



Sanders CT classification of calcaneus fractures.

(Reproduced, with permission, from Coughlin MJ, Mann RA, eds: S

Intraarticular Fractures

The subtalar joint is almost always involved, and occasionally the f

TYPES OF FRACTURES

Nondisplaced Fractures

These fractures are successfully treated by protection from weight

Tongue-Type Fractures

This fracture pattern (Figure 3–22) involves the subtalar joint with

Figure 3–22.

Tongue-type fracture of the calcaneus showing involvement of the

Joint Depression

This fracture pattern (Figure 3–23) creates a separate fragment o

Figure 3–23.

Joint depression-type fracture of the calcaneus. The posterior face

Comminuted Fractures

Some fracture patterns create such comminution and impaction th

TREATMENT

Treatment of displaced intraarticular fractures remains controversi

Some surgeons still advise conservative treatment.

Other surgeons advocate early closed manipulation of displaced int the tongue fragment, which is then disimpacted and reduced. The through stable fixation. A recent study has demonstrated a correla

COMPLICATIONS

The most significant complication is posttraumatic degenerative ar complications include compartment syndrome, neurovascular and

Extraarticular Fractures

Because posttraumatic joint disease is usually not a complication o

TYPES OF FRACTURES

Fracture of the Tuberosity

Isolated fractures of the calcaneal tuberosity are rare.

Horizontal Fracture

These fractures may be limited to the superior portion of the regio application of skeletal traction can reduce it to the plantar-flexed f

Vertical Fracture

Vertical fracture occurs in the sagittal plane somewhat medially thr

Non-Articular Fracture of the Body

Comminuted fractures of the entire tuberosity, sparing the subtala reduction to improve heel contour.

Fracture of the Sustentaculum

A rare injury, fracture of the sustentaculum tali should be suspecte
successful. In the rare instance of symptomatic nonunion, careful

Fracture of the Anterior Process

Usually caused by forced inversion of the foot, it must be different
radiograph will demonstrate the fracture line.

Treatment is by a non-weight–bearing short leg cast in neutral pos

Fracture of the Medial Process

This process gives origin to the abductor hallucis and part of the fl

COMPLICATIONS

Posttraumatic arthritis of the subtalar joint has already been ment
postsurgical scarring).

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ANKLE FRACTURES & DISLOCATIONS

Fractures and dislocations of the ankle are among the most comm
With incorporation of the motion of the subtalar joint (which allows

Anatomy & Biomechanical Principles

The distal tibia and fibula are structures easily palpable because of
The tibia has a tubular diaphysis with wide flaring metaphyses bot
The inner and distal articular surfaces of the distal tibia and fibula
geometric configuration resists rotation of the talus in the ankle m
syndesmotic ligament connects the tibia to the fibula at the level c
provided by the cup-shaped tibial plafond and the slightly increase

The distal tibia also serves to absorb the compressive loads and st
compressive resistance of the distal tibia.

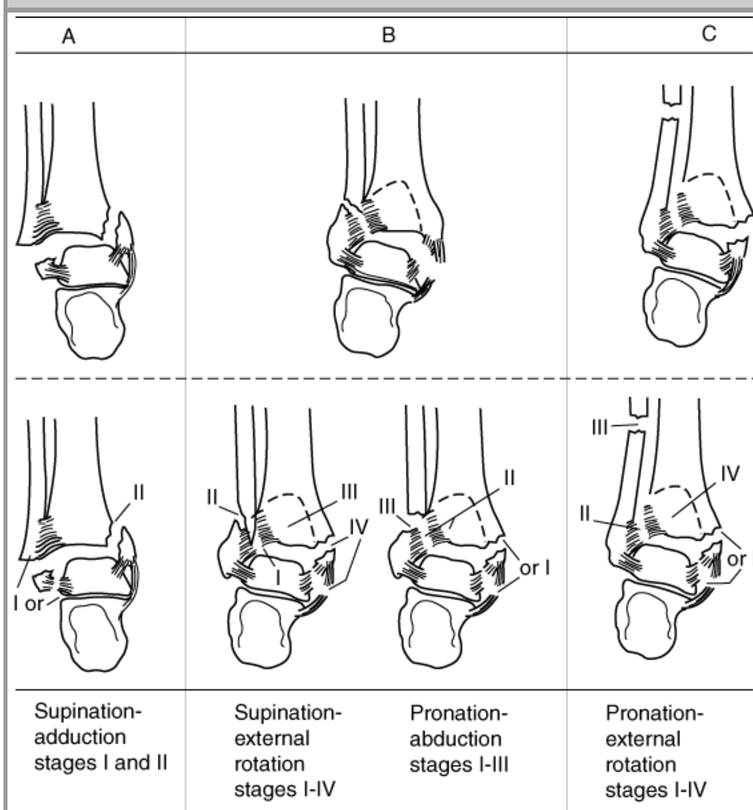
Fracture-dislocations of the ankle are frequently referred to as **bir**
complete disruption of the syndesmosis and a proximal fibular sha

Classification

The purpose of any classification scheme is to provide a means to

In 1950, Lauge-Hansen described a classification system based on
and supination refer to the position of the patient's foot at the inst
pronation-external rotation. Lauge-Hansen later added a fifth type

Figure 3–24.



Comparison of Lauge-Hansen and Danis-Weber ankle classification

(Reproduced, with permission, from Browner BD et al, eds: *Skele*

The Weber classification is much simpler, and is based on the level

Type A: Fracture in which the fibula is avulsed distal to the joint lir

Type B: Spiral fracture of the fibula beginning at the level of the jo
syndesmotic disruptions, however can result from this fracture pat

The medial malleolus can either be left intact or sustain a transver

Type C: Fracture of the fibula proximal to the syndesmotic ligamer

Many studies have stated that the above classification systems hav

The AO classification system has better reproducibility as it is base

Treatment

Four criteria should be met for the optimal treatment of ankle frac

If these treatment goals are met, a good outcome can be expecte

Previous studies have demonstrated that the ankle has the thinnes
important to obtain anatomic reduction of the articular surfaces of

Initial treatment of ankle fractures should include immediate close
antibiotics and taken to the operating room on an urgent basis for

With the advent of excellent results obtained from the techniques
stage 2), distal fibular avulsion fractures, fractures in nonambulat
walking cast for 6 weeks. Unstable ankle fractures treated by imm
operatively.

When performing ORIF of ankle fractures, several principles must
first. This has two benefits: (1) it helps to correctly restore the ori
the lateral malleolus is present, fixation can sometimes be adequa

When performing ORIF of the medial malleolus, it is important to r

The necessity for fixation of the posterior malleolar fragment is de
there is less than 2 mm of displacement, internal fixation is not al
this, utilizing either direct fixation posteriorly via the lateral or me

Following surgery, the limb is placed in a bulky sterile dressing wit
ankle joint. If the patient is reliable and stable fixation was achiev
Usually at 6 weeks all immobilization is discontinued and weight be

Barrie J et al: Ankle fractures-Pathomechanics and classification. E

Egol KA, Dolan R, Koval KJ: Functional outcome of surgery for frac

Gehrmann RM et al: Athlete's ankle injuries: diagnosis and manag

Hintermann B et al: Arthroscopic findings in acute fractures of the

Kay RM, Matthys GA: Pediatric ankle fractures: Evaluation and tre

Obremskey WT et al: Change over time of SF-36 functional outcor

Pankovich AM: Acute indirect ankle injuries in the adult. J Orthop T

Saltzman R, French BG, Mizel MS: Ankle fracture with syndesmoti

Tabrizi P et al: Limited dorsiflexion predisposes to injuries of the a

Tornetta P: Competence of the deltoid ligament in bimalleolar ankl

Tornetta P, Creevy W: Lag screw only fixation of the lateral malleo

TIBIA & FIBULA INJURIES

Anatomy

The tibial diaphysis is straight and triangular in cross-section. Its a patellar tendon. The distal half of the leg has more tendons and le

From a surgical standpoint, the leg has been divided into four com crural fascia. It contains the tibialis anterior, extensor hallucis long responsible for ankle flexion and foot eversion and the superficial b tibia, the interosseous membrane, and the deep transverse fascia.

Tib-Fib Fractures

Fractures of the tibial or fibular diaphysis are the result of direct o A 1 cm skin laceration can be associated with an extensive muscle severity (grades 0 to 3):

Grade 0: soft-tissue damage is absent or negligible.

Grade 1: there is a superficial abrasion or contusion caused by fra

Grade 2: a deep contaminated abrasion is present associated with

Grade 3: the skin is extensively contused or crushed and muscular

When the fracture is displaced, the clinical diagnosis is usually evic

Radiographs in the anteroposterior and lateral projections are take

Fibula Diaphysis Fractures

Isolated fibula fractures can be associated with other injuries of th
mechanism; however, it can also coincide with syndesmosis disrup

Tibia Diaphyseal Fractures

Isolated fractures of the tibial diaphysis are usually the result of to

Fractures of both the tibia and fibula are more unstable, and displa
are generally accepted: apposition of 50% or more of the diamete
position (ie, malunion) will affect the mechanics of the knee or ank

Acceptable reduction can be obtained in one of many ways, and th
anesthesia if necessary, and the patient is immobilized in a long le
direction after corrective manipulation. At 6 weeks, some shaft fra

If acceptable and stable reduction cannot be obtained by closed m
rigid fixation and still allows access for wound care. This is still the
proximal starting point anterior to the tibial tubercle and across th

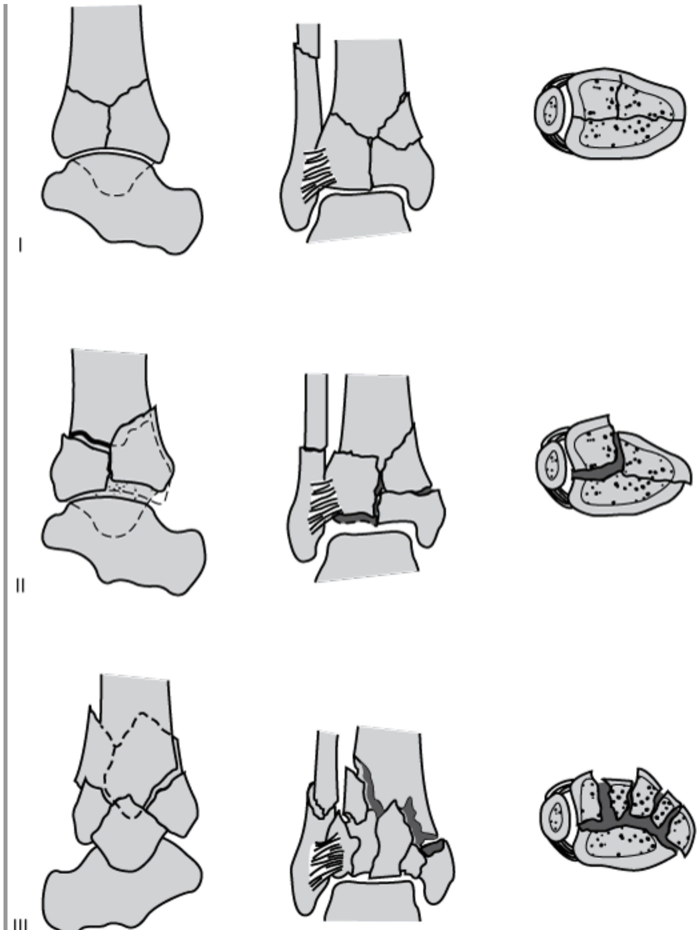
Open reduction and internal fixation with plates and screws using
with diaphyseal extension.

Recent studies comparing tibia fractures treated with cast immobil
possible contractures. The advantages of closed treatment are ear
more difficult wound care. Sound clinical judgment is needed in th

Fracture of the Distal End of the Tibia

Also referred to as **pilon** or **plafond** fractures, these fractures inv

Figure 3–25.



Ruedi and Allgower classification of Pilon fractures.

(Reproduced, with permission, from Browner BD et al, eds: *Skele*

As for any intraarticular fracture, the goal of treatment is to restor swelling subsides, minimally invasive open reduction and percutan fibular fracture to restore length, and closed reduction and externa

These fractures are notorious for associated soft-tissue damage. S usually 7 to 14 days, once the "wrinkle" sign appears. Surgical inci

Compartment Syndrome

Compartment syndrome is a frequent concern in tibia fractures an

Fasciotomies are performed through a lateral and a medial incision delayed primary closure or split-thickness skin grafting 5 days late

Complications

Complications are common after tibia and fibula fractures and may

DELAYED UNION OR NONUNION

Because of its relatively poor soft-tissue coverage, the tibia, partic
fracture line without bridging callus. Sclerosis and flaring of the bo
bone grafting (atrophic nonunion) may be required in order for the

MALUNION

Malunion may lead to premature degenerative joint disease. Corre

INFECTION

Infection of the tibia following open fracture or surgical treatment
generous utilization of free muscle flaps to increase the local blood

COMPLEX REGIONAL PAIN SYNDROME (REFLEX SYMPATHET

Complex regional pain syndrome is a fortunately rare complication
complication. Chemical or surgical sympathetic blockade may be h

OTHER COMPLICATIONS

Posttraumatic arthritis is a frequent occurrence after pilon fracture
dropfoot and claw toe deformities and may require further soft-tis

Blauth M et al: Surgical options for the treatment of severe tibial p

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Ziran BH, Darowish M, Klatt BA, Agudelo JF, Smith WR. Intramedu

Injuries Around the Knee

Anatomy & Biomechanical Principles

The knee is a modified synovial hinge joint formed by three bones

The distal femoral diaphysis broadens into two curved condyles at
wider in the sagittal plane (preventing lateral patella displacement
surfaces form a horizontal plane parallel to the ground and create
Fractures proximal to this are considered femoral shaft fractures a

As for the distal femur, the proximal tibia widens proximally at the
attachment for the cruciate ligaments and the menisci. Distal to th
form the proximal tibiofibular joint.

The patella is the biggest sesamoid bone in the body. It lies within
by a longitudinal ridge. The area of contact at the patellofemoral j
intact, they can allow active knee extension even in the presence o

The main plane of motion of the knee is flexion and extension, but
physiologic loading. It includes passive stabilizers such as medial a
components work together in an extremely complex and finely tun
These may be isolated or combined, partial or complete, and may

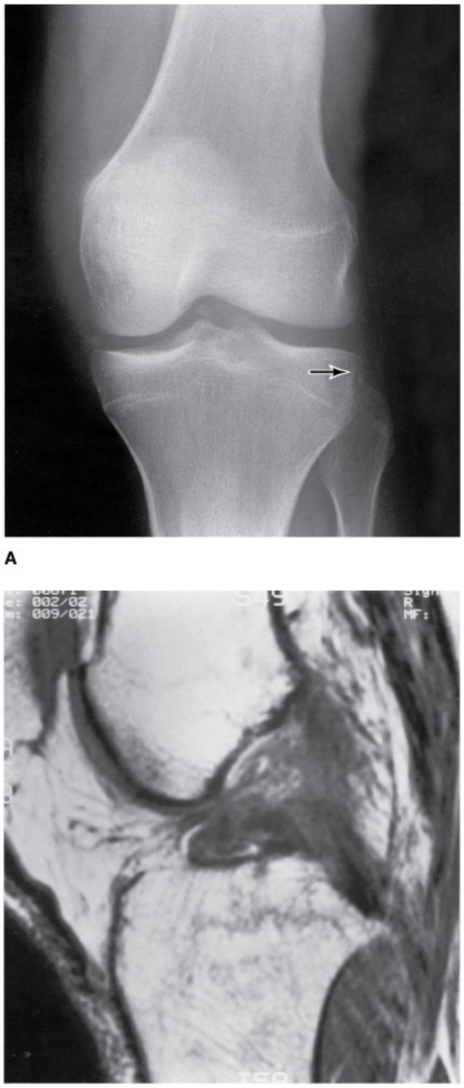
LIGAMENTOUS INJURIES

As already stated, a wide spectrum of ligamentous injuries, from p

Knowledge of the mechanism of injury is of paramount importance
anterior cruciate ligament. Tackles at knee level in football often cr
extremity, but it is essential and will usually provide key diagnostic

Plain radiographs are of limited benefit. They will show fractures, b

Figure 3–26.



A

B

Lateral capsular sign, diagnostic of anterior cruciate ligament injur

Tomograms and contrast arthrograms have only limited indications
surgical treatment of a lesion will be necessary.

Medial (Tibial) Collateral Ligament Injury

This ligament normally resists valgus angulation at the knee joint.
degrees will show exaggerated laxity at the joint line, signaling a c

Grade 1 and 2 sprains (incomplete) are treated with protective we
be systematically ruled out. Most surgeons now favor conservative

Lateral (Fibular) Collateral Ligament Injury

This ligament originates from the lateral femoral condyle and inser
and iliotibial band. Injury to the peroneal nerve is not uncommon.

Radiographs often show avulsion of the fibular head. When this fra
be indicated for the low-demand patient with mild laxity.

Anterior Cruciate Ligament Injury

This ligament originates at the posteromedial aspect of the lateral
condyles. Isolated injuries are frequent, especially with hyperexter
at the femoral or tibial attachment will be seen on plain radiogram

Clinical Findings

The patient usually recalls the mechanism of injury, and classically
test performed with 20–30 degrees of knee flexion. The classic dra
out and other clinical signs, such as the pivot shift and the active

Treatment

Treatment remains controversial despite the abundance of literatu
present, surgical repair is indicated as bone-to-bone healing and g

Primary repair of the ligament stumps without reconstruction is lik
conservative treatment can still benefit from delayed reconstructiv

Posterior Cruciate Ligament Injury

The posterior cruciate ligament is a broad thick ligament that exte
after a posteriorly directed force on the proximal tibia as is someti

Clinical Findings

The posterior drawer test will be positive, as will the sag test, sho

Treatment

Reattachment of bony avulsions should restore functional compete
even bracing, of isolated posterior cruciate ligament injuries is cur

Meniscal Injury

The meniscus is a fibrocartilage that allows a more congruous fit b
shaped, with both anterior and posterior horns almost touching me
stabilizers but are more important in the ligament-deficient knee.

Clinical Findings

Tears can be secondary to trauma or attrition. The medial meniscu
knee flexed to 90 degrees (McMurray's sign). Radiographs are of r

Treatment

Initial conservative management with immobilization, bracing, prot
attempted. For other tears, the affected area should be removed,

Chondral & Osteochondral Injuries

The hyaline articular cartilage is avascular and has no intrinsic cap
shearing stresses that can loosen chondral or osteochondral fragm

Clinical Findings

Chondral injuries usually give nonspecific symptoms that mimic me
of which can easily miss the smaller fragments. Arthroscopy remai

Treatment

Treatment is controversial. The age of the patient, skeletal maturit

Removal of the free fragment, debridement of the donor site, and

Knee Dislocation

Traumatic dislocation of the knee is a rare injury that often results
supporting ligaments and soft tissues. Injury to the neighboring ne

Treatment

Knee dislocations require prompt reduction. This is most easily acc
have shown that the isolated presence of abnormal foot pulses is r
should not delay treatment. Any vascular injury should be repairec

The timing of the treatment of the ligamentous damage is also cor
to prevent subluxation, usually posteriorly. If subluxation occurs, t
functional loss. The need for a brace for strenuous activities may b

PROXIMAL TIBIA FRACTURES

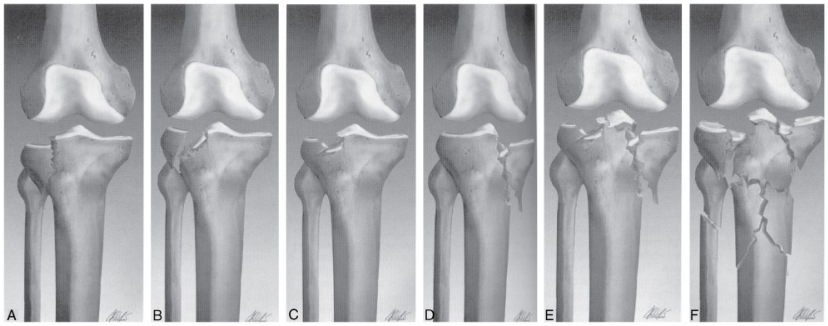
Tibial Plateau Fractures

Proximal tibia fractures account for 1% of all fractures. There is a
there can be a void with functional bone loss. These fractures usua
in compression and shear, with the ligament in tension. This is not

Classification

Many different classification systems have been proposed, none w
bicondylar fracture, and type VI: a fracture with metaphyseal-diap
MRI have all been used successfully for this purpose. MRI has also

Figure 3–27.



Schatzker classification of tibial plateau fractures: **A** (type I: latera
(Reproduced, with permission, from Rockwood CA et al, eds: *Frac*

Treatment

The goal of treatment is to restore anatomic contours to the articu
general medical condition, the degree of displacement and commir

Closed treatment with a cast or fracture brace is appropriate for m
valgus tilt up to 5 degrees is well tolerated. Medial plateau fractur
of motion is usually allowed after 6 weeks and weight bearing afte

Recently, reduction of the articular fragment under arthroscopic vi

Open reduction and internal fixation with plates and screws remai
Systems (LISS) are being used in the treatment of these injuries.

An external monolateral or ring fixator can be used for provisional

Hybrid and ring external fixators have been found to be useful for

Bai B et al: Effect of articular step-off and meniscectomy on joint

Cain EL, Clancy WG: Treatment algorithm for osteochondral injurie

Chen FS, Rokito AS, Pitman MI: Acute and chronic posterolateral r

Collinge CA, Sanders RW: Percutaneous plating in the lower extrer

Geller J et al: Tension wire position for hybrid external fixation of t

Griffin LY et al: Noncontact anterior cruciate ligament injuries: Ris

Kumar A, Whittle AP: Treatment of complex (Schatzker type VI) fr

Larsson S, Bauer TW: Use of injectable calcium phosphate cement

Lonner JH, Dupuy DE, Siliski JM: Comparison of magnetic resonan

Lundy DW, Johnson KD: "Floating knee" injuries: Ipsilateral fractu

Stevens DG et al: The long-term functional outcome of operatively

Yacoubian SV et al: Impact of MRI on treatment plan and fracture

Complications

Early complications include infection, deep vein thrombosis, compa

Tibial Tuberosity Fracture

Tibial tuberosity fractures can occur with a violent quadriceps mus

Although conservative treatment of a nondisplaced avulsion fractu

Tibial Eminence (Spine) Fracture

A tibial eminence fracture occurs as an isolated injury or as part o

Myers has classified this lesion into three stages and has recomme attachment to the anterior cruciate ligament, and anatomic reduct

DISTAL FEMUR FRACTURES

These fractures involve the distal metaphysis and epiphysis of the in the elderly) and high energy fractures (young patient). The dist impinge on the popliteal neurovascular bundle, and an immediate indicated. Injuries to the tibial or peroneal nerves are less frequen

A temporary spanning external fixation can be used to stabilize th provided that no infection at the pin sites has occurred. Complex T possible associated neurovascular injuries. Because of the comple

Extraarticular Fractures

Most of these fractures, are best treated with internal fixation, wh surgery is contraindicated and is fraught with all the previously me

Intraarticular Fractures

As for any intraarticular fracture, maximal functional recovery of t variety of methods including Dynamic Compression Screws (DCS), facilitates anatomic articular reconstruction and percutaneous plat

Intercondylar Fracture

A comminuted fracture of the distal femoral epiphysis is classically Even if the fracture heals in anatomic position, joint stiffness, pain

Condylar Fracture

Isolated fractures of the lateral or medial femoral condyles are rar

Closed reduction of displaced fragments is rarely successful. Open
early. Weight bearing is usually allowed at 3 months when clinical a

PATELLAR INJURIES

Transverse Patellar Fracture

Transverse fractures of the patella (Figure 3–28) are the result of
the patellar retinacula depends upon the force of the initiating inju

Figure 3–28.

Transverse fracture of the patella.

(Reprinted from Campbells Operative Orthopaedics, 9/e, Vol. 3, Ca

Clinical Findings

Swelling of the anterior knee region is caused by hemarthrosis and

Treatment

Nondisplaced fractures can be treated with a walking cylinder cast
If the minor fragment is small (no more than 1 cm in length) or se
early motion of the knee joint. This is best achieved by figure-of-e

Accurate reduction of the articular surface must be confirmed by la

Comminuted Patellar Fracture

Comminuted fractures of the patella are usually caused by a direct

If comminution is not severe and displacement is insignificant, imn

Severe comminution can often be treated with ORIF with addition matter what the treatment, high-energy injuries are frequently co

Patellar Dislocation

Acute traumatic dislocation of the patella should be differentiated f almost always lateral. Spontaneous reduction is apt to occur if the of the medial aspect of the knee has been extensive.

Reduction is maintained in a brace or cylinder cast with the knee i

Tear of the Quadriceps Tendon

Tear of the quadriceps tendon occurs most often in patients over t from sudden deceleration, such as stumbling or slipping on a wet s

Pain may be noted in the anterior knee region. Swelling is caused

Operative repair is recommended for complete tear. Postoperative

Tear of the Patellar Tendon

The same mechanism that causes tears of the quadriceps tendon, place in the proximal patellar tendon.

Operative treatment is necessary for a complete tear. The ligamen

Jutson JJ, Zych GA: Treatment of comminuted intraarticular distal

Meyer RW et al: Mechanical comparison of a distal femoral side pl

Stahelin T, Hardegger F, Ward JC: Supracondylar osteotomy of the

Woo SL et al: Healing and repair of ligament injuries in the knee. J

DIAPHYSEAL FRACTURES

Fracture of the shaft of the femur usually occurs as a result of sev

Clinical Findings

Extensive soft-tissue injury, bleeding, and shock are commonly pre Careful radiographic examination in at least two planes is necessar patient morbidity.

Injuries to the sciatic nerve and the superficial femoral artery and infection.

Classification

No classification is universally accepted for fractures of the femora

Type 1: Fracture that involves no, or minimal, comminution at the

Type 2: Fracture with comminution leaving at least 50% of the circ

Type 3: Fracture with comminution of 50–100% of the circumferer

Type 4: Fracture with completely comminuted segmental pattern w

Treatment

Treatment depends upon the age and medical status of the patien

CLOSED TREATMENT

This remains a treatment option for some skeletally immature pati casting.

Closed treatment of femoral shaft fractures in the adult is rarely ir

OPERATIVE TREATMENT

Most fractures in the middle third of the femur can be internally fi knee and hip function by decreasing the time spent in traction; an

Although open nailing procedures have been described, intramedu

In closed nailing, the fracture is reduced by closed manipulation or nailing decreases the chance of infection by decreasing the amoun standard of treatment. Screws are inserted percutaneously throug to 10% of dynamic interlocking may undergo secondary rotation o grade 1, 2, and 3a open fractures. When associated with extensive

Complications of this procedure can arise from technical problems severely comminuted fractures with weight bearing can suffer rod be removed after healing is complete, usually at 12–16 months. Th

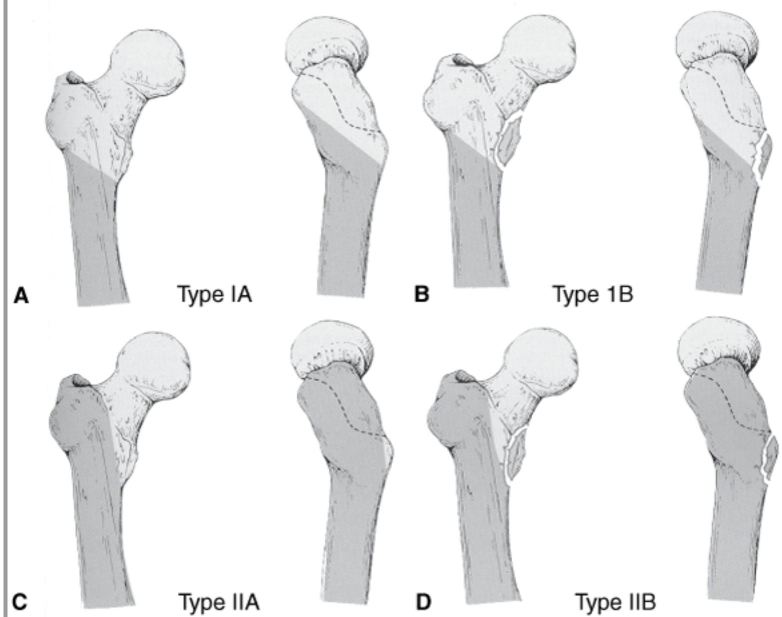
Other fixation devices are seldom used. Flexible intramedullary roc such as ipsilateral femoral neck and diaphyseal fractures. External also recently gained acceptance as treatment for closed femoral sh involves the bone. A course of oral antibiotics, proper pin care, and

SUBTROCHANTERIC FRACTURES

Subtrochanteric fractures occur below the level of the lesser troch

The Russell and Taylor classification (Figure 3–29) is a treatment b intramedullary nail. Type Ib fractures do not involve the piriformis sliding hip screw or fixed angle plate. The patient usually presents

Figure 3–29.



Russell and Taylor classification of subtrochanteric femur fractures
(Reproduced, with permission, from Browner BD et al, eds: *Skele*

In the vast majority of cases, internal fixation (by closed or open r

Closed intramedullary interlocking nails have gained more populari
or with a variety of cephalomedullary nails or blades and long side

Postoperative activity depends on the adequacy of internal fixatior
uncommon. Hardware failure in these cases are frequent. Repeat i

Brumback RJ, Virkus WW: Intramedullary nailing of the femur: Re

Dora C et al: Entry point soft tissue damage in antegrade femoral

Giannoudis PV et al: Nonunion of the femoral diaphysis. J Bone Joi

Herscovici D et al: Treatment of femoral shaft fracture using unrea

Nowotarski PJ et al: Conversion of external fixation to intramedulla

Ostrum RF et al: Prospective comparison of retrograde and antegr

Patton JT et al: Late fracture of the hip after reamed intramedulla

Ricci WM et al: Angular malalignment after intramedullary nailing

Ricci WM et al: Retrograde versus antegrade nailing of femoral sh

Scalea TM, Boswell SA, Scott JD, Mitchell KA, Kramer ME, Pollak A

Shepherd LE et al: Prospective randomized study of reamed versu

Tornetta P, Tiburzi D: Antegrade or retrograde reamed femoral na

Tornetta P, Tiburzi D: Reamed versus nonreamed anterograde fem

Hip Fractures & Dislocations

Epidemiology & Social Costs

Hip fractures include intertrochanteric fractures and femoral neck
patients (>55 years), unable in many cases to care for themselves
effective care is necessary to avoid the all too frequent occurrence

Anatomy & Biomechanical Principles

The hip joint is the articulation between the acetabulum and the fe
arm is factored in, surprising forces across the hip joint are attaine
standing on that leg. For the same reasons, forces across the joint

The hip capsule is a strong thick fibrous structure that attaches or
union. Interposition of synovial fluid between fracture fragments, a

The vascular supply of the femoral head is also of paramount impo
anteriorly and posteriorly; (2) the interosseous circulation crossing
thrombosed. Secondary avascular necrosis of part or all of the fem
of necrotic bony substrate with a "softer" granulation tissue and se

Intertrochanteric fractures usually do not suffer this same fate. Th

Femoral Neck Fractures

Femoral neck fractures are intracapsular fractures. Because of the
time before the fracture is reduced.

Fractures of the femoral neck occur most commonly in patients ov
radiographs are mandatory.

Classification

The Garden classification for acute fractures is the most widely use

Type 1: Valgus impaction of the femoral head

Type 2: Complete but nondisplaced

Type 3: Complete fracture, displaced less than 50%

Type 4: Complete fracture displaced greater than 50%

This classification is of prognostic value for the incidence of avascu

Stable Femoral Neck Fractures

These include stress fractures and Garden type 1 fractures. Stress
impaction on the radiographs are important factors influencing fra

Toe-touch weight bearing (with crutches) until radiologic evidence

The Garden type 1 fracture is impacted in valgus position and is u
contraindicated, closed treatment with toe-touch crutch ambulatio

Unstable Femoral Neck Fractures

Although undisplaced, a Garden type 2 femoral neck fracture is un

Treatment is directed toward preservation of life and restoration o
requires prolonged recumbency with constant nursing care and is
as pain permits. Subsequent nonunion can be treated at a later st

Treatment

INTERNAL FIXATION

The goal of internal fixation is to preserve a viable femoral head fr
performed as soon as possible. General or spinal anesthesia is use
less disruption of blood supply than a posterior approach. Rigid int

PRIMARY ARTHROPLASTY

This procedure is indicated in the elderly patient for Garden type 4
of Garden type 4 fractures frequently fails and repeat surgery is r
preexisting disease, total hip replacement may be indicated. Prima

Complications

The most common sequelae of femoral neck fractures are loss of r
varies from 0 to 15%, for type 2 fractures 10–25%, for type 3 fra

Trochanteric Fractures

Lesser Trochanter Fracture

Isolated fracture of the lesser trochanter is rare. When it occurs, i

Greater Trochanter Fracture

Isolated fracture of the greater trochanter may be caused by direc

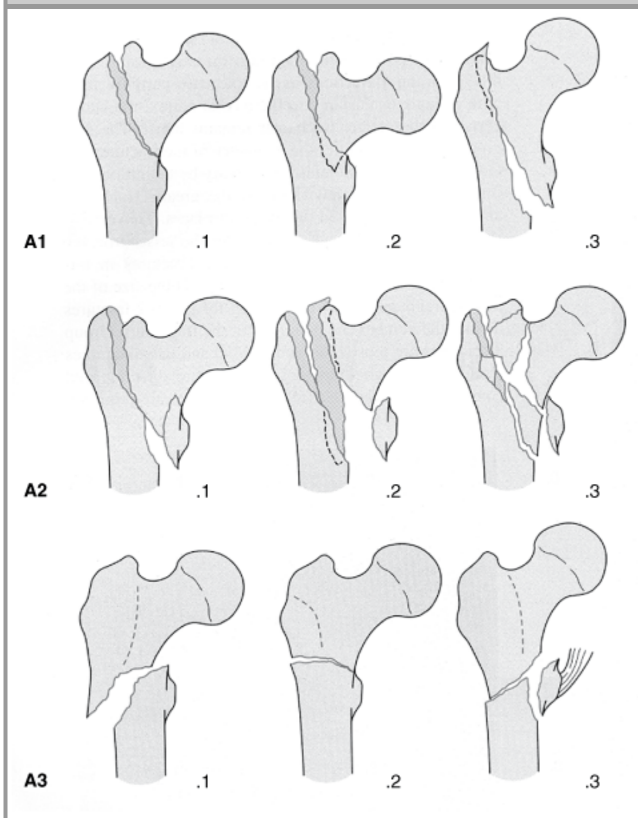
If displacement of the isolated fracture fragment is less than 1 cm
weight bearing is permitted as soon as healing is apparent, usually

Intertrochanteric Fractures

By definition, these fractures usually occur along a line between th
and avascular necrosis of the femoral head are not significant prob

Clinically, the involved extremity is usually shortened and can be in
(head and neck, greater trochanter, lesser trochanter, and femoral

Figure 3–30.



Muller/AO system for intertrochanteric femur fracture classificatio

(Reproduced, with permission, from Browner BD et al, eds: *Skele*

The selection of definitive treatment depends upon the general co
surgery can be performed within 48 hours. Initial treatment in the
mental status, and varus malunion. When surgery is contraindicat

The great majority of these fractures are amenable to surgery. Th
fluoroscopic imaging. Some surgeons do not attempt to anatomica
fracture to impact in a stable position. The patient can be taken o
Recent results of series have shown more complications of fractur

General complications include infection, hardware failure, loss of r

Traumatic Dislocation of the Hip Joint

Traumatic dislocation of the hip joint may occur with or without fra
femur cannot be completely displaced from the normal acetabulum

Posterior Hip Dislocation

Usually, the head of the femur is dislocated posterior to the acetab

The significant clinical findings are shortening, adduction, and inte
nerve injury. The head of the femur may be displaced through a te

If the acetabulum is not fractured or if the fragment is small, redu
femoral head increases with time until reduction. The main feature

The stability of the reduction is evaluated clinically by ranging the
tissue or bone fragment interposition will be manifested by wideni
indications for immediate open reduction and internal fixation if ne
surgery. Recently, hip arthroscopy has gained popularity, but it ren

Minor fragments of the posterior margin of the acetabulum may be

Postreduction treatment will vary according to the type of initial su
weeks. An unstable reduction can be immobilized in a spica cast or
necessary.

Complications include infection, avascular necrosis of the femoral h
dislocation. It can occur as late as 2 years after the injury. MRI stu
sequelae in about 20% of cases. The rare patient who is neurologi
weight–bearing surface should be ignored if they do not disturb hi

Anterior Hip Dislocation

Anterior dislocation of the hip is rare compared to its posterior cou
found rarely beneath it (obturator dislocation) or under the iliopso

The hip is classically flexed, abducted, and externally rotated. The

Closed reduction under general anesthesia is generally successful.
is encouraged, and the patient is usually fully weight bearing by 4

Rehabilitation of Hip Fracture Patients

There has been an increased interest in the psychosocial outcome
status, myocardial function, upper extremity strength, balance, an

For the rare patient treated conservatively, rehabilitation focuses e
are focused toward early range of motion, muscle strengthening, a
agree that the same applies for femoral neck fractures with stable
a spica cast or brace However, it is highly undesirable in elderly pa

Conn KS, Parker MJ: Undisplaced intracapsular hip fractures: resu

Gotfried Y: Percutaneous compression plating of intertrochanteric

Gruson et al: The relationship between admission hemoglobin leve

Jaglal S, Lakhani Z, Schatzker J: Reliability, validity and responsive

Kenny AM et al: Osteoporosis in older men and women. Conn Med

Parker MJ, Handoll HH, Bhargara A: Conservative versus operative

Parker MJ, Handoll HH: Pre-operative traction for fractures of the

Parker MJ, Handoll HH: Gamma and other cephalocondylic intrame

Rosen JE et al: Efficacy of preoperative skin traction in hip fractur

Shah MR et al: Outcome after hip fracture in individuals ninety yea

Tidermark J et al: Quality of life related to fracture displacement a

PELVIC FRACTURES & DISLOCATIONS

The innominate bones articulate with the sacrum through the sacr
Osteoarticular structures and adjacent soft tissues will be involved

Mechanism of Injury

Four patterns of injury are responsible for pelvic fractures. Antero
sacrospinous and sacrotuberous ligaments remain intact limiting th
transmitted through the femur. The fourth pattern is a shear force

Clinical Findings

Knowledge of the injury mechanism is of prime importance and sh
landmarks, including posterior palpation of the sacrum and sacroili
should be performed only once or avoided in hemodynamically uns

An initial anteroposterior pelvic radiograph as per ATLS protocol is

Open Pelvic Fractures

Open pelvic fractures account for 2–4% of all pelvic fractures. Bec
10–25%, probably because of the application of multidisciplinary p

Treatment

Significant forces, either directly or indirectly through the lower ex
pelvic injury; rapid resuscitation; hemorrhage control (using angio
pelvis temporarily. Antiseptic pressure dressings should be applied

status stabilizes, the need for definitive versus temporizing mecha
percutaneous fixation) is usually deferred until a later time. When
those from weight bearing, and further internal fixation is often re

In open pelvic fractures, early surgical intervention using a multidi
repeated daily in an attempt to reduce the incidence of pelvic seps
Otherwise, external fixation is preferred when faecal or environme

ASSOCIATED INJURIES

Hemorrhage

Bleeding associated with pelvic ring fractures usually comes from t
vessels such as the femoral artery or the common iliac artery or v
required if there is distal ischemia.

Thrombosis

It is now well recognized that patients with pelvic fractures have a
trauma and pharmacologic anticoagulation once the acute hemorrh

Neurologic Injury

Neurologic injuries are common, with an overall incidence between
peripheral nerve itself (sciatic, femoral, obturator, pudendal, or su
all previously mentioned nerves. Peripheral nerve injuries have, ov
sequelae.

Urogenital Injuries

Urogenital injuries are also common, especially in men. The inciden
or perineum, or a high-riding or "floating" prostate on rectal exam
cystostomy should be performed. Late sequelae are common and

Injuries to the Pelvic Ring

Pelvic ring fractures account for 3% of all fractures. There is an ex

From the anatomic standpoint, the posterior sacroiliac ligamentous
views and CT scanning are necessary imaging techniques to make

Classification & Treatment

Tile devised a dynamic classification system based on the mechani

Table 3–4. The Tile Classification of Pelvic Ring Disru

Type A: Stable, posterior arch intact	A1: Posterior arch intact, fracture of innominate	A1.1 Iliac spine	A1.2 Iliac crest	A1.3 Ischial tuberosity	A2: Posterior arch intact, fracture of innominate	A2.1 Iliac wing fractures	U f c a a

	bone (avulsion)				bone (direct blow)		

Reproduced, with permission, from Browner BD et al, eds: *Skeleta*

Type A: Fractures that involve the pelvic ring in only one place anc

Type A1: Avulsion fractures of the pelvis, which usually occurs at r
usually sufficient. On rare occasions, symptomatic nonunion occurs

Type A2: Stable fractures with minimal displacement. Isolated frac
may heal with significant heterotopic ossification.

Type A3: Obturator fractures. Isolated fractures of the pubic or isc

Type B: Fractures that involve the pelvic ring in two or more sites.

Type B1: Open-book fractures occur from anteroposterior compres
should remember that fragment displacement at the time of injury
reduction is done by lateral compression using the intact posterior
mobilization, which is beneficial to the polytrauma patient.

Type B2 and B3: Lateral compression fractures. A lateral force app
degree of instability. The posterior lesion may be impacted in its d
hazardous after the first few days. Reduction can be maintained w

Type C: Fractures that are both rotationally and vertically unstable
immediately adjacent to the sacroiliac joint, but there is always los
Indirect radiologic clues of pelvic instability should be looked for su
weeks. Bony injuries heal quicker than ligamentous injuries. Exter
complications. It is best left to experienced pelvic surgeons.

Complications

Long-term complications of unstable pelvic ring disruptions are mc
some series. Nearly 5% of type C injuries are left with a leg length

Clinically significant neurologic deficit is present in 6–10% of patie

Fractures of the Acetabulum

The acetabulum results from the closure of the Y or triradiate cart

Fractures of the acetabulum occur through direct trauma on the tr

Anatomy

The acetabulum appears to be contained within an arch. It is supp
acetabulum to include the ischial spine and ischial tuberosity. The
The medial part of the anterior column is the true pelvic brim. The
posterior column.

Classification

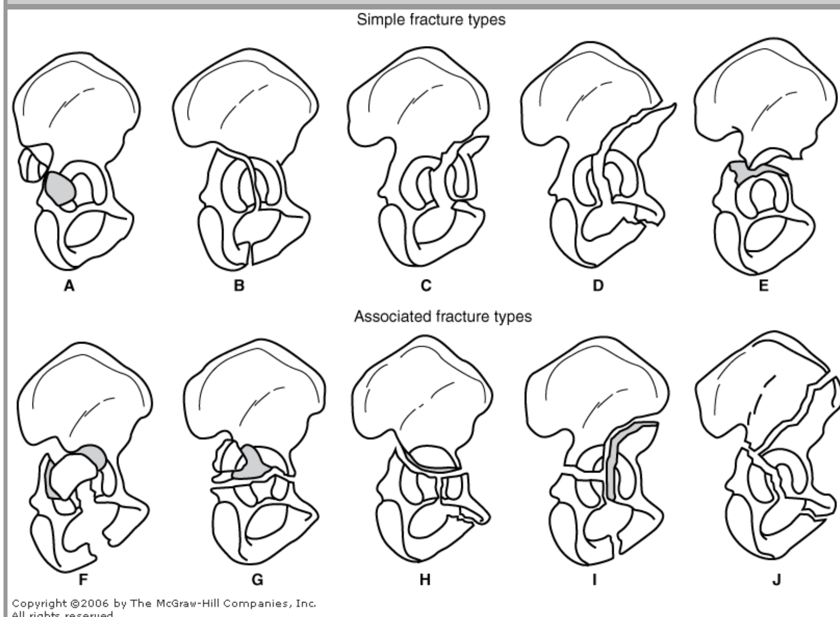
Letournel has classified acetabular fractures based on the involved

Proper fracture classification requires good-quality radiographs. Tw
the anterior column and the posterior lip of the acetabulum, and tl
non-fractured hip 45°. This view best shows the posterior column,

CT scanning gives further information on the fracture pattern, the

Letournel has classified acetabular fractures into 10 different type:

Figure 3–31.



Letournel classification of acetabular fractures.

(Reproduced, with permission, from Canale ST, ed: *Campbell's Op*

Treatment

The goal of treatment is to attain a spherical congruency between
and treated. Significant bleeding can be present and should be ad
branch of the sciatic nerve, the femoral nerve, and the lateral fem
as 60%.

The stabilized patient should be put in longitudinal skeletal tractior
obtained. In general, a displaced acetabular fracture is rarely redu

displacement of 2 mm or more, an incongruous hip reduction, mar
performed by trained pelvic surgeons. Other surgical indications in

Complications

Complications inherent to the injury include posttraumatic degener
infection, iatrogenic neurovascular injury, and increased heterotop
anticoagulation and heterotopic bone formation prophylaxis with ir

Bellabarba C, Ricci WM, Bolhofner BR: Distraction external fixation

Carlson DA et al: Safe placement of S1 and S2 iliosacral screws: tl

Ertel W et al: Control of Severe hemorrhage using C-clamp and pe

Grotz MRW, Allami MK, Harwood P, Pape HC, Kretekk C, Giannoudi

McCormick JP, Morgan SJ, Smith WR. Clinical effectiveness of the p

Routt ML, et al. Circumferential pelvic antishock sheeting: A tempo

Saterbak AM et al: Clinical failure after posterior wall acetabular fr

Switzer JA, Nork SE, Routt ML: Comminuted fractures of the iliac v

Tornetta P: Displaced acetabular fractures: Indications for operativ

SPORTS MEDICINE: INTRODUCTION

Sports medicine developed in the 1970s as an orthopedic specialty
and women's athletics. This wide range of care requires a multidis

KNEE INJURIES

Anatomy

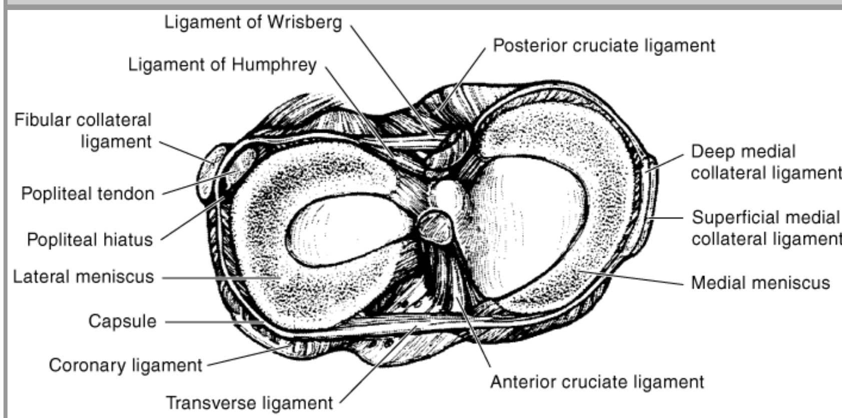
The bones of the knee are the distal femur, the proximal tibia, anc

MENISCI AND JOINT CAPSULE

The menisci, or semilunar cartilages, are C-shaped fibrocartilagino

The medial and lateral menisci provide a concave surface with whi
attached to the and posterior capsule, but there is a region poster

Figure 4–1.



The medial and lateral menisci with their associated intermeniscal

(Reproduced, with permission, from Scott WN: *Ligament and Exte*

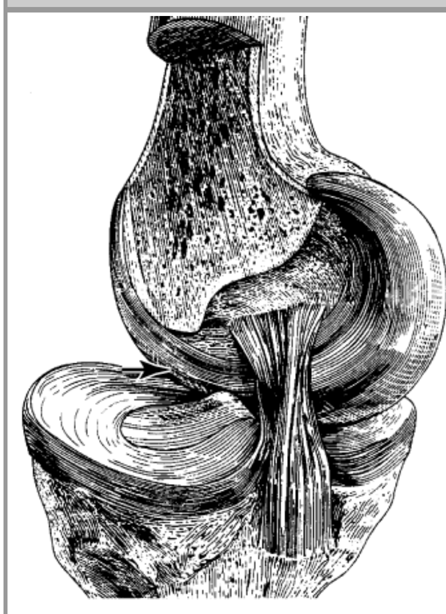
LIGAMENTS

Within the knee, the anterior cruciate ligament (ACL) travels from
deep portions (Figure 4–4), which stabilize the knee to valgus stre

Figure 4–2.

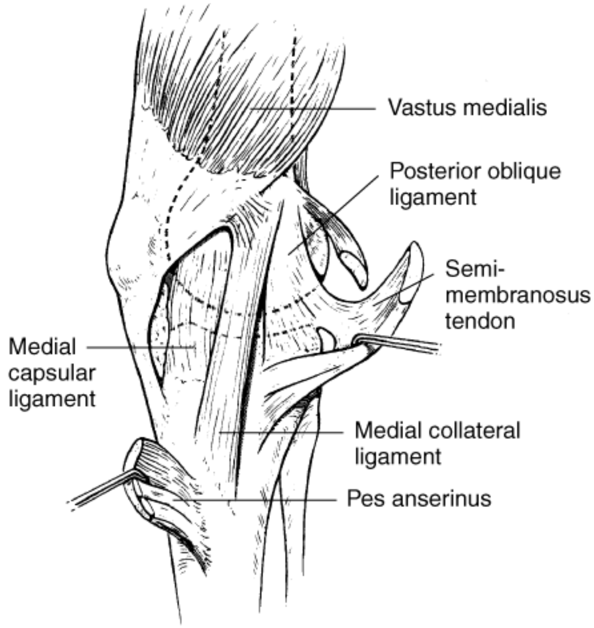
Drawing of the anterior cruciate ligament with the knee in extensi
(Reproduced, with permission, from Girgis FG et al: The cruciate l

Figure 4–3.



Drawing of the posterior cruciate ligament, showing the course of
(Adapted, with permission, from Girgis FG et al: The cruciate ligar

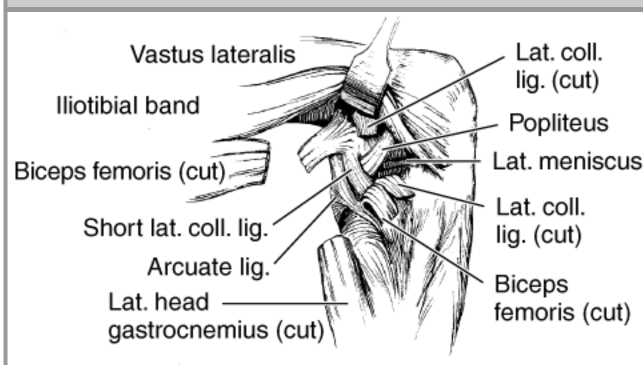
Figure 4–4.



Medial capsuloligamentous complex.

(Reproduced, with permission, from Feagin JA Jr: *The Crucial Liga*

Figure 4–5.



The lateral supporting structures of the knee.

(Reproduced, with permission, from Rockwood CA Jr et al: *Fractu*

History & Physical Examination

GENERAL APPROACH

The history of knee injury may be obtained by asking the patient t
and then passive range of motion is tested carefully. The knee is p

Table 4–1. History of a Knee Injury.

Did an injury occur?	Yes: possible ligament tear or meniscus tear.	No: overuse problem or degenerative condition.	
Was it a noncontact injury?			Yes the

ACL = anterior cruciate ligament; MCL = medial collateral ligamen

LIGAMENT LAXITY EVALUATION

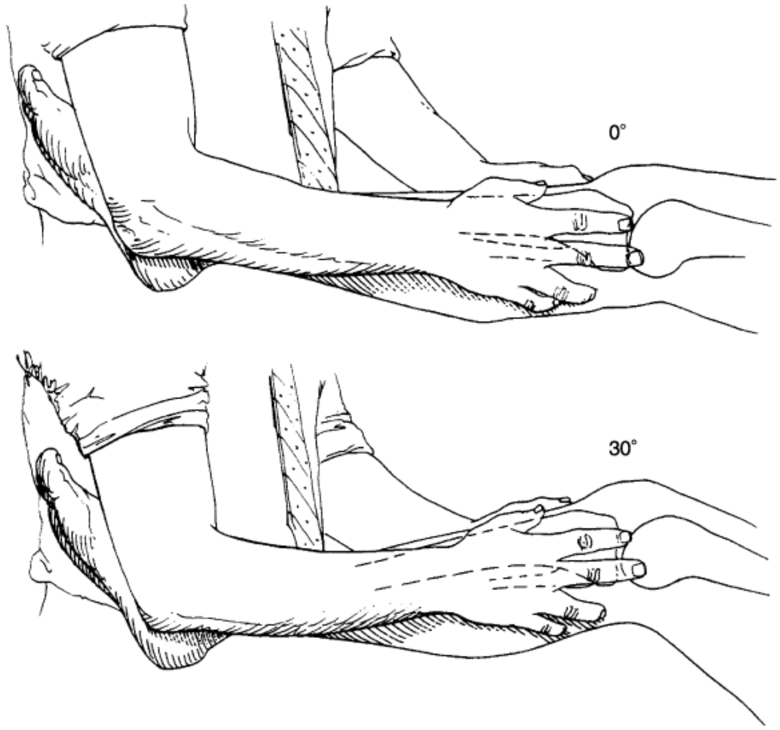
To determine varus and valgus stability (Table 4–2), the patient's f
extension, the posteromedial capsule and medial collateral ligamer

Table 4–2. Anatomic Correlation of Clinical Ligament I

Direction of Force	Position	Ligament Instability
Varus or valgus	Full extension	Posterior cruciate, posterior cap

AP = anteroposterior.

Figure 4–6.



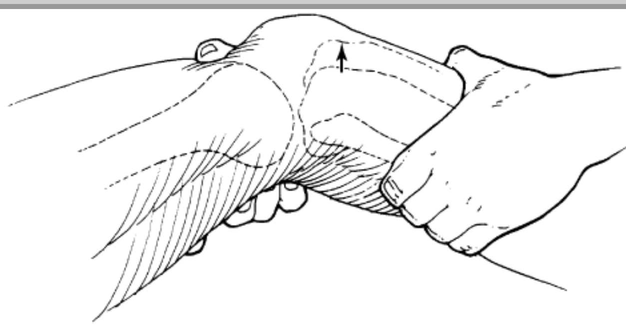
The collateral ligaments being tested in extension and 30 degrees

(Reproduced, with permission, from Feagin JA Jr: *The Crucial Liga*

The Lachman Test

The Lachman test is the most sensitive test for ACL tears. It is dor

Figure 4–7.



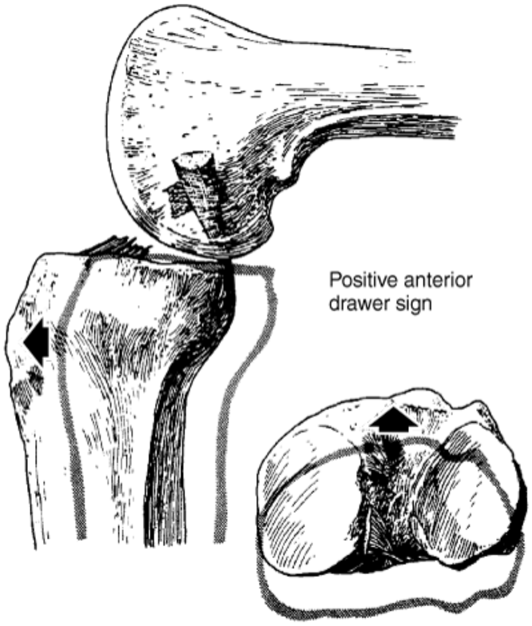
Lachman test.

(Reproduced, with permission, from Feagin JA Jr: *The Crucial Liga*

Anterior Drawer Test

The anterior drawer test is done with the knee at 90 degrees of fle

Figure 4–8.

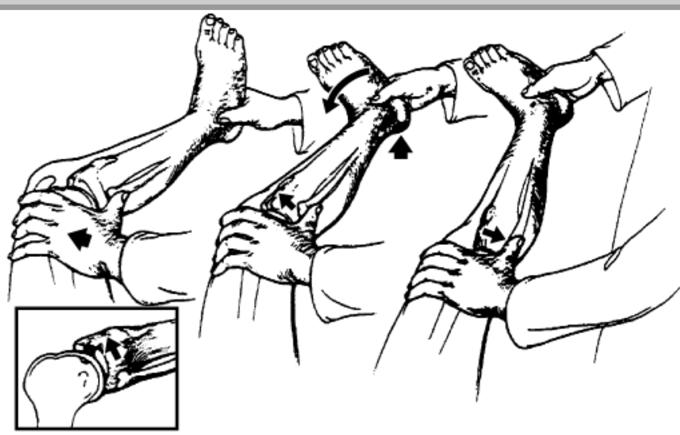


A positive anterior drawer test signifying a tear of the anterior cru
(Reproduced, with permission, from Insall JN: *Surgery of the Kne*

The Losee Test

The pivot shift phenomenon demonstrates the instability associate
other ways of doing this test are described, but the phenomenon a

Figure 4–9.



The Losee pivot shift test.

(Reproduced, with permission, from Scott WN: *Ligament and Exte*

Posterior Drawer Test

The posterior drawer test evaluates the integrity of the PCL. It is p

Figure 4–10.

The posterior drawer test is done in the same fashion as the anter

(Reproduced, with permission, from Scott WN: *Ligament and Exte*

Figure 4–11.

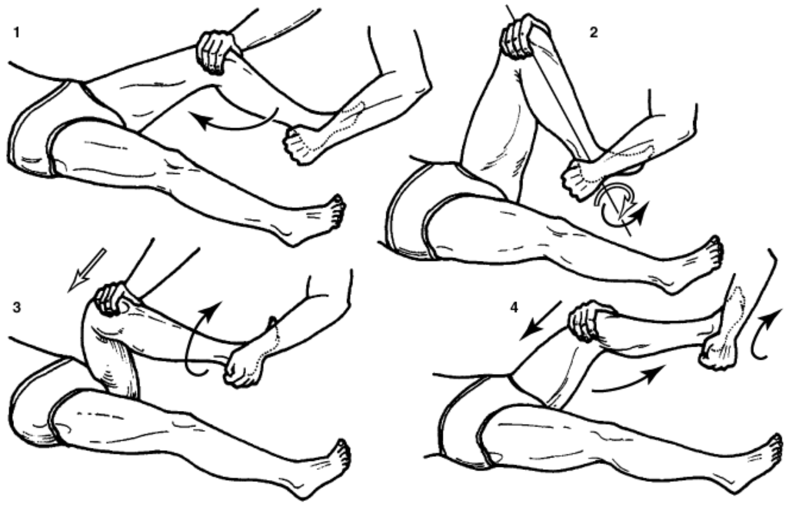
The posterior sag seen in posterior cruciate disruption.

(Reproduced, with permission, from Scott WN: *Ligament and Exte*

The McMurray Test

With the McMurray test, forced flexion and rotation of the knee eli

Figure 4–12.



The McMurray test to produce click.

(Reproduced, with permission, from American Academy of Orthop

Arthroscopic Examination

INDICATIONS FOR KNEE INJURIES

Indications for arthroscopic examination in the knee include the fo

1. acute hemarthrosis;
2. meniscus injuries;
3. loose bodies;
4. selected tibial plateau fractures;
5. patellar chondromalacia and/or malalignment;
6. chronic synovitis;
7. knee instability;
8. recurrent effusions; and
9. chondral and osteochondral fractures.

Today, a specific diagnosis of the type of knee injury can now usua

TECHNIQUE

Examination under anesthesia is very helpful in diagnosing ligamen level, but just medial to the patellar tendon for introducing arthros including the , is inspected. The lateral compartment is then exam

Imaging & Other Studies

MAGNETIC RESONANCE IMAGING

MRI is a powerful technique for evaluation of the knee joint. Althou less helpful for the diagnosis of problems in knees with previous su

IMAGING STUDIES

Roentgenographic examination of the knee is indicated in the evalu

LABORATORY TESTS

Laboratory tests may be helpful in ruling out nonmechanical disord

Chang CY et al: Imaging evaluation of meniscal injury of the knee

Luhmann SJ et al: Magnetic resonance imaging of the knee in chilc

Sanders TG, Miller MD: A systematic approach to magnetic resona

Scholten RJ et al. The accuracy of physical examination diagnostic

MENISCUS INJURY

Meniscal injuries are the most common reason for arthroscopy of t

Clinical Findings

Acute traumatic tears of the menisci are often caused by axial loac often involve a lateral meniscus tear as the lateral compartment o

Conversely, chronic or degenerative tears of the menisci often pre

The most important physical examination findings in the knee with when the torn meniscus is trapped between the femoral condyle a the lower leg in external and internal rotation. A positive tests resu

In addition to the procedure just described, physical examination c meniscus lesion, fracture, or chondrosis, respectively. Ligamentous

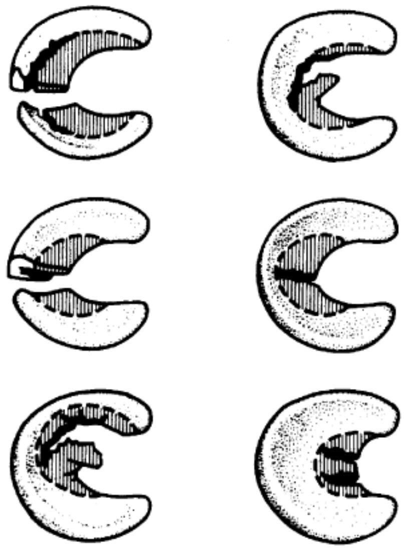
Tear Classification

Meniscal tears can be classified either by etiology or by their arthr

Classification should describe the tear location and its associated v

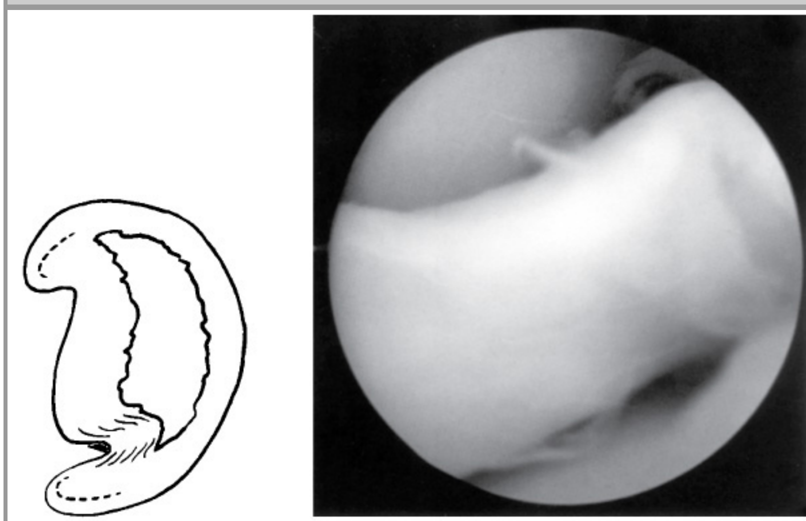
Tear morphology describes the orientation of the tear within the m Long tears can cause significant mobility of the torn meniscal fragı near the posterior horns, and are more common in patients more

Figure 4–13.



Patterns of meniscal tears: bucket-handle, flap, horizontal cleavag
(Reproduced, with permission, from Scott WN: *Arthroscopy of the*

Figure 4–14.



A: Diagram of a typical bucket-handle tear of the medial meniscu
(Reproduced, with permission, from McGinty JB: *Operative Arthro*

Treatment & Prognosis

Small stable asymptomatic meniscus tears do not need to be treat
During arthroscopy, the meniscus should be visualized and palpate

Tears in the peripheral third of the meniscus, if small (less than 15

PARTIAL MENISCAL RESECTION

Partial meniscectomy has 90% good or excellent results in patients are associated with a better prognosis.

MENISCUS REPAIR

Most surgeons attempt a meniscus repair rather than a partial me repair.

Multiple factors affect the success of meniscus repair. Although no the red/white or white/white zones. Tears 5 mm or more from the considered the gold standard in meniscus repair.

Meniscus repair is successful in up to 90% of meniscus tears when

Types of repairs include the traditional open repair and arthroscop bleeding. Restoration of biomechanical function is encouraged by a

OPEN MENISCAL REPAIR

Open repair of meniscus tears has successful long-term results. Th tears or fracture repair cases.

ARTHROSCOPIC MENISCAL REPAIR

Inside-Out Meniscal Repair

Arthroscopic inside-out meniscus repairs are performed using long outside the joint. This technique requires a posteromedial or poste technique is ideal for posterior and midposterior horn tears. There

Outside-in Meniscal Repair

The arthroscopic outside-in repair was developed in part to decrea retrieve the suture through the second needle. This can be done u

All-Inside Meniscal Repair

The popularity of the all-inside repairs has increased as numerous

The initial devices introduced in the early 1990s included biodegra cartilage injuries. Additionally, mechanical testing of these first-ge

Updated first-generation and second-generation devices were deve Endoscopy Div., Andover, MA) and RapidLoc (Mitek, Westwood, MA

It is difficult to compare studies for these updated first-generation Some were even comparable to traditional open suture techniques

Biomechanical studies on second-generation devices are also publi mattress over horizontal mattress sutures is derived from the abili

Caution should be exercised in interpreting biomechanical studies

In general, however, multidevice studies show that (1) vertical ma

Repairable meniscus tears often occur with an ACL tear. Stabilizing

MENISCAL TRANSPLANTATION

An alternative to leaving the patient with a meniscus-deficient kne

Ahn JH, Wang JH, Yoo JC: Arthroscopic all-inside suture repair of r

Englund M et al: Patient-relevant outcomes fourteen years after m

McNicholas MJ et al: Total meniscectomy in adolescence: A thirty-y

Metcalf MH, Barrett GR: Prospective evaluation of 1485 meniscal t

Rijk PC. Meniscal allograft transplantation—part I: Background, re

Shelbourne KD, Dersam MD: Comparison of partial meniscectomy

Steenbrugge F, Verstraete K, Verdonk R. Magnetic resonance imag

KNEE FRACTURE

Articular cartilage injuries of the knee are infrequent, and the exar

Osteochondral Lesions

Osteochondral Fracture

There is much confusion about the nomenclature and etiology of ju
osteochondral fractures to pure chondral injuries. Currently, OCLs
injury may provoke further vascular compromise, which results in

Both adult and juvenile lesions that do not heal have the potential
recognition of OCL lesions.

Clinical Findings

A common presentation of a patient with an OCL is aching and act

An antalgic gait may be observed as the patient. An effusion may

Patients with unstable lesions may have crepitus and pain with ran
is confirmed on plain radiographs. MRI can give an estimation of th
surface, and a high signal line traversing the subchondral plate int

Equivocal prognostic value was found in the use of intravenous ga

Treatment & Prognosis

There is general agreement that initial nonoperative management

As failure of the subchondral bone precedes failure of the overlying

A general consensus is that patients should at least be non– or pa
recurrence of symptoms or pain or any progression of the OCL on

Operative treatment should be considered in the following instance

For stable lesions with an intact articular surface, arthroscopic drill

Patients with flap lesions or partially unstable lesions should be ma
screws and bioabsorbable screws or pins. Complication, however, i

Simple excision of the larger fragments shows poor results with m
site morbidity and incongruent articular fit. Advantages include bio

Cepero S, Ullot R, Sastre S: Osteochondritis of the femoral condyl

KNEE LIGAMENT INJURY

Knee injuries occur during both contact and noncontact athletic ac

Ligament injuries are graded as follows: grade 1, stretching of the

Anatomy

Knee stability requires proper functioning of four ligaments. These

The MCL is the primary static stabilizer against valgus stress at th

The LCL is the primary static stabilizer against varus stress at the
also contribute to stability on the lateral aspect of the knee.

The ACL is the primary static stabilizer of the knee against anterio
and extrasynovial.

The PCL is the primary static stabilizer of the knee against posteri
anterolateral band is tight in flexion and loose in extension. The po

Differential Diagnosis of Knee Instability

The differential diagnosis of acute or chronic knee instability can in
confirm clinical suspicions and to evaluate for occult injuries.

Brown JR, Trojian TH: Anterior and posterior cruciate ligament inju

Medial Collateral Ligament Injuries

Clinical Findings

An MCL tear typically presents with medial knee pain after either a

Symptoms (History)

How and when the patient was hurt are important parts of the his
injury, fracture, and/or patellar dislocation. A prior history of knee

Signs (Physical Examination)

MCL injuries are evaluated with a complete knee examination to ev

Medial joint line tenderness along the course of the MCL is typical
mm indicating a grade II injury; and 10–15 mm indicating a comp

Imaging Studies

RADIOGRAPHS

A series of knee radiographs should be obtained in any patient wit

MAGNETIC RESONANCE IMAGING

MRI is useful for confirming MCL injury and identifying the site of i

SPECIAL TESTS

An examination under anesthesia can be valuable when physical ex

Treatment: Nonsurgical & Surgical

Treatment of an isolated MCL injury is generally nonoperative with

Grade III injuries are a bit more controversial. Several authors sho

The exception to the current trend of nonsurgical treatment of gra
insufficient for a stand alone repair. Chronic reconstructions also o

Traditionally, casting or operative treatment of MCL injuries signific

Complications

With nonsurgical treatment becoming the standard of care, compli

Results/Return to Play

In general, good outcomes can be achieved with nonsurgical treatı

Robinson JR et al: The posteromedial corner revisited. An anatomi

Woo SL, Vogrin TM, Abramowitch SD: Healing and repair of ligame

Lateral Collateral Ligament Injuries

Symptoms (History)

The most consistent symptom of an acute LCL injury is lateral kne
complain of lateral joint line pain and a varus thrust of their leg wi

Signs (Physical Examination)

Patients with a LCL and/or posterolateral corner injury often also h

The integrity of the LCL is assessed with a varus stress with the kı

Note that a significant posterolateral knee injury can be present w

Imaging Studies

RADIOGRAPHS

A series of knee radiographs should be obtained in any patient wit
present.

MAGNETIC RESONANCE IMAGING

MRI is often a useful adjunct for diagnosing posterolateral corner a

SPECIAL TESTS/EXAMINATIONS

Reverse Pivot Shift Test

This test involves starting with the knee flexed to 90 degrees. Whi

External Rotation Recurvatum Test

This test is performed with the patient supine and the hip and kne

Posterolateral Drawer Test

A standard posterior drawer test (see PCL physical examination) is

Examination under Anesthesia

An examination while the patient is relaxed under general anesthe

Treatment

NONSURGICAL

Isolated LCL ligament injuries, as noted earlier, are rare injuries. H

SURGICAL

LCL and posterolateral ligaments, as already discussed, rarely occu

The knee with chronic posterolateral instability often requires ligar

To improve the success rate of reconstruction of chronic lateral liga

Rehabilitation

The rehabilitation of the knee after posterolateral reconstructions

Complications

The peroneal nerve runs just posterior to the fibular head. It is im

Results

If injuries to the posterolateral corner of the knee are diagnosed a

Jakob RP, Warner JP: Lateral and posterolateral instability of the k

Ross G et al: Evaluation and treatment of acute posterolateral cor

Shahane SA, Ibbotson C, Strachan R et al: The popliteofibular liga

Anterior Cruciate Ligament Injuries

Symptoms (History)

The mechanism of injury should be elicited in any knee injury eval

ACL injury is often associated with a pop heard by the patient at t

Signs (Physical Examination)

With the history obtained and a proper physical examination, an A

The Lachman test is the most useful test for anterior laxity of the to the injured contralateral knee.

The anterior drawer test is another test to evaluate anterior tibial

In the acute setting of an ACL tear, there is often a window where

The pivot shift test is performed to test the rotational instability as

The pivot shift test is considered the most functional test to evalua

Imaging Studies

Plain radiographs of the knee should be obtained to rule out fractu tibial plateau are noted in up to 80% of ACL injuries.

Special Studies

Instrumented laxity evaluations can augment the physical examina

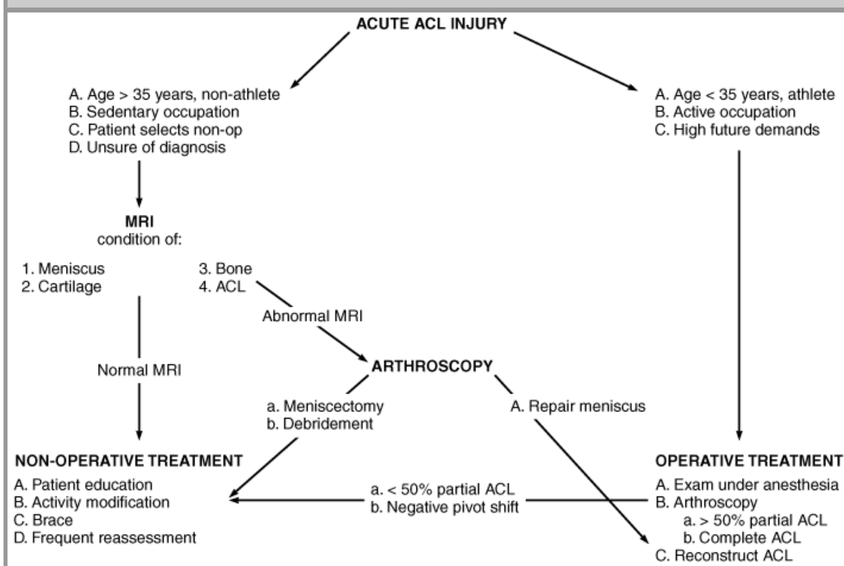
Treatment

NONSURGICAL

Rehabilitation following an isolated ACL injury should include an ef

Nonoperative management with rehabilitation after an ACL injury g

Figure 4–15.



Flow chart that summarizes the current management of acute ant

(Reproduced, with permission, from Marzo JM, Warren RF: Results

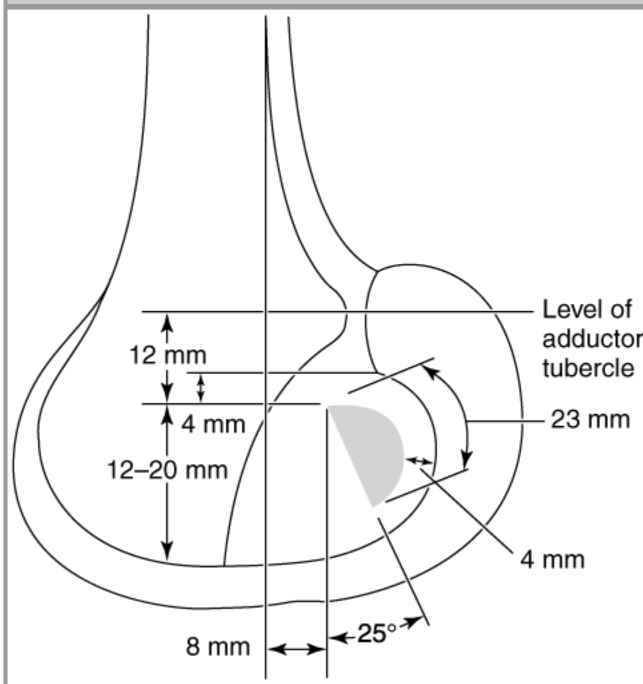
SURGICAL

The decision to reconstruct an ACL tear surgically is individualized
subjective instability would be much more suited to nonsurgical ca

Early in the history of ACL surgery, primary repairs of the ligamen

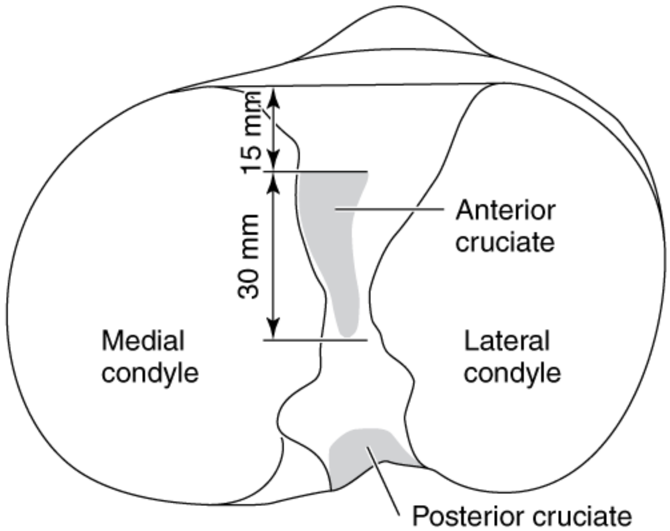
The goal of ACL reconstruction is to reproduce the strength, locati

Figure 4–16.



Drawing of the medial surface of the right lateral femoral condyle
(Reproduced, with permission, from Arnoczky SP: Anatomy of the

Figure 4–17.



The upper surface of the tibial plateau to show average measurem
(Reproduced, with permission, from Girgis FC et al: The cruciate l

Once the graft is in place, the proper tension and fixation of the gr
devices located on the outer cortex of the tunnels.

Complications

Although ACL reconstruction often results in a successful outcome,
this pain is unclear; however, it is thought that patellar tendon aut

Results/Return to Play

The goal of any rehabilitation protocol for an ACL reconstruction is
from institution to institution with a combination of functional testi

Herrington L et al: Anterior cruciate ligament reconstruction, hams

Hewett TE, Myer GD, Ford KR: Reducing knee and anterior cruciat

Laxdal G et al: A prospective randomized comparison of bone-pate

Marx RG et al: Beliefs and attitudes of members of the American A

Seitz H et al: Anterior instability of the knee despite an intensive r

Posterior Cruciate Ligament Injuries

Symptoms (History)

When evaluating a patient for a PCL injury, it is important to obtai

The presentation of a patient with a subacute or chronically injured
dashboard with the knee in 90 degrees of flexion. Sports injuries t
or valgus stress is applied to the hyperextended knee.

Signs (Physical Examination)

As with other ligamentous injuries, a thorough knee examination is

Examination of the PCL in the acutely injured knee can be challeng
anteromedial tibial plateau and the medial femoral condyle. The tib

Another test for examination of the PCL is the posterior sag or Go

The reverse pivot shift is the analogue to the pivot shift in the eva

It is extremely important to evaluate the posterolateral structures

Imaging Studies

RADIOGRAPHS

Given the magnitude of the forces required to injure the PCL, plain
occur over time.

MAGNETIC RESONANCE IMAGING

Although plain films are necessary and useful in the evaluations of
of the ACL is challenging in the setting of a complete PCL tear.

SPECIAL STUDIES

In the setting of a chronic isolated PCL tear, pain in the medial and

Treatment

There is significant controversy in the treatment of isolated PCL in

NONSURGICAL

Rehabilitation of the PCL injured knee often largely depends on the
injured PCL. With partial injuries (grade I and II), the prognosis is

Overall, most patients benefit from nonsurgical treatment of a PCL

The main subjective complaint with chronic PCL insufficiency, howe

SURGICAL

Surgical management of PCL injuries are broken down into avulsio

The majority of surgeons generally still treat isolated PCL injuries w
Therefore, given the risks of continued instability and the potentia

Initially, surgical care of complete PCL tears consisted of a primary
anterolateral bundle of the native PCL with a single-bundle reconst

The severe instability noted with PCL injuries associated with multi
challenging patient population.

Complications

The most common complication following PCL reconstruction is the

Results/Return to Play

Even with nonsurgical management of a PCL injury, the prognosis

However, the prognosis for a PCL tear associated with a multiligam

Allen CR, Kaplan LD, Fluhme DJ et al: Posterior cruciate ligament i

Fanelli GC, Edson CJ: Combined posterior cruciate ligament-poster

Patella Dislocation

Dislocation of the patella is a potential cause of acute hemarthrosis

Clinical Findings

The patella almost always dislocates laterally. The patient may not

Examination demonstrates tenderness over the medial retinaculum excisions or internal fixation. Examination of the uninjured knee is approximately 10 degrees, with a range of approximately plus or r

Treatment & Prognosis

A wide variety of treatment options are recommended for patellar

Treatment is based on which predisposing factors are present. Litt

Atkin DM et al: Characteristics of patients with primary acute later

Bensahal H et al: The unstable patella in children. J Pediatr Orthop

Buchner M et al: Acute traumatic primary patellar dislocation: Lon

KNEE TENDON INJURY

Ruptures of the quadriceps and patellar tendons usually result fror

Rupture of the Quadriceps Tendon

Quadriceps tendon ruptures occur most frequently in patients olde

The cardinal symptom is inability to extend the knee. When extens

Acute complete quadriceps tendon ruptures should be paired surgi

Ilan DI et al: Quadriceps tendon rupture. J Am Acad Orthop Surg

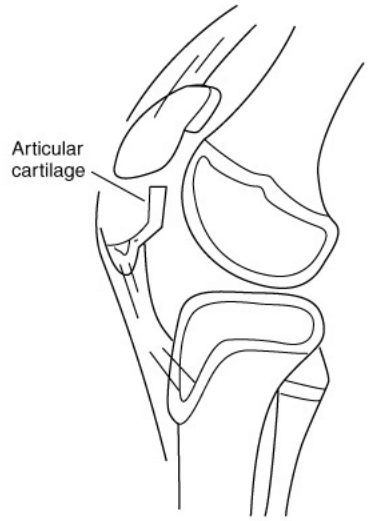
Konrath GA et al: Outcomes following repair of quadriceps tendon

Rupture of the Patellar Tendon

Rupture of the patella tendon occurs more frequently in patients y
femur and the patella pulled down to the proper location. The grac

The extensor mechanism may also be disrupted at the inferior pole

Figure 4–18.



A

B

Sleeve fracture of the patella. **A:** A small segment of the distal po

(Reproduced, with permission, from Rockwood CA Jr, ed: *Fracture*

KNEE PAIN

Pain in the knee region is a very common complaint of athletes. If

Anterior Knee Pain

Clinical Findings

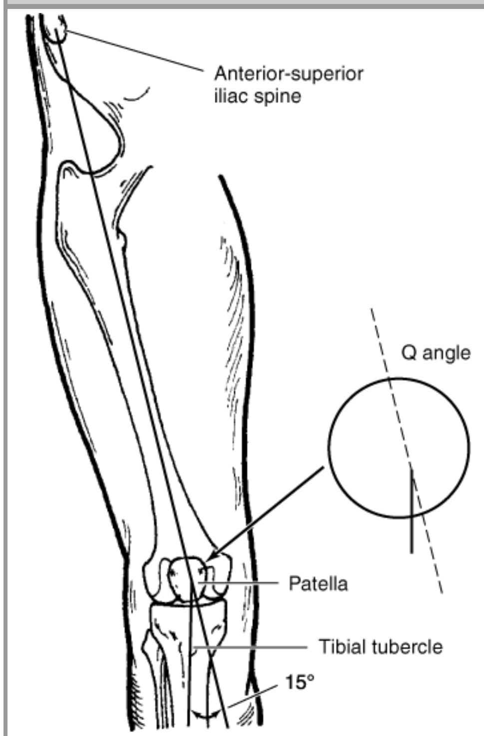
SYMPTOMS AND SIGNS

Anterior knee pain is a common complaint and frequently bilateral

Patellar pain is often felt when going up or down hills or stairs, and

Many of these problems arise because the patellofemoral joint is s
patella to frank dislocation, although subluxation is a much more c

Figure 4–19.



Q angle and valgus angulation.

(Reproduced, with permission, from American Academy of Orthop

On physical examination of the patient with patellofemoral subluxa

IMAGING STUDIES

Roentgenographic examination frequently shows a valgus angulati

This syndrome with a normal roentgenographic examination is freq

Treatment

CHONDROMALACIA PATELLAE

Initially, treatment is conservative, with the intent of improving qu

PATELLOFEMORAL ARTHRALGIA

Only when conservative treatment is exhausted should surgical tre

PATELLOFEMORAL COMPRESSION SYNDROME

With lateral patellofemoral compression syndrome, there is tender
respond to this regimen and gradually resume their activities. The

PATELLAR TENDINITIS

Patellar tendinitis, or jumper's knee, is seen in basketball and volle

Prognosis

The prognosis for jumper's knee is quite good. The condition is oft

Csintalan R et al: Gender effects on the biomechanical properties o

Kettunen JA, Visuri T, Harilainen A et al: Primary cartilage lesions a

Witvrouw E, Werner S, Mikkelsen C et al: Clinical classification of p

Lateral Knee Pain

Lateral knee pain that is not located on the joint line may result fr

Treatment involves decreasing the athlete's activities, ice-massage
prognosis is good.

Gunter P, Schwellnus MP: Local corticosteroid injection in iliotibial b

ANKLE OR FOOT PAIN

Evaluation of foot and ankle injuries is described in Chapter 9. Inju

Clinical Findings

Achilles tendonitis, a frequent complaint in runners, may result

Heel pain is a common problem in runners and difficult to treat b

Many patients have pain localized in the posteromedial surface of t

Posterior tibial syndrome occurs in runners with hyperpronation

Treatment

Treatment depends on the cause of the injury, but it includes decr

Surgical intervention for chronic Achilles tendinitis or retrocalcanea
disability for 6–12 weeks.

Hyperpronation may also cause fibular stress fractures. A semirigid

Mizel MS et al: Evaluation and treatment of chronic ankle pain. Ins

Shalabi A et al: Eccentric training of the gastrocnemius-soleus com

OTHER INJURIES OF THE LOWER BODY

Many disorders seen while caring for athletes may be difficult to d

OVERUSE SYNDROMES OF THE LOWER EXTREMITIES

Many athletes, such as runners, cyclists, aerobics enthusiasts, voll physician.

The physical examination should include not only the affected area

Muscle Strains

Muscle strains of the lower extremity are frequent, and disabling r

In spite of the frequency of muscle strains and the disability they contraction (muscle contraction while the muscle is lengthening) is

Clinical Findings

The diagnosis is relatively easy. Often the athlete feels the muscle

Treatment & Prognosis

The treatment of muscle strains should begin with ice in the imme

Strengthening of the muscles might make them less susceptible to

Askling C, Karlsson J, Thorstensson A: Hamstring injury occurrenc

Gabbe BJ, Finch CF, Bennell KL et al:. Risk factors for hamstring ir

Levine WN et al: Intramuscular corticosteroid injection for hamstri

Shin Pain

Clinical Findings

SHIN SPLINTS

The term *shin splints* is widely used for shin pain, but it is not a di complications if not cared for properly.

MEDIAL TIBIAL SYNDROME

Medial tibial syndrome is also seen in runners, occurring along the

Treatment

Treatment for shin splints and medial tibial syndrome is rest and r

Stress Fractures

Stress fractures may occur in the pelvis, femoral neck, tibia, navic persist for over a month, radiographs may become positive.

Treatment of stress fractures involves rest and avoidance of high-i

Armstrong DW III, Rue JP, Wilckens JH et al: Stress fracture injury

Perron AD, Brady WJ, Keats TA: Principles of stress fracture mana

Exertional Compartment Syndromes

Exertional compartment syndromes may result from muscle hyper

The syndrome presents as recurrent claudication during exertional

Treatment consists activity modification including gradual onset of

Shah SN, Miller BS, Kuhn JE : Chronic exertional compartment syr

CONTUSIONS & AVULSIONS OF THE LOWER BODY

Contusion to the Quadriceps Muscle

Clinical Findings

A severe contusion to the quadriceps muscle (charley horse) is dis

Myositis ossificans may occur after these injuries. It may be appar

Treatment & Prognosis

Quadriceps contusions should be treated with elevation of the leg
2 weeks; for severe contusions, 3 weeks.

If heterotopic ossification is present, no specific treatment is recor

Cooper DE: Severe quadriceps muscle contusions in athletes. Am

Diaz JA, Fischer DA, Rettig AC et al: Severe quadriceps muscle cor

CONTUSIONS ABOUT THE HIP AND PELVIS

Clinical Findings

Contusions about the pelvis and hip region may be very painful an

A contusion over the greater trochanter may cause persistent burs

A hip pointer is a very painful contusion over the iliac crest that oc

Treatment & Prognosis

For contusion over the greater trochanter, treatment consists of ic

AVULSION OF THE TIBIAL TUBERCLE

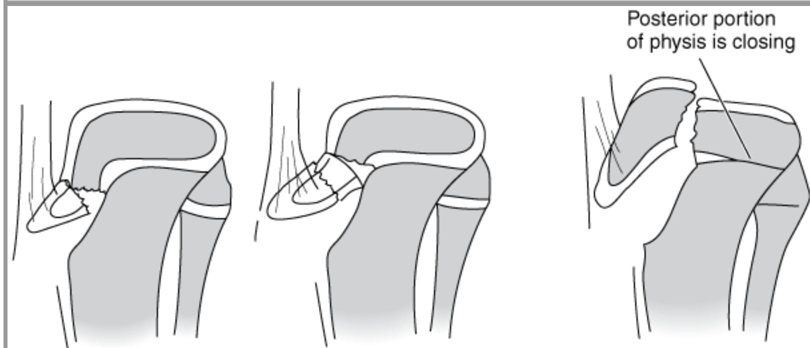
Clinical Findings

Tibial tubercle avulsions occur in adolescent athletes, most often ir surrounding perichondrium, and the adjacent periosteum.

Swelling and tenderness are located over the proximal anterior tib

Watson-Jones defined three types of avulsion fractures, which wer severity of injury to the surrounding soft-tissue moorings. A latera

Figure 4–20.



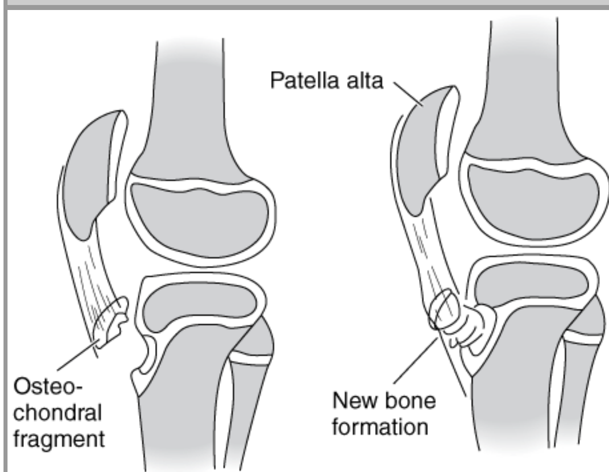
Classification of avulsion fractures of the tibial tubercle. Type 1 fra the posterior portion of the physis of the proximal tibia is closing.

(Reproduced, with permission, from Odgen JA et al: Fractures of t

Differential Diagnosis

Osgood-Schlatter disease, or osteochondrosis of the tuberosity of

Figure 4–21.



Development of Osgood-Schlatter lesion. (**Left**) Avulsion of osteoc

(Reproduced, with permission, from Rockwood CA Jr (ed): *Fractur*

Treatment recommendations vary from decreasing the amount of
usually allows continued participation in athletics. Hamstring stretc

Treatment

Full function of the extensor mechanism is necessary, and therefor
recommended, with screws if the piece or pieces are large enough

Prognosis

Because the injury occurs in children who are close to skeletal mat

AVULSIONS ABOUT THE PELVIS

Clinical Findings

In the skeletally immature athlete, the apophysis, or growth plate
(sartorius origin), anterior inferior iliac spine (rectus femoris origin

Treatment & Prognosis

Symptomatic care with a few days of rest followed by ambulation
is a painful fibrous nonunion, which also may be cured with excisio

Rossi F, Dragoni S: Acute avulsion fractures of the pelvis in adoles

SHOULDER INJURIES

The shoulder is the third most commonly injured joint during athle
this mobility is less structural restraint to undesirable and potentia

Kim DH et al: Shoulder injuries in golf. Am J Sports Med 2004;32(

Anatomy

THE BONY ARTICULATION OF THE GLENOHUMERAL JOINT

The glenohumeral joint is a modified ball-and-socket joint. The gle
medially, or laterally to accommodate changing humeral head posi

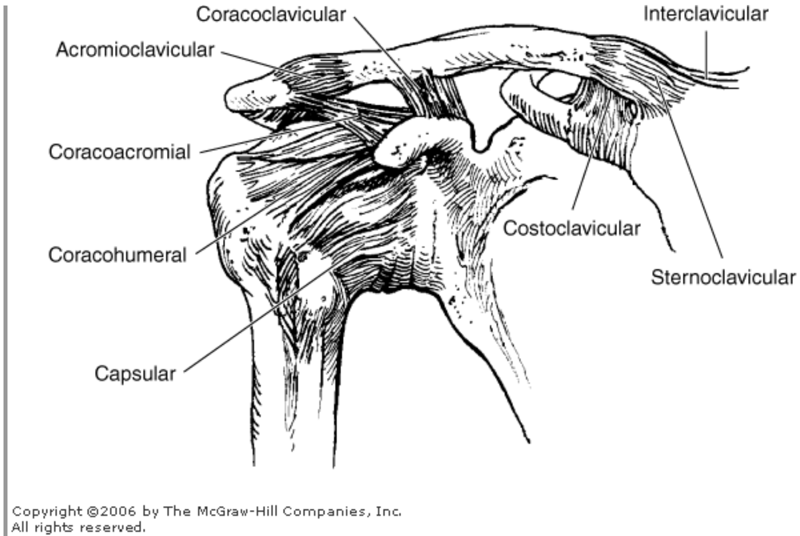
THE CLAVICLE AND ITS ARTICULATIONS

The clavicle articulates medially with the sternum at the sternocla

THE GLENOHUMERAL JOINT CAPSULE, LIGAMENTS, AND LA

The capsule of the glenohumeral joint may be the most lax of all t
be associated with joint instability more often than others. For exa

Figure 4–22.



Ligaments about the shoulder girdle.

The glenoid labrum not only acts as an attachment site for the cap

THE SHOULDER MUSCULATURE

The muscles around the shoulder may be divided into three functi

Glenohumeral Muscles

Four muscles compose the rotator cuff: the supraspinatus, subsca muscles originate on the posterior scapula, inferior to the scapular subscapularis muscle arises from the anterior scapula and is the o

The deltoid is the largest of the glenohumeral muscles. It covers t 50% loss of abduction torque. The deltoid muscle can fully abduct

The teres major muscle originates from the inferior angle of the sc

Thoracohumeral Muscles

The pectoralis major and the latissimus dorsi muscles are powerfu

Muscles that have origin on the thorax contribute to glenohumeral

Biceps Brachii Muscle

Both heads of the biceps brachii muscle have their origin on the sc humeral ligament.

Its origin on the scapula and insertion of the radius leaves the lon tendon may then contribute to glenohumeral joint stability.

THE NEUROVASCULAR SUPPLY

The axillary artery traverses the axilla, extending from the outer b nerve. This network of nerve fibers begins with the joining of the the brachial plexus.

Eberly VC, McMahon PJ, Lee TQ: Variation in the glenoid origin of t

Enad JG: Bifurcate origin of the long head of the biceps tendon. A

Price MR et al: Determining the relationship of the axillary nerve t

History & Physical Examination

GENERAL APPROACH

The history of shoulder complaints must include age, arm dominar
undressing so both shoulders are fully exposed. Patients should be

Table 4–3. History and Physical Examination of the Sh

	History	Physical Examination						
Cuff tendonitis	Pain over the lateral shoulder with overhead activity	Neer and Hawkin impingement signs		Night pain	Normal ROM		Mild weakness	Mild weakne

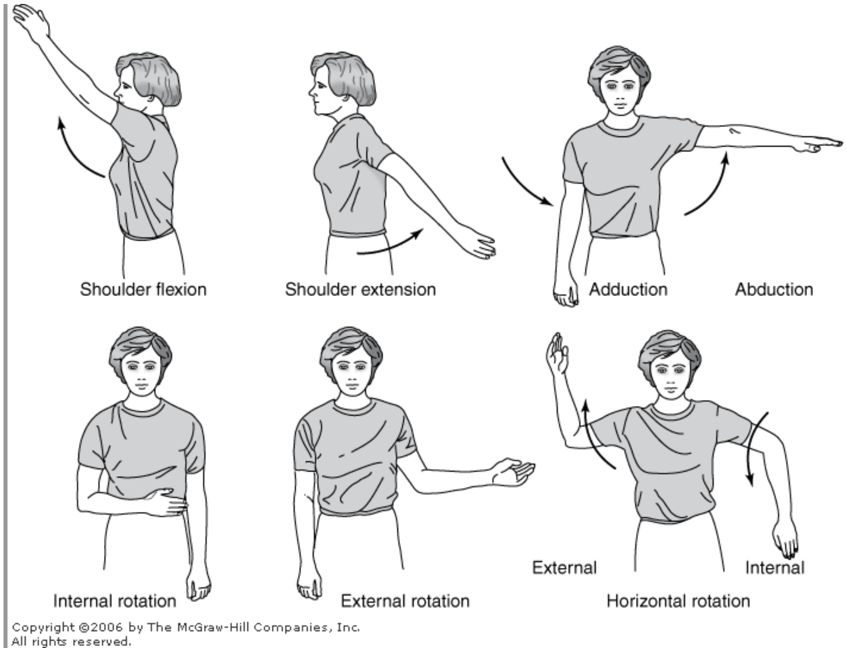
AC = acromioclavicular; ROM = range of motion.

SHOULDER RANGE OF MOTION

Types of Movement

Many terms may be used to describe movements of the shoulder j
arm rotates laterally or outward from the body. Horizontal adducti

Figure 4–23.



Description of shoulder motion.

Evaluation of Movement

Range of motion of the injured shoulder should be compared with
contractures. Loss of flexibility usually occurs in the capsular tissu

Provocative Tests

Specific tests are then performed that aid in making the correct di

Imaging & Other Studies

Many varieties of radiologic views and projections are available to
invasive and has little or no advantage over MRI. Ultrasonography

Arthroscopic Evaluation

INDICATIONS FOR ARTHROSCOPIC EVALUATION OF SHOUL

Indications for arthroscopic examination of the shoulder include th

1. impingement syndrome including subacromial bursitis, rotator cuff tendonitis, an
2. acromioclavicular joint osteoarthritis;
3. loose bodies;
4. chronic synovitis;
5. glenohumeral instability;
6. superior capsulolabral/biceps anchor lesions; and
7. adhesive capsulitis (frozen shoulder).

TECHNIQUE

With the patient either in the lateral decubitus or the beach chair
technique. The arthroscope is then removed from the joint and pla

STEPS IN EVALUATION

Examination of shoulder range of motion and stability with the pat

1. glenohumeral articular surfaces;
2. rotator cuff from inside the joint;
3. labrum including the biceps anchor;
4. anterior capsuloligamentous structures;
5. rotator cuff from the subacromial bursal space;
6. coracoacromial ligament;
7. acromion; and
8. acromioclavicular joint

Applegate GR et al: Chronic labral tears: Value of magnetic resona

Kaplan LD et al: Internal impingement: Findings on magnetic reso

Lee DH et al: The double-density sign: A radiographic finding sugg

Lindauer KR et al: MR imaging appearance of 180–360 degrees lal

Magee T, Williams D, Mani N: Shoulder MR arthrography: Which pa

Middleton WD, Teefey SA, Yamaguchi K: Sonography of the rotato

Porcellini G et al: Arthroscopic treatment of calcifying tendinitis of

SHOULDER TENDON & MUSCLE INJURY

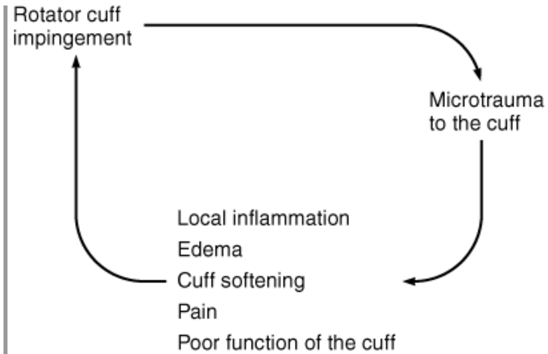
Rotator Cuff Tendon Injuries

Injury to the rotator cuff, a common cause of shoulder pain and di
tendonitis may also be the cause. Each of these entities most ofte

Impingement Syndrome

Any prolonged repetitive overhead activity such as tennis, pitching
tendon itself. Blood supply to this tendon is precarious, thus decre

Figure 4–24.



The cycle of injury and reinjury resulting from rotator cuff impinge

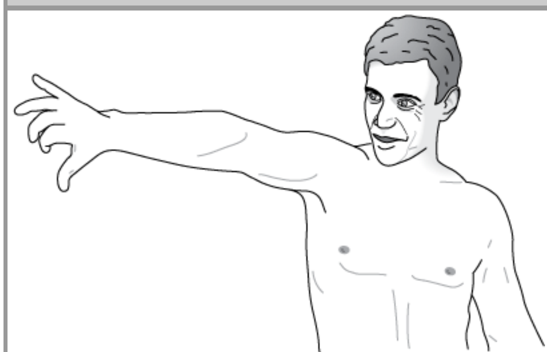
Subacromial Bursitis

Clinical Findings

Bursitis of the shoulder refers to the inflammation of the subacron

Active range of shoulder motion is limited by pain. No atrophy of t

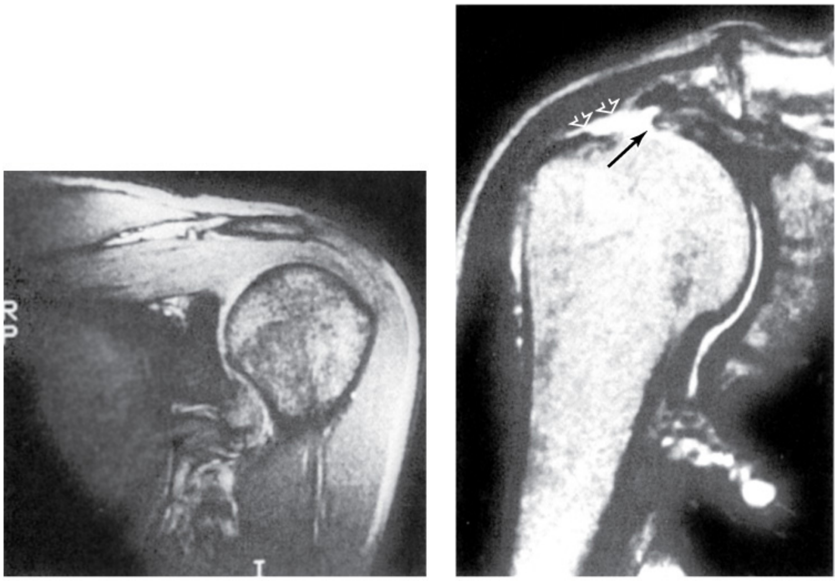
Figure 4–25.



Evaluating for impingement of the supraspinatus tendon with the

Radiographic views of the subacromial space, such as the supraspi

Figure 4–26.



A B

MRI demonstrating (**A**) normal shoulder anatomy and (**B**) cystic c

Treatment & Prognosis

Treatment for impingement syndrome starts with conservative me
a subacromial injection of corticosteroids may be helpful.

Surgical intervention is indicated only after failure of a prolonged c

Never has there been more controversy about this surgical proced
edema, cuff softening, pain, and poor function. These problems m

Other rationales are proposed for the efficacy of subacromial deco

Rotator cuff pathology is associated with the shape and geometry
scapulas to classify the acromions. Routine use of subacromial dec

Rotator Cuff Tendonitis

Clinical Findings

Of the four rotator cuff muscles, the supraspinatus tendon is most

Treatment & Prognosis

Radiographic evaluation and treatment are similar to subacromial I

Rotator Cuff Tendon Tear

Clinical Findings

A rotator cuff tendon tear is characterized by pain with overhead a

Active range of shoulder motion is limited, and if the tear is severe

Treatment & Prognosis

Radiographic evaluation and treatment are similar to subacromial I

Tears are most common at the humeral insertion site of the supras
may also cause a full-thickness tear in an athlete with mild or mod

If the tear is small, a prolonged period of rest, lasting 4–9 months

Rehabilitation lasts from 6 months to a year with gradual exercise
range of motion.

Although the lesion location and size are helpful in describing the r
nature of injury, patient age, activity level, humeral head superior

Partial-Thickness Rotator Cuff Tear

A partial articular sided tendon avulsion is much more common tha
healing in athletes with partial-thickness posttraumatic tears. Follo

Gartsman GM, O'Connor DP: Arthroscopic rotator cuff repair with

Hyvonen P, Lohi S, Jalovaara P: Open acromioplasty does not prev

Klepps S et al: Prospective evaluation of the effect of rotator cuff

Lam F, Mok D: Open repair of massive rotator cuff tears in patient

Millstein ES, Snyder SJ: Arthroscopic evaluation and management

O'Holleran JD et al: Determinants of patient satisfaction with outco

Rebuzzi E et al: Arthroscopic rotator cuff repair in patients older th

Romeo AA et al: Shoulder scoring scales for the evaluation of rota

Sperling JW, Cofield RH, Schleck C: Rotator cuff repair in patients

BICEPS TENDON INJURIES

Bicipital Tendinitis

Clinical Findings

The long head of the biceps muscle is an intraarticular structure d
impingement or tendon subluxation, are essentially the same. Pair

Treatment & Prognosis

If the tendinitis is associated with shoulder impingement, therapy
the substance of the tendon because they promote tendon degene

Biceps Tendon Rupture

Clinical Findings

The long head of the biceps tendon may rupture proximally, either
athletes (greater than 50 years old) or with direct trauma. Microte

Treatment & Prognosis

Surgical treatment of proximal ruptures, if indicated, is usually res
supination strength. In this case, the tendon is usually found appr

Cope MR, Ali A, Bayliss NC: Biceps rupture in body builders: Three

Vidal AF, Drakos MC, Allen AA: Biceps tendon and triceps tendon in

PECTORALIS MAJOR RUPTURE

Rupture of the pectoralis major tendon is an uncommon injury, usu
life. Surgery may be considered if the athlete wishes to return to h

Aarimaa V et al: Rupture of the pectoralis major muscle. Am J Spo

GLENOHUMERAL JOINT INSTABILITY

To make the correct diagnosis, the glenohumeral joint must be tes
the etiology of multidirectional instability is thought to be enlargen

The positive sulcus sign is used as the diagnostic hallmark for mult
based on etiology, or direction alone, extremely difficult. Instead,

Table 4–4. Classification of Glenohumeral Instability

	Direction	
Normal laxity	Very common 60%	Very rare 3%

Adapted, with permission, from Gerber C: Observations of the clas

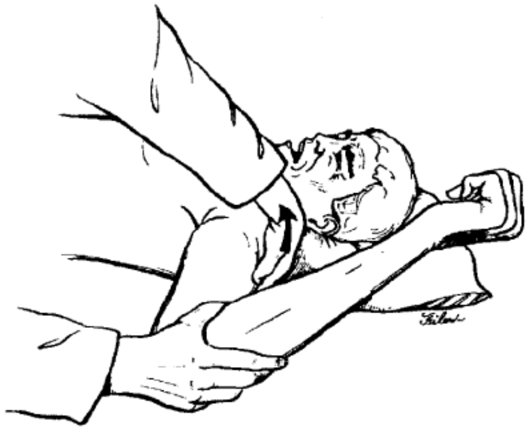
Gerber C, Nyffeler RW: Classification of glenohumeral instability. C

Glenohumeral Joint Instability Evaluation

ANTERIOR INSTABILITY

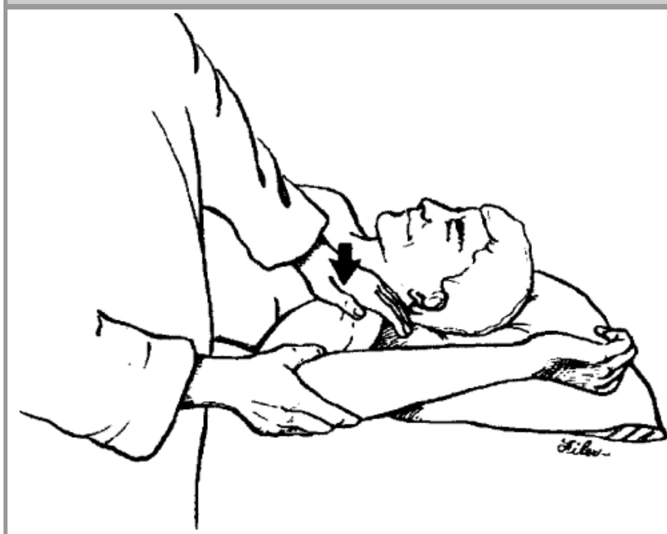
The apprehension test is performed to assess anterior instability. T

Figure 4–27.



The apprehension test for anterior instability.

Figure 4–28.

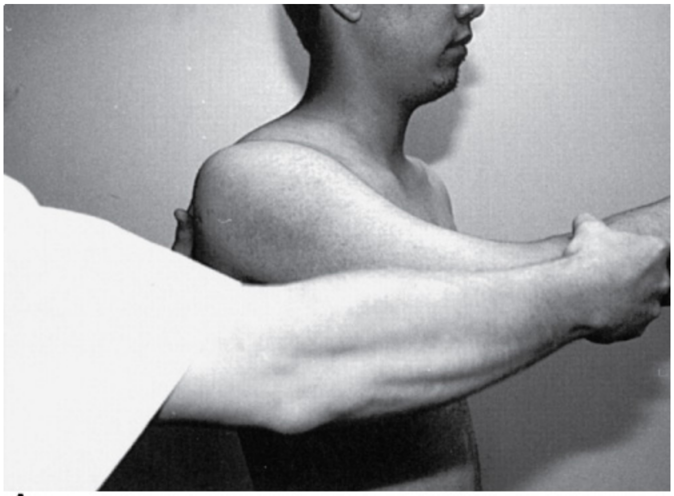


The relocation test is positive if relief is obtained by applying a po

POSTERIOR INSTABILITY

No single test has high sensitivity and specificity for posterior insta shoulder. If positive, the joint subluxes in the flexed, internally rot

Figure 4–29.



A

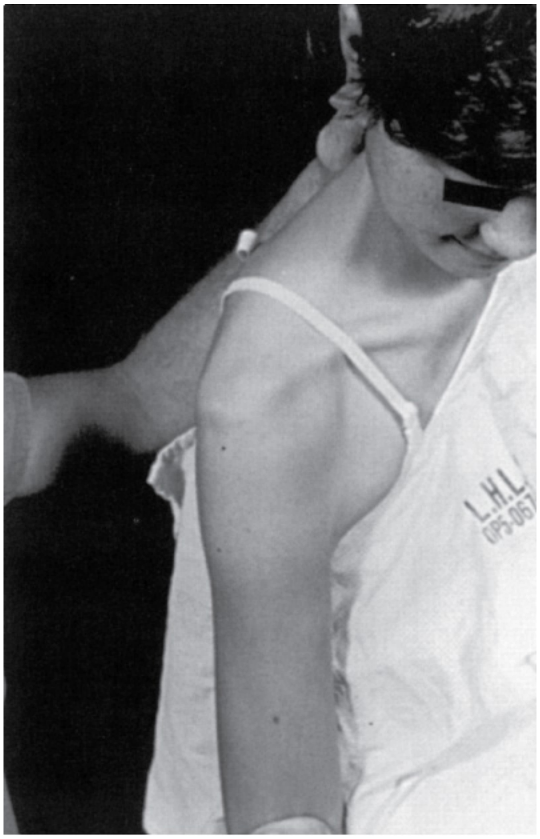
B

The Jahnke test for posterior instability. **A:** A posterior directed fo
(Reprinted, with permission, from Hawkins RJ, Bokor DJ: Clinical e

INFERIOR INSTABILITY

The sulcus sign is used to evaluate laxity and inferior instability. Tl

Figure 4–30.



The sulcus test for inferior instability.

(Reprinted, with permission, from Hawkins RJ, Bokor DJ: Clinical e

Glenohumeral Dislocation

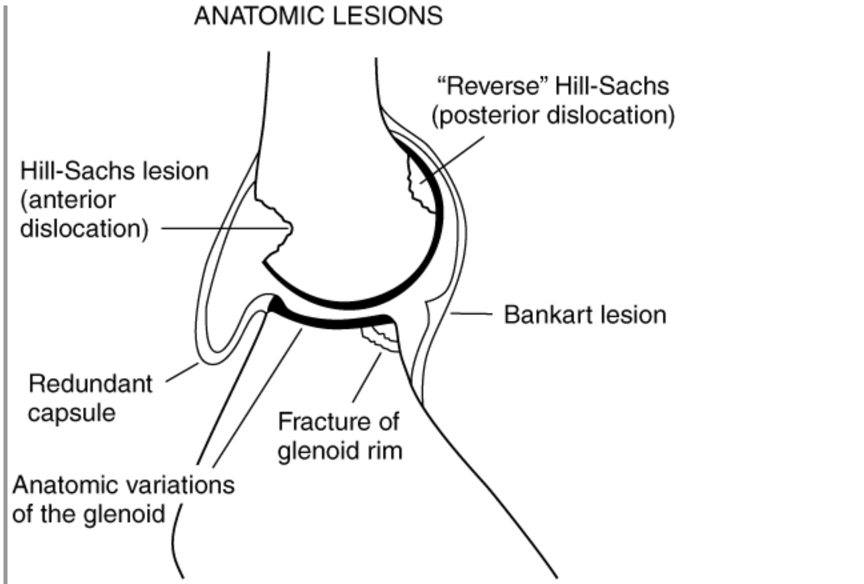
When the shoulder is forced beyond the limit of its normal range c

Anterior Dislocation

CLINICAL FINDINGS

Anterior glenohumeral dislocation occurs from either an external r
anterior capsular injury associated with a tear of the glenoid labru
and the Hill-Sachs lesions predispose to recurrent dislocations whe

Figure 4–31.



Anatomic lesions producing shoulder instability.

Other injuries associated with anterior dislocation may occur. Thes
later in the section on axillary nerve injuries, may be the best way

Athletes who sustain a shoulder dislocation try to hold the injured

TREATMENT AND PROGNOSIS

One must distinguish between acute and recurrent anterior glenoh
structures. Another method is to have the patient lie face down or

Following reduction of an initial dislocation, the shoulder should be
time elapses and complete healing is realized.

Recurrent dislocations should be treated with minimal immobilizati

If an athlete has sustained multiple dislocations and is unresponsiv

Table 4–5. Repair of Capsule and Labrum Back to the

Bankart procedure	duToit procedure	Viek procedure	Eyre-Brook procedure

For most surgical procedures, aggressive range-of-motion exercise

Posterior Dislocation

CLINICAL FINDINGS

Posterior glenohumeral dislocations result from the posterior capsu
injured shoulder in internal rotation and the examiner cannot rotat

TREATMENT AND PROGNOSIS

Applying traction in the line of the adducted humerus, with an ant

Multidirectional Instability

CLINICAL FINDINGS

Some patients have instability in both the anterior and posterior d

TREATMENT AND PROGNOSIS

A rotator cuff strengthening program is often successful treatment

Brophy RH, Marx RG: Osteoarthritis following shoulder instability.

Good CR, Macgillivray JD: Traumatic shoulder dislocation in the ad

Kim SH et al: Loss of chondrolabral containment of the glenohume

Kim SH et al: Painful jerk test: A predictor of success in nonoperat

Kirkley A et al: Prospective randomized clinical trial comparing the

Krishnan SG et al: A soft tissue attempt to stabilize the multiply o

GLENOID LABRUM INJURY

Clinical Findings

The glenoid labrum is a fibrocartilaginous rim around the glenoid f

Weight lifters may also develop glenoid labrum tears from repetiti

Patients with glenoid labrum injuries may describe their pain as int cuff muscles. Diagnostic tests such as a CT scan and MRI following

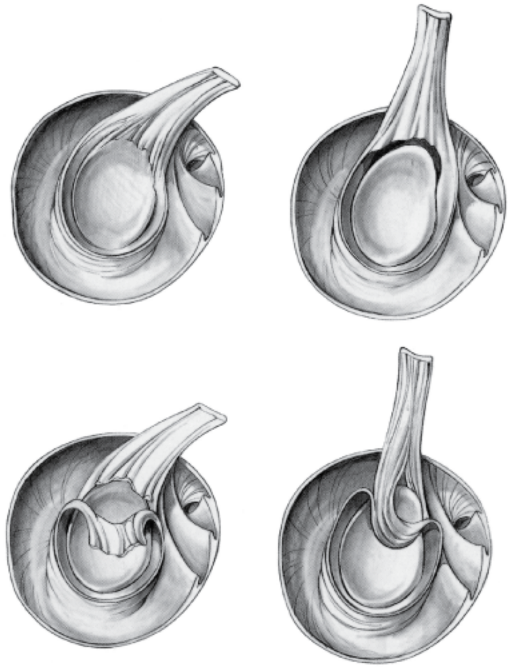
Treatment & Prognosis

Range-of-motion exercises and gradual return to activity are often athlete may begin a throwing program. Baseball pitchers may be r

SLAP LESIONS

The use of shoulder arthroscopy in the diagnosis and treatment of bucket-handle tear of the superior labrum with firm attachment of

Figure 4–32.



The five types of the SLAP lesion include fraying of the superior ca

Types V through VII SLAP lesions were later added to this initial fo

Clinical Findings

Patients present with nonspecific shoulder pain associated with act

No single test is both sensitive and specific for diagnosis of SLAP le rotation of the shoulder.

Treatment

Treatment of SLAP lesions can be simplified by noting whether or r

Holtby R, Razmjou H: Accuracy of the Speed's and Yergason's test

Musgrave DS, Rodosky MW: SLAP lesions: Current concepts. Am J

Parentis MA, Mohr KJ, El-Attrache NS: Disorders of the superior la

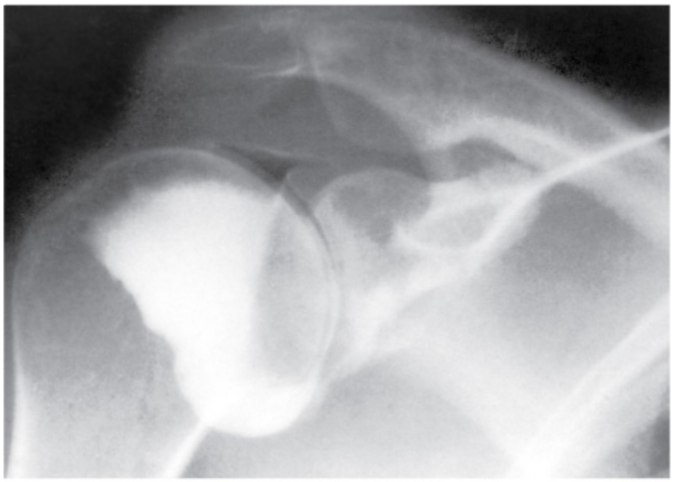
SHOULDER STIFFNESS

Clinical Findings

Often called adhesive capsulitis or frozen shoulder, shoulder stiffne is, none of the shoulder planes of motion is spared.

Shoulder stiffness may be separated into idiopathic and posttraum greatest incidence and bilateral involvement. The pathophysiology

Figure 4–33.



Adhesive capsulitis of the shoulder. Note the small irregular joint c

Although all patients can recall some traumatic event that precede
bypass grafting with sternotomy, and thoracotomy. All surgeons sh

The clinical presentation of idiopathic shoulder stiffness is classical
2 and 9 months.

The second phase of progressive stiffness lasts between 3 and 12
lasting for extended periods. In the resolution, or thawing phase, t

On clinical examination, there is loss of both active and passive ra

Treatment & Prognosis

Treatment varies, but conservative modalities and progressive ran

Ide J, Takagi K: Early and long-term results of arthroscopic treatm

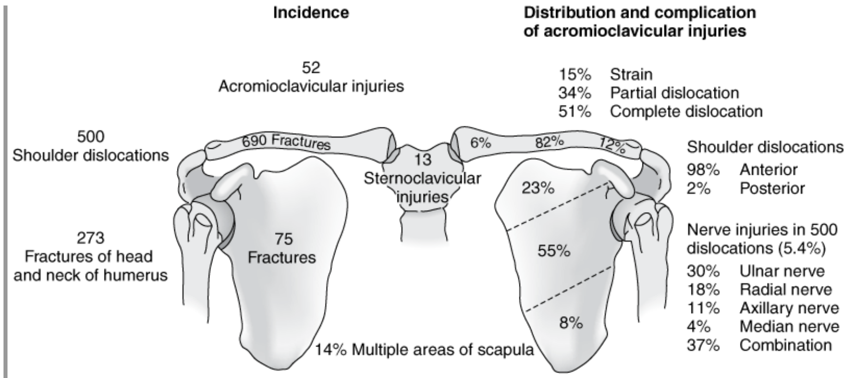
Nicholson GP: Arthroscopic capsular release for stiff shoulders: Eff

Wolf JM, Green A: Influence of comorbidity on self-assessment ins

CLAVICULAR FRACTURE

The clavicle is one of the most commonly fractured bones in the b

Figure 4–34.



Analysis of 1603 shoulder girdle injuries, showing the frequency a

Clinical Findings

Despite the proximity of vital structures, clavicular fractures that c
fractures account for 80% of clavicular fractures, with distal fractu

Because the clavicle is the single bone structure that fixes the sho
acromioclavicular dislocation. Delayed union in this type of fracture

Treatment & Prognosis

Mid and proximal clavicular fractures are usually treated with a sh

Grassi FS, Tajana MS, D'Angelo F: Management of midclavicular fra

Robinson CM, Cairns DA: Primary nonoperative treatment of displa

Robinson CM, Court-Brown CM, McQueen MM et al: Estimating the

PROXIMAL HUMERUS FRACTURE

Fractures of the proximal humerus, which represent approximately

Clinical Findings

The proximal humerus consists of four major bony components: th
tenderness about the shoulder, ecchymosis that may extend down
fracture and is essential in determining the treatment plan. Necess

Treatment & Prognosis

Most proximal humerus fractures are minimally displaced and can

For minimally displaced fractures, the prognosis is generally good.

Fankhauser F et al: A new locking plate for unstable fractures of th

Iannotti JP, Ramsey ML, Williams GR et al: Nonprosthetic manager

Robinson CM, Aderinto J: Posterior shoulder dislocations and fractu

PROXIMAL HUMERAL EPIPHYSEAL FRACTURE

In skeletally immature athletes, epiphyseal fractures of the proxim
Injury can occur to the shoulder of the growing musculoskeletal sy
Dobbs MB et al: Severely displaced proximal humeral epiphyseal f

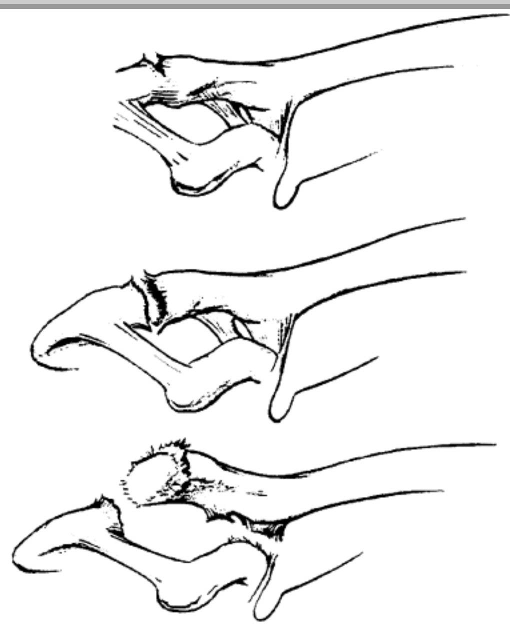
Karatosun V et al: Treatment of displaced, proximal, humeral, epi

ACROMIOCLAVICULAR JOINT INJURY

Clinical Findings

Acromioclavicular dislocations or subluxations, commonly referred
When checking for instability of the acromioclavicular joint, the exa
Acromioclavicular joint injuries were initially divided into grades I t

Figure 4–35.



Grades of acromioclavicular joint separations.

Three additional injuries were later added to the classification. In g
Acromioclavicular joint displacement is often obvious on physical e
classification.

Treatment & Prognosis

Management of acromioclavicular joint injuries depends on their se
reduction and internal fixation along with reconstruction of the cor

Nonsurgical treatment may either be a sling for comfort or an acrc
exercises may then follow because isometric exercises are more ef

Before resuming athletic activities, the patient must have full rang

Fractures of the coracoid process are rare, usually seen in profess

Dumonski M et al: Evaluation and management of acromioclavicula

Su EP et al: Using suture anchors for coracoclavicular fixation in tr

STERNOCLAVICULAR JOINT INJURY

In the skeletally mature adult athlete, injury to the sternoclavicula

Anterior Dislocation

The most common type of sternoclavicular dislocation is anterior d

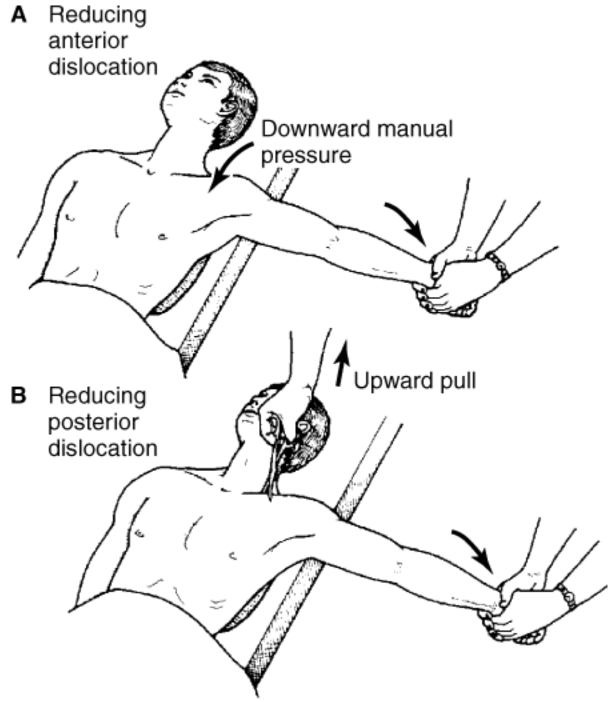
Although dislocation of the anterior sternoclavicular joint may caus

Posterior Dislocation

Posterior sternoclavicular dislocation is much less common but has

In most instances, closed reduction of posterior dislocations, if per

Figure 4–36.



Method for reducing (**A**): anterior sternoclavicular dislocation and

After reduction, the patient is put in an immobilization splint, instr

Medial Clavicular Epiphyseal Fracture

In athletes younger than 25 years, sternoclavicular injuries may n
enlarging mass at the sternoclavicular joint and parents are worrie

Battaglia TC et al: Interposition arthroplasty with bone-tendon allo

SHOULDER NEUROVASCULAR INJURY

Brachial Plexus Injury

Brachial plexus injuries are typically caused by a fall on the should
duration of upper extremity paresthesias and shoulder weakness,

Rarely, a severe injury occurs (eg, from motorcycle racing). Chron

Peripheral Nerve Injury

LONG THORACIC NERVE INJURY

Traction incidents may cause a long thoracic nerve palsy, with subs
divided.

Safran MR: Nerve injury about the shoulder in athletes, part 2: Lo

SUPRASCAPULAR NERVE INJURY

Entrapment of the suprascapular nerve is often associated with ac
of the shoulder girdle. This may be followed by atrophy of the sup

Conservative therapy consists of rest, antiinflammatory medicatior

Safran MR: Nerve injury about the shoulder in athletes, part 1: Su

MUSCULOCUTANEOUS NERVE INJURY

The musculocutaneous nerve is susceptible to damage from direct

Lo IK, Burkhart SS, Parten PM: Surgery about the coracoid: neuro

AXILLARY NERVE INJURY

The usual mechanism of injury is trauma either by direct blow to t
this test, the examiner elevates the arm into a position of near ful
with exploration, utilizing neurolysis or grafting, or both, as necess

Hertel R et al: The deltoid extension lag sign for diagnosis and gra

THORACIC OUTLET SYNDROME

The symptoms resulting from thoracic outlet compression may be

Nonoperative treatment is recommended for less severe forms of
pathologic factors encountered.

Degeorges R, Reynaud C, Becquemin JP: Thoracic outlet syndrome

EPICONDYLITIS (TENNIS ELBOW)

Tennis elbow is the term given to many painful conditions about th

Lateral Epicondylitis

Lateral tennis elbow involves the common tendon to the extensor
including radiocapitellar arthritis and posterior interosseous nerve

Treatment includes decreasing specific activities and using a tennis
described to take care of this malady. Commonplace in all procedu

Medial Epicondylitis

Medial epicondylitis involves the common flexor pronator origin. Tr

Ciccotti MC, Schwartz MA, Ciccotti MG: Diagnosis and treatment o

Jobe FW, Ciccotti MG: Lateral and medial epicondylitis of the elbow

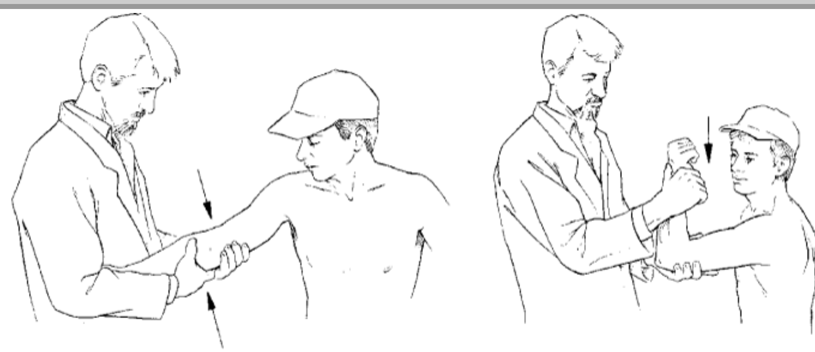
ELBOW INSTABILITY

Rupture of the collateral ligaments of the elbow occurs most comm
degrees, commonly results.

Valgus Instability

Valgus instability may result from overuse in overhead throwing sp
to the contralateral side aids in making the correct diagnosis. If th

Figure 4–37.



The valgus stress and milking maneuver tests for medial ulnar col

(Reprinted, with permission, from Chen FS et al: Medial elbow pro

A stress radiograph may aid in making the diagnosis. An anteropo
dye leaking through the ulnar collateral ligament is diagnostic of a

Surgical repair may be indicated in overhead throwing athletes wh
residual pain and instability after participation in such a program s

Chen FS, Rokito AS, Jobe FW: Medial elbow problems in the overh

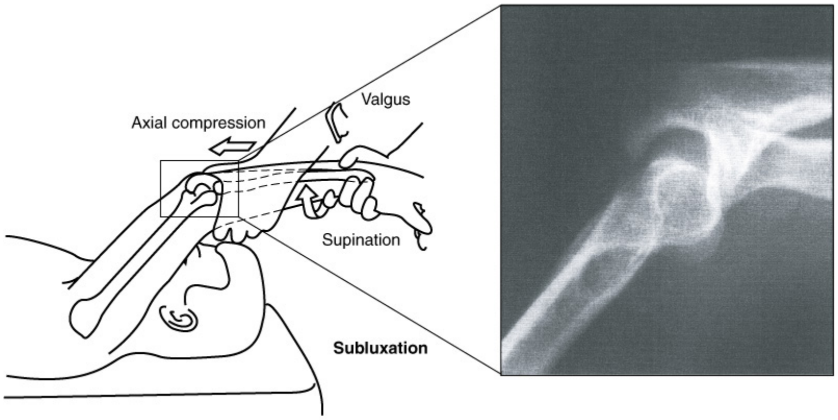
O'Driscoll SW, Lawton RL, Smith AM: The "moving valgus stress te

Thompson WH et al: Ulnar collateral ligament reconstruction in ath

Posterolateral Rotatory Instability

Posterolateral rotatory instability of the elbow may result from a fa
posterolateral rotatory instability test, a valgus stress is applied to
the forearm in pronation and restricted terminal elbow extension f

Figure 4–38.



The posterolateral rotatory instability test reproduces the patient's

Olsen BS, Sojbjerg JO: The treatment of recurrent posterolateral i

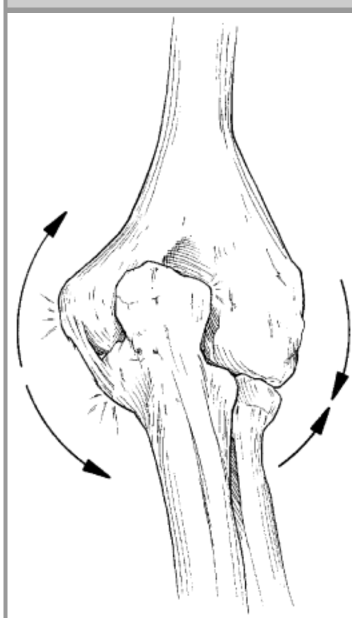
Sanchez-Sotelo J, Morrey BF, O'Driscoll SW: Ligamentous repair ar

OTHER ELBOW OVERUSE INJURIES

Posterior Elbow Impingement

Impingement may result from mechanical abutment of bone and s
athletes, the lesion is posteromedial. In this case, the impingemen

Figure 4–39.



Mechanism of posteromedial impingement between the medial asp

(Reprinted, with permission, from Chen FS et al: Medial elbow pro

As with most injuries caused by repetitive trauma, treatment begi

Moskal MJ, Savoie FH III, Field LD: Arthroscopic treatment of post

Fatigue Fracture of the Medial Epicondyle

In children, fatigue fractures of the medial epicondyle cause pain a
throwing immediately. An accurate pitching count should be kept c

Osteochondritis Dissecans of the Capitellum

Osteochondritis dissecans of the capitellum usually affects pitchers

Figure 4–40.

AP view of an elbow with osteochondritis dissecans of the capitellu

Stubbs MJ, Field LD, Savoie FH: Osteochondritis dissecans of the e

CERVICAL SPINE INJURY

Cervical spine injuries in athletes are relatively infrequent, but the

Brachial Plexus Neurapraxia

The most common cervical injury is pinching or stretching neurapr
frequently involve the C5 and C6 root levels. Recovery is usually s

Patients who demonstrate full muscle strength of the intrinsic mus

Persistence of paresthesia or weakness requires further evaluation

Prevention of so-called stinger injuries is chiefly through correct he

Cervical Strain

Acute strains of the muscles of the neck are probably the most fre

Cervical Sprain

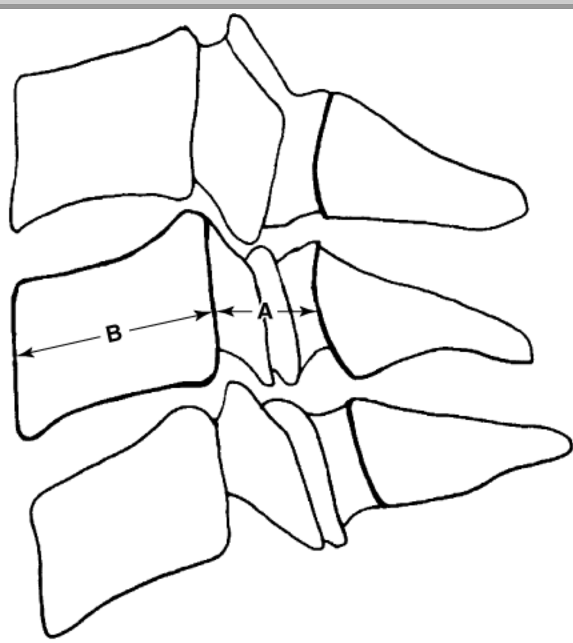
With cervical sprain, there is damage to the ligamentous and caps
may be done with flexion and extension radiographs.

Treatment of a cervical sprain consists of immobilization, rest, sup

Cervical Spinal Cord Neurapraxia with Transient Tetra

The phenomenon of cervical spinal cord neurapraxia with transient
findings include spinal stenosis, congenital fusions, cervical instabil

Figure 4–41.



The ratio of the spinal canal to the vertebral body is the distance

(Reproduced, with permission, from Torg JS et al: Neurapraxia of

Athletes who have suffered transient tetraplegia are not known to

More severe injuries, including fractures and dislocation of the cer

Torg JS et al. Cervical cord neurapraxia: Classification, pathomech

Torg JS et al: Neurapraxia of the cervical spinal cord with transien

LUMBAR SPINE INJURY

Clinical Findings

Spondylolysis is a disruption of the pars interarticularis, whereas s
gymnasts, for example, often have back pain but normal early rad

Treatment & Prognosis

The treatment of spondylolisthesis involves cessation of all aggrav

Many patients with spondylolisthesis engage in high-level sporting

Bono CM: Low-back pain in athletes. J Bone Joint Surg Am 2004;8

Miller SF, Congeni J, Swanson K: Long-term functional and anatom

OSTEOMYELITIS OF THE SPINE

Osteomyelitis of the spine comprises approximately 1% of all case
tissues as a result of trauma, surgery, diskography, or intravenous
Spinal sepsis is most common in adolescents, the elderly (more th
than 50 years, a cephalad level of infection, and infection with *S. a*

Clinical Findings

SYMPTOMS AND SIGNS

Patients with osteomyelitis of the spine may or may not present w
osteomyelitis of the spine often exhibit significant percussion tend
dysphagia. Pyogenic osteomyelitis should be suspected in any pati

LABORATORY STUDIES

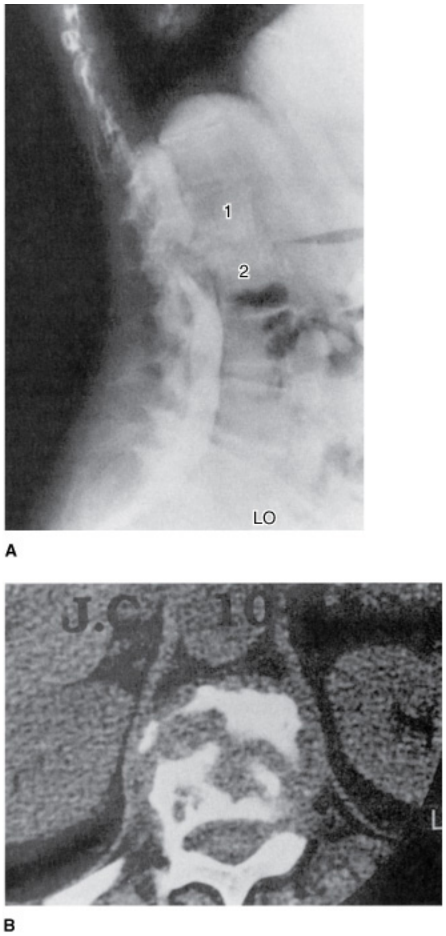
The results of laboratory tests can be equivocal. The white cell cou
process. However, both of these tests are systemic indicators of in

IMAGING STUDIES

Radiographic signs of osteomyelitis typically lag behind symptomat

In pyogenic osteomyelitis, early radiographic changes may include

Figure 5–1.



Imaging studies in patients with osteomyelitis of the spine. **A:** Rac

In tubercular osteomyelitis, radiographic studies typically demonst

Treatment

Early diagnosis and identification of the responsible organism is th
deformity. Success of nonoperative treatment is linked to patient a
antibiotics. Paraspinal abscesses may be managed conservatively w

Pediatric diskitis often responds to spinal column bracing, immobili

The incidence of epidural abscesses may be on the rise, associatec
able to delineate other disease entities, making it the imaging moc

For surgical candidates with osteomyelitis or diskitis, the treatmen
although newer studies suggest that instrumentation can be safely
surgical principles with expanding surgeon experience, although cu

Dimar JR et al: Treatment of pyogenic vertebral osteomyelitis with

Eismont FJ et al: Pyogenic and fungal vertebral osteomyelitis with

Emery SE, Chan DP, Woodward HR: Treatment of hematogenous p

Fayazi AH et al: Preliminary results of staged anterior debridemen

Frazier DD et al: Fungal infections of the spine. Report of eleven p

Gasbarrini AL, Bertoldi E, Mazzetti M et al: Clinical features, diagn

Hee HT et al: Better treatment of vertebral osteomyelitis using po

Muckley T et al: The role of thoracoscopic spinal surgery in the ma

Ogden AT, Kaiser MG: Single-stage debridement and instrumentat

Schuster JM et al: Use of structural allografts in spinal osteomyelit

Tay BK, Deckey J, Hu SS: Spinal infections. J Am Acad Orthop Sur

Weinstein MA, Eismont FJ: Infections of the spine in patients with

PRIMARY TUMORS OF THE SPINE

Primary tumors of the spine account for 0.04% of all tumors and 1
malignant tumors are found in patients older than 21 years.

Principles of Diagnosis

HISTORY AND PHYSICAL EXAMINATION

If the presence of a spinal tumor is suspected, a thorough history
establishing the differential diagnosis (see Chapter 6). In adults, m

On examination, the patient may complain of tenderness over the
fractures may present with acute onset of pain and paraparesis. E

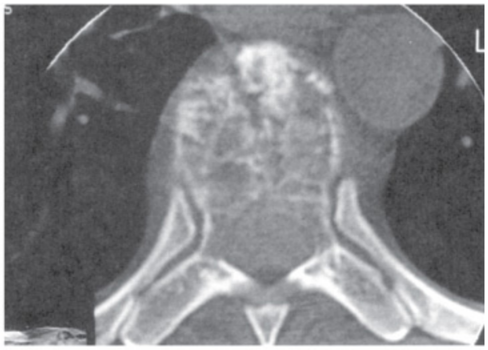
IMAGING STUDIES

The workup begins with high-quality plain radiographs, followed by
erosive appearance. It is important to realize that radiographic evi

Early on it is often difficult on plain radiographs to distinguish a ne
scanning is limited in its usefulness in staging of the tumor.

CT scanning with or without myelography is of great benefit in det

Figure 5–2.



A

B

Imaging studies in a patient with a hemangioendothelioma. **A:** CT

Arteriography enables the surgeon to evaluate the vascular supply
lower thoracic spine may help identify possible vascular supply to t

MRI is the study of choice in the diagnosis and evaluation of prima

BIOPSY

An open or closed percutaneous biopsy may be necessary for esta
nondiagnostic.

SURGICAL TREATMENT

The surgical treatment of spinal tumors depends on (1) biologic tu

Bauer HC: Controversies in the surgical management of skeletal m

Bilsky MH et al: Operative management of metastatic and maligna

Degen JW et al: CyberKnife stereotactic radiosurgical treatment of

Fisher CG et al: The surgical management of primary tumors of th

Flemming DJ et al: Primary tumors of the spine. Semin Musculosk

Saad RS et al: Fine needle aspiration biopsy of vertebral lesions. A

Vialle R et al: Chondroblastoma of the lumbar spine. Report of two

Weinstein JN, McLain RF: Primary tumors of the spine. Spine 1987

Benign Tumors

Benign primary tumors of the spine include osteoid osteoma, osteo

Osteoid Osteoma

Osteoid osteoma and osteoblastoma are osteoblastic lesions that a involves the lumbar spine, followed by the cervical and then the th

The patient presents with a complaint of a progressive localized ac bending. In the majority of cases, the tumor is located on the conc

Osteoid osteomas appear radiographically as a nidus surrounded b osteoma generally requires thorough local excision of the lesion be

Osteoblastoma

When osteoid osteomas grow larger than 2 cm, they are called ost

Patients generally complain of localized pain or scoliosis. Fifty-thre

Radiographic examination may reveal an expanded sclerotic cortex

Curettage can offer a high rate of disease remission when the lesio aided by the use of adjuvant radiotherapy. The local recurrence ra

Osteochondroma

Osteochondromas result when metaplastic cartilage cells in the pe

Aneurysmal Bone Cyst

Aneurysmal bone cysts result from an expansile hyperemic osteoly osteolytic tumor with poor demarcation, peripheral ballooning, and

The differential diagnosis includes giant cell tumors and cavernous

Appropriate treatment of aneurysmal bone cysts requires recognit depending on the extent of the lesion.

Profound hemorrhage is a risk with primary surgical resection and

Hemangioma

Hemangiomas, common tumors of the vertebral column, arise fror

Hemangiomas are frequently asymptomatic. In some cases, they a
weighted images and low signal intensity on T_1-weighted images.

Eosinophilic Granuloma (Langerhans Cell Histiocytosis

Eosinophilic granuloma is a proliferative disorder of the Langerhan

Patients frequently present with localized pain. Spinal cord compre

Eosinophilic granuloma can present with a spectrum of radiograph vertebral body collapse leading to a flattening of the vertebral bon

The differential diagnosis includes Ewing sarcoma and infection, ar

Eosinophilic granuloma usually resolves spontaneously. If the patie

Giant Cell Tumor

Giant cell tumors comprise approximately 10% of all primary bone present with neurologic deficits. Plain radiographs show a lytic lesi extension, anterior and posterior tumor, and spinal canal involvem

Bertram C, Madert J, Eggers C: Eosinophilic granuloma of the cerv

Brown CW et al: Treatment and outcome of vertebral Langerhans

Fidler MW: Surgical treatment of giant cell tumours of the thoracic

Garg S, Mehta S, Dormans JP: Modern surgical treatment of prima

Kak VK et al: Solitary osteochondroma of the spine causing spinal

Ozaki T et al: Osteoid osteoma and osteoblastoma of the spine: ex

Papagelopoulos PJ et al: Treatment of aneurysmal bone cysts of th

Zileli M et al: Osteoid osteomas and osteoblastomas of the spine.

Malignant Tumors

Primary malignant tumors of the spine are rare and carry a poor p

Solitary Plasmacytoma & Multiple Myeloma

Multiple myeloma and solitary plasmacytoma are B-cell lymphopro 100,000 among the general population. Genetic analysis of the tur may detect the presence of immunoglobulin light chains called Ber

The initial treatment of myeloma consists of chemotherapy and irr
may reduce pain and prevent vertebral collapse, deformity, and ne

Osteosarcoma

Primary osteosarcoma is a malignant tumor of mesenchymal cells

Patients with retinoblastoma (caused by a hereditary mutation in t

Radiographically, osteosarcomas present as mixed lytic and sclerot
local radiotherapy demonstrated promising early results. Secondar

Ewing Sarcoma

Ewing sarcoma is a malignant round cell tumor with a peak incider

Metastatic involvement of the spine is more common in the late st

When the lesion is localized to the sacrum, the prognosis is worse

Chondrosarcoma

Chondrosarcoma is the third most common primary bone tumor be

Pain in the area of involvement is the first symptom. Fifty percent

Radiographs show typical cortical destruction and paraspinal soft t

Chondrosarcomas are radio resistant. Thus, the mainstay of treatr

Chordoma

A chordoma is a slow-growing tumor that arises from notochordal
sixth decades of life and afflicts men twice as often as women. Ch
dyspnea. Rectal examination can reveal a presacral mass.

After wide surgical resection, the local recurrence rate varies from
rate in patients treated with irradiation alone is approximately 50%

Boriani S et al: Chondrosarcoma of the mobile spine: Report on 22

Fourney DR, Gokaslan ZL: Current management of sacral chordom

Ilaslan H et al: Primary vertebral osteosarcoma: Imaging findings.

Lane JM et al: Kyphoplasty enhances function and structural alignr

McLain RF, Weinstein JN: Solitary plasmacytomas of the spine: A r

Ozaki T et al: Osteosarcoma of the spine: experience of the Coope

Papagelopoulos PJ et al: Chordoma of the spine: Clinicopathologica

Sell M et al: Chordomas: A histological and immunohistochemical s

Venkateswaran L et al: Primary Ewing tumor of the vertebrae: Clir

Zeifang F et al: Long-term survival after surgical intervention for b

METASTATIC DISEASE OF THE SPINE

Although the skeleton is the third most common site for metastati

Lung, breast, prostate, renal, thyroid, and gastrointestinal carcino

Many patients with spinal metastasis are asymptomatic. Symptom rapid, leading to paraplegia or quadriplegia.

Technetium bone scanning reveals multiple sites of radioisotope up

Most patients who do not develop progressive instability or neurolo

Radiation therapy and chemotherapy protocols depend on the prin indicated in patients who have significant neurologic dysfunction o metal, or methylmethacrylate (Figure 5–3).

Figure 5–3.

Radiograph showing metastasizing adenocarcinoma of C4 and C5,

Alvarez L et al: Vertebroplasty in the treatment of vertebral tumor

Barr JD et al: Percutaneous vertebroplasty for pain relief and spin

Chataigner H, Onimus M: Surgery in spinal metastasis without spi

Ghogawala Z, Mansfield FL, Borges LF: Spinal radiation before sur

Holman PJ et al: Surgical management of metastatic disease of th

Jeremic B: Single fraction external beam radiation therapy in the t

Manabe J et al: Surgical treatment of bone metastasis: Indications

North RB et al: Surgical management of spinal metastases: Analys

Ryu S et al: Image-guided and intensity-modulated radiosurgery f

Togao O et al: Percutaneous vertebroplasty in the treatment of pa

EXTRADURAL TUMORS

Extradural tumors include hemangiomas, lipomas, meningiomas, a

Loblaw DA et al: Systematic review of the diagnosis and managem

RHEUMATOID ARTHRITIS

Rheumatoid arthritis is the most common form of inflammatory ar involvement are C1-C2 instability, basilar invagination, and subaxi

Clinical Findings

SYMPTOMS AND SIGNS

From 7% to 34% of patients present with neurologic problems. Do spinal cord results in severe myelopathy with gait abnormalities, w

IMAGING STUDIES

Instability of the upper cervical spine is determined on lateral flexi measurement for traumatic instability of the C1-C2 complex, the p cord is less than 13 mm, the likelihood that the patient will develo

Cranial settling is present in from 5% to 32% of patients. The odo
in the sagittal plane. In severe cases of cranial settling, the anteri

Lateral subluxation and posterior atlantoaxial instability are less fr

LABORATORY STUDIES

Rheumatoid factor is positive in up to 80% of patients. The ESR ra

After plain radiographs, which should include lateral flexion-extens

Treatment

Indications for surgery are severe neck pain and increasing loss of
halo traction is often required to reduce the subluxation or pull the

Alberstone CD, Benzel EC: Cervical spine complications in rheumat

Boden SD et al: Rheumatoid arthritis of the cervical spine. A long-

Christensson D, Saveland H, Rydholm U: Cervical spine surgery in

Clark CR, Goetz DD, Menezes AH: Arthrodesis of the cervical spine

Faraj AA, Webb JK, Prince H: Surgical treatment for rheumatoid ne

Graziano GP, Hensinger R, Patel CK: The use of traction methods t

Grob D: Posterior occipitocervical fusion in rheumatoid arthritis an

Haid RW Jr et al: C1-C2 transarticular screw fixation for atlantoaxi

Kauppi MJ, Barcelos A, da Silva JA: Cervical complications of rheur

Matsunaga S, Ijiri K, Koga H: Results of a longer than 10-year foll

Matsuyama Y et al: Long-term results of occipitothoracic fusion su

van Asselt KM et al: Outcome of cervical spine surgery in patients

ANKYLOSING SPONDYLITIS

Ankylosing spondylitis is a chronic seronegative inflammatory dise
during early adulthood. However, juvenile ankylosing spondylitis af
cases but does not accurately reflect disease activity. The serum c

Clinical Findings

SYMPTOMS AND SIGNS

The onset is insidious, with early symptoms including pain in the b
Synovitis in the early stages leads to progressive fibrosis and anky
Limited chest expansion indicates thoracic involvement. Fewer tha

IMAGING STUDIES

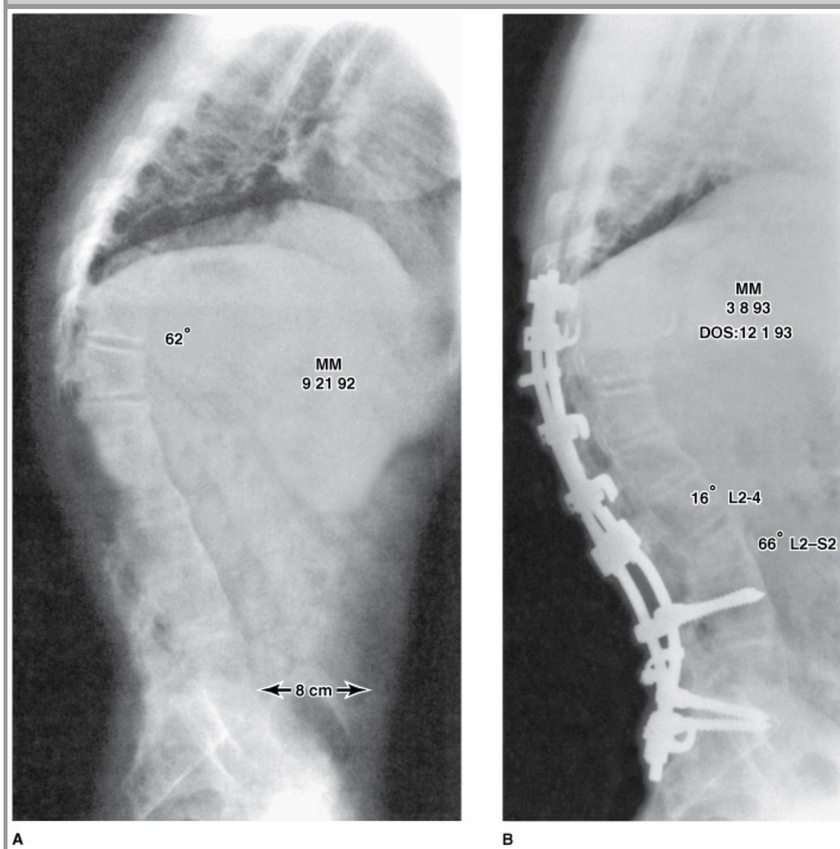
The earliest radiographic changes are visible in the sacroiliac joints
develops. The disease generally starts in the lumbar spine and mig

Treatment

The natural history of ankylosing spondylitis, with its slow progres
before correction of spinal deformities because correction of hip fle

Loss of lumbar lordosis can be treated by multilevel V-shaped oste

Figure 5–4.



Imaging studies in a patient with ankylosing spondylitis. **A:** Radiog

The spine is then fused in the corrected position. Utilization of mod
be injured when the spine is extended.

The cervical osteotomy is performed between C7 and T1. This app
is corrected with gentle extension of the head. The head is held in

Berven SH et al: Management of fixed sagittal plane deformity: Re

Braun J et al: Therapy of ankylosing spondylitis. Part II: Biological

Chen IH, Chien JT, Yu TC: Transpedicular wedge osteotomy for cor

Danisa OA, Turner D, Richardson WJ: Surgical correction of lumba

Kim KT et al: Clinical outcome results of pedicle subtraction osteot

Kubiak EN et al: Orthopaedic management of ankylosing spondylit

Taggard DA, Traynelis VC: Management of cervical spinal fractures

van der Linden S, van der Heijde D: Clinical aspects, outcome asse

DISEASES & DISORDERS OF THE CERVICAL SPINE

Principles of Diagnosis

In evaluating the cervical spine, the use of appropriate imaging stu

PLAIN RADIOGRAPHY

In evaluating the patient with neck pain, cervical spine radiograph
When all five views are taken, sensitivity is 92%. Cervical spine pr

The lateral view reveals the majority of traumatic lesions if perforr
themselves, the posterior border of the bodies, the spinal canal pr

The prevertebral region may reveal swelling consistent with a hem
familiarity with them may prevent an overzealous workup. The AD

In reviewing the AP radiograph, careful assessment of the interspi

Oblique views taken at 45 degrees allow visualization of the articul
offset); the opposite mass is farther away from the midline (latera

This radiographic series is equally important in evaluating infants a

COMPUTED TOMOGRAPHY

CT scans allow excellent visualization of the bony architecture and

CT is an appropriate modality for evaluating congenital variations a

In the trauma patient with questionable findings on plain radiograp

Three-dimensional reconstruction of CT images gained wide clinica

MAGNETIC RESONANCE IMAGING

MRI permits axial, sagittal, coronal, or oblique plane analysis of th

MRI is the standard for assessing cervical spinal cord damage. Spi

Intravenous paramagnetic agent gadolinium is commonly used to

SCINTIGRAPHY

Bone scans that employ technetium-99m phosphate permit assess fractures, avascular necrosis, and osteomyelitis can be detected. C

Daffner RH: Controversies in cervical spine imaging in trauma pati

Holmes JF, Akkinepalli R: Computed tomography versus plain radic

Larsson EM et al: Comparison of myelography, CT myelography ar

Mower WR et al: NEXUS Group. Use of plain radiography to screer

Sanchez B et al: Cervical spine clearance in blunt trauma: Evaluat

Schuster R et al: Magnetic resonance imaging is not needed to cle

Taneichi H et al: Traumatically induced vertebral artery occlusion a

CONGENITAL MALFORMATIONS

The atlantooccipital region is a frequent location for abnormalities. become the occiput and posterior part of the foramen magnum. Tl

Disturbances of embryologic development can result in incomplete basilar impression, Arnold-Chiari malformation, and syringomyelia,

Os Odontoideum

Os odontoideum is an uncommon type of pseudarthrosis between the axis or the posterior ring of the atlas. In some cases, extrinsic

Clinical Findings

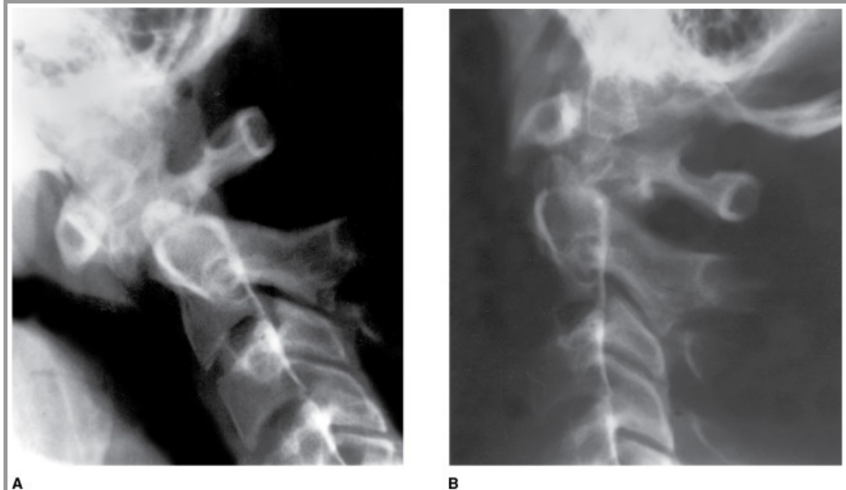
SYMPTOMS AND SIGNS

Patients with os odontoideum may be asymptomatic or may prese

IMAGING STUDIES

The radiographic findings may be extremely subtle and difficult to round or ovoid, with a smooth surface and uniform cortical thickne travels with the anterior ring of the atlas (Figure 5–5). In cases th

Figure 5–5.



Imaging studies in a patient with os odontoideum. **A:** Radiograph

Treatment

Patients diagnosed with os odontoideum must be warned of the gr
attempt to avoid potentially lethal injury from relatively minor trau

If fusion is indicated, usually a posterior fusion of C1-C2 is adequa
are wedged between the laminae of C1 and C2. The loss of motior

Dai L et al: Os odontoideum: Etiology, diagnosis, and managemen

Gluf WM, Brockmeyer DL: Atlantoaxial transarticular screw fixatior

Klippel-Feil Syndrome

Klippel-Feil syndrome refers to an array of clinical disorders associ
low posterior hair line, and limited cervical neck motion. Interestin

Various conditions were subsequently seen in association with conç
palsy, syndactyly, and upper extremity diffuse or focal hypoplasia.

Clinical Findings

SYMPTOMS AND SIGNS

Decreased range of motion is the most frequent finding in patients

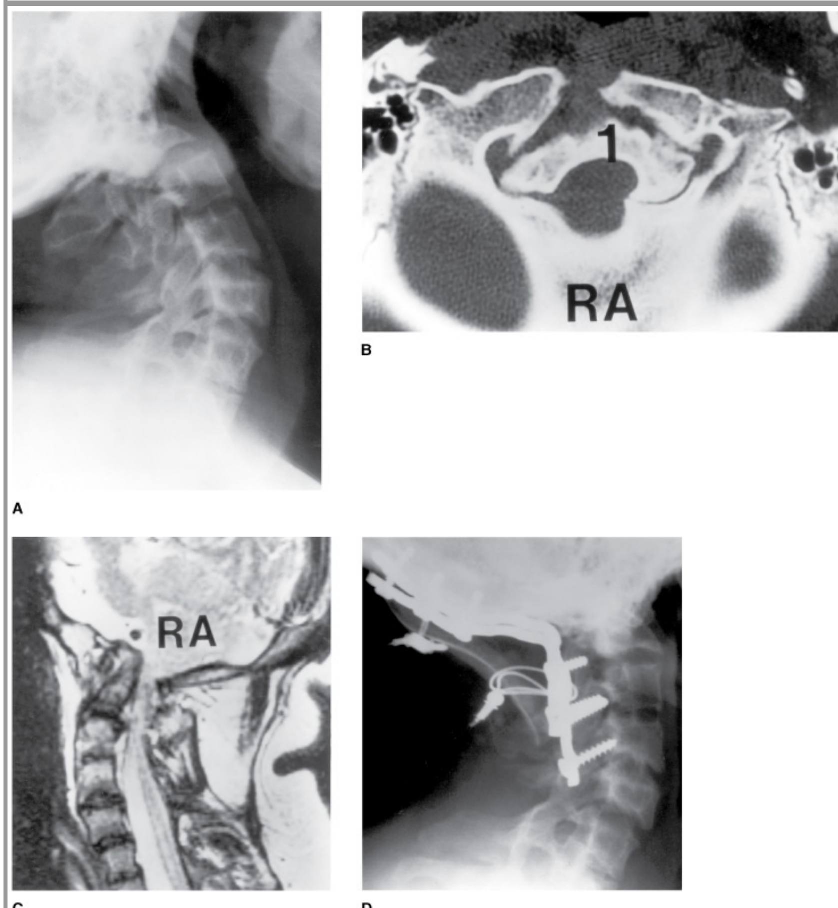
Neck shortening is difficult to detect unless extreme. Webbing of t
of patients. Sometimes an omovertebral bone bridges the cervical

Cervical spine symptoms in Klippel-Feil syndrome are related to th
Neurologic sequelae, usually confined to the head, neck, and uppe

IMAGING STUDIES

Radiographic findings (Figure 5–6) of congenital cervical vertebral
views can be taken. CT scanning and MRI have improved the asse

Figure 5–6.



Imaging studies in a patient with Klippel-Feil syndrome and cervic

Spinal canal stenosis is not usually seen until adulthood. Although

Involvement of the upper thoracic spine can occur and may be the

Because of the potential for multiorgan involvement in patients wit

Treatment

Treatment of the cervical spine abnormalities is limited. Multilevel

Secondary osteoarthritis may be treated in the usual manner, inclu

Surgical correction of the aesthetic deformities is only moderately

Prognosis

Children with mild involvement can be expected to grow up to leac

Herman MJ, Pizzutillo PD: Cervical spine disorders in children. Orth

Tracy MR, Dormans JP, Kusumi K: Klippel-Feil syndrome: Clinical fe

CERVICAL SPONDYLOSIS

Cervical spondylosis is defined as a generalized disease process af may be seen secondarily. Cervical myelopathy is the most commor

Pathophysiology

The relationship between the spinal cord and its bony arcade has b impingement.

Acute traumatic disk herniation was distinguished from the chronic The longitudinal ligaments degenerate and form bony spurs at the flavum, with further narrowing of the spinal canal. Segmental insta

Further work revealed that the sagittal cervical canal diameter was neuroforaminal diameter decrease.

Clinical Findings

SYMPTOMS AND SIGNS

Headache may be the presenting symptom of cervical spondylosis.

Cervical Spondylotic Radiculopathy

Cervical radiculopathy in spondylosis can be quite complex, with n dermatomal levels may be involved, with radiation into the anterio

Cervical Spondylotic Myelopathy

Cervical myelopathy has a variable clinical presentation, given the myelopathy is usually progressive, leading to complete disability o

Patients often present with paresthesias, dyskinesias, or weakness

Hyperextension injuries of the spondylotic cervical spine can precip

Deep tendon reflexes can be either hyporeflexic or hyperreflexic, w though asymmetric. Upper extremity involvement is often unilater

Abdominal reflexes are usually intact, enabling the clinician to diffe

IMAGING STUDIES

Although spondylosis results from cervical spine degeneration, not space to buffer the degenerative lesion.

The average AP diameter of the spinal canal measures 17 mm fror less than 10 mm. The stenosis is relative if the diameter measures

Plain film findings also vary according to the stage of spondylosis a
inflammatory process such as rheumatoid arthritis.

Figure 5–7.

Imaging studies in a patient with cervical spondylosis and chronic

Oblique views permit evaluation of the facet joints and detection o
posteroinferior corner of the vertebral body), foraminal stenosis as

MRI permits visualization of the entire cervical canal and spinal cor
nerve root blocks and electromyography may be useful to identify

Differential Diagnosis

Inflammatory, neoplastic, and infectious conditions can mimic cerv

The cervical spine is affected in most rheumatoid arthritis patients
60 years) or immunocompromised individuals. Multiple sclerosis sh
Disorders of the shoulder, especially rotator cuff tendinitis, can imi

Treatment

Patients should be divided into three groups, according to the prec

CONSERVATIVE TREATMENT

Initial management of patients with cervical spondylosis may invol
Diazepam should be avoided because of its side effects as a clinica

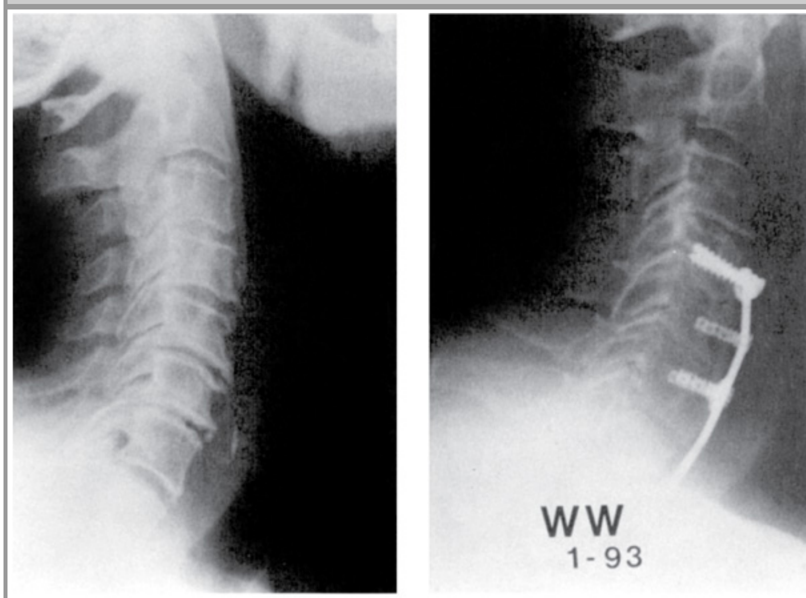
The value of cervical traction remains unclear. It is contraindicated
instructed to start a home exercise program early, to avoid long-te

SURGICAL TREATMENT

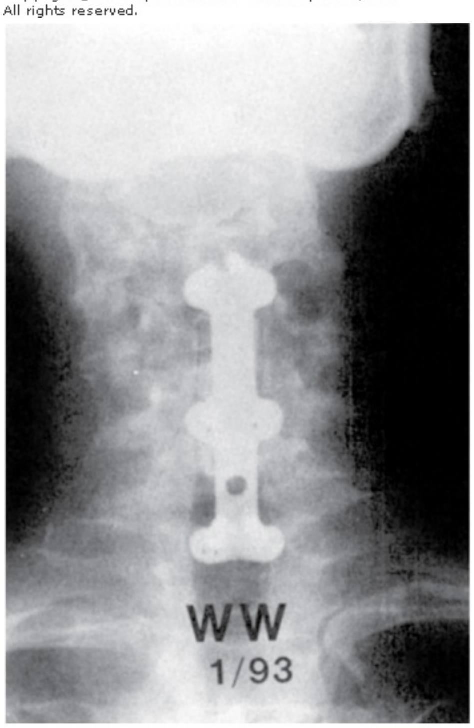
Surgical intervention should be considered if the patient does not r

The anterior approach allows multilevel diskectomy, vertebrectomy
dislodgement of the graft even in the presence of solid anterior fix

Figure 5–8.



A B



C

Imaging studies in a patient with cervical spondylotic myelopathy.

Figure 5–9.

Imaging studies in a patient with cervical disk herniation. **A:** MRI s

Cervical disk replacement prostheses were also developed to provi
these devices against the outcomes that can be obtained with ante

The number of involved levels may be important in deciding which
swan-neck deformities after laminectomy can be avoided with simu

Operative treatment in cases of cervical spondylotic radiculopathy

Prognosis

Cervical spondylosis is generally a progressive, chronic disease pro
involving less than three vertebral levels, early anterior decompres

Belanger TA et al: Ossification of the posterior longitudinal ligamen

Chagas H et al: Cervical spondylotic myelopathy: 10 years of pros

Edwards CC II et al: Cervical myelopathy. current diagnostic and t

Edwards CC II, Heller JG, Murakami H: Corpectomy versus lamino

Emery SE: Cervical spondylotic myelopathy: Diagnosis and treatm

Epstein N: Anterior approaches to cervical spondylosis and ossifica

Heller JG et al: Laminoplasty versus laminectomy and fusion for m

Mehdorn HM, Fritsch MJ, Stiller RU: Treatment options and results

Onari K et al: Long-term follow-up results of anterior interbody fu

Phillips FM, Garfin SR: Cervical disc replacement. Spine 2005;30(S

Takayama H et al: Proprioceptive recovery of patients with cervica

Wada E et al: Subtotal corpectomy versus laminoplasty for multile

Wang MY, Shah S, Green BA: Clinical outcomes following cervical l

OSSIFICATION OF THE POSTERIOR LONGITUDINAL LI

Ossification of the posterior longitudinal ligament (OPLL) is a relati
inheritance because it is found in 26% of the parents and 29% of

Clinical Findings

Almost all patients have only mild subjective complaints at the ons

Ossification of the posterior longitudinal ligament can easily be dia
the ossification is localized in the cervical spine, although extensio

Enchondral ossification is mainly responsible for the formation of t

Treatment

Neurologic improvement with either conservative or surgical treat
sectional area.

Belanger TA et al: Ossification of the posterior longitudinal ligamer

Chiba K et al: Multicenter study investigating the postoperative pr

Epstein NE: Circumferential cervical surgery for ossification of the

Kawaguchi Y et al: Progression of ossification of the posterior long

Matsuoka T et al: Long-term results of the anterior floating metho

Nakanishi K et al: Positive effect of posterior instrumentation after

Ogawa Y et al: Long-term results of expansive open-door laminopl

Takeshita K et al: Can laminoplasty maintain the cervical alignmen

LOW BACK PAIN

Low back pain is a very common symptom in the general populatic
with 50% of affected patients recovering by 2 weeks and 90% rec

The socioeconomic impact of back problems is enormous. Over 14'
vocation, viewing it as boring and repetitious. They also have an ir

Etiology & Pathophysiology

The exact cause of symptoms is found in only 12–15% of patients
and the intervertebral disk. It forms a three-joint complex with the

Significant emphasis is newly placed on the idea of the interverteb
ganglion. Irritation of the sinuvertebral nerve is thought to be resp

Principles of Diagnosis

HISTORY AND PHYSICAL EXAMINATION

A focused history and physical examination of the patient are cruc
equina syndrome. Leg and buttock pain are usually indicative of ne

The physical examination is subjective and requires the patient's ir
for sensory and motor deficits, the clinician should check the patie

The pain is considered acute if it lasts less than 6 weeks and chror
and the straight leg–raising test is negative. Sensation and reflexe

IMAGING STUDIES

Radiography

Radiographs are not necessary during the initial evaluation. If a pa
association is established between low back pain and the presence

Other Studies

If plain radiographs are unsuccessful in establishing the cause of t

MRI of the lumbar spine is noninvasive and excellent in assessing
myelography is especially useful to assess patients who have had s

Disk degeneration is common in adults with low back pain. Cautior
years, and 36% of those older than 60 years. In the oldest group,

If disk degeneration is suspected to be the cause of lower back pa
continues to be controversial. The results are subjective and deper

Principles of Treatment

Management of low back pain has to be tailored to the individual.
social activities leads to illness behavior, depression, and loss of int

No evidence indicates that the following treatment modalities are u

Patients who have low back pain that persists for more than 3 mor
work, whereas only 41% of control subjects did so.

A subgroup of patients who have persistent, disabling axial low ba

Disk replacement surgery was first introduced in the early 1950s w
restoring motion after removal of the painful disk, preventing late
first 6 months following surgery. However, the results are similar t

Other less invasive therapies for diskogenic axial back pain are als

Blumenthal S et al: A prospective, randomized, multicenter Food a

Delamarter RB, Bae HW, Pradhan BB: Clinical results of ProDisc-II

Derby R et al: The ability of pressure-controlled discography to pr

Fritzell P et al; Swedish Lumbar Spine Study Group, 2001 Volvo Av

Geisler FH et al: Neurological complications of lumbar artificial disc
15346999]

Humphreys SC et al: Comparison of posterior and transforaminal a

McAfee PC et al: A prospective, randomized, multicenter Food and

Saal JA, Saal JS: Intradiscal electrothermal treatment for chronic d

LUMBAR DISK HERNIATION

Symptomatic disk herniations are seen in all age groups but have
Approximately 50% of patients recover within 1 month, and 96%

Pathophysiology

A disk herniation is usually preceded by degenerative changes insi
a free fragment. The pain accompanying disk herniation may be ca
process. The hydration of the disk changes from 90% during child

Clinical Findings

SYMPTOMS AND SIGNS

The typical sciatica is commonly preceded by back pain for a perio
diminished more in flexion than in extension. Coughing, sneezing,

In more than 90% of cases, lumbar disk herniations are localized a
the L4 nerve root is affected, there may be weakness of the quadr
weak plantarflexion of the foot, loss of the Achilles tendon reflex, c

The straight leg–raising test should be performed. The Lasègue si
root, the femoral nerve stretch test should be applied. The radicul

IMAGING STUDIES

MRI is the study of choice for diagnosis of a herniated disk (Figure

Figure 5–10.

MRI in a patient with disk herniation at L4-L5 and L5-S1. Both dis

Differential Diagnosis

Radicular pain is typical and should be distinguished from referred
presence of incontinence, perianal numbness, and bilateral leg pai

Treatment

In cases of lumbar disk herniation, the goal of treatment is to retu
treated with diskectomy. Although better results were seen in the

CONSERVATIVE TREATMENT

Two days of bed rest followed by a good physical therapy program

SURGICAL TREATMENT

Approximately 10% of patients with lumbar disk herniation ultimat

When a standard diskectomy is used, the overall success rate is 8! is necessary. Postoperative discomfort is minimized and speed of r

In cases of contained disk protrusion, percutaneous automated dis extra portal makes direct visualization of the disk possible. Althoug

Chemonucleolysis of herniated disks is used extensively in Europe. subarachnoid hemorrhage. Many of the previous bad results have

Because experience with laser diskectomy is limited, this extradur

Atlas SJ et al: Long-term outcomes of surgical and nonsurgical ma

Burton AK, Tillotson KM, Cleary J: Single-blind randomised control

Choi JY, Choi YW, Sung KH: Anterior lumbar interbody fusion in pa

Dai LY et al: Recurrent lumbar disc herniation after discectomy: O

Ito T, Takano Y, Yuasa N: Types of lumbar herniated disc and clinic

Ng L, Chaudhary N, Sell P: The efficacy of corticosteroids in perira

Nygaard OP, Kloster R, Solberg T: Duration of leg pain as a predict

Park YK, Kim JH, Chung HS: Outcome analysis of patients after lig

Riew KD et al: The effect of nerve-root injections on the need for

Yorimitsu E, Chiba K, Toyama Y et al: Long-term outcomes of stan

FACET SYNDROME

The facet joint is probably not a common source of pain. The term elements and the facet joints in particular.

Later research showed innervation of the facet joint by the medial

The lumbar facet joints are biomechanically important. They absor

Clinical Findings

SYMPTOMS AND SIGNS

Although patients with facet syndrome tend to have problems loca

IMAGING STUDIES

Plain radiographs demonstrate a narrowed disk space. Oblique vie

Treatment

Conservative care with antiinflammatory medication, an external b better studies are necessary to assess accurately its overall efficac

Jackson RP, Jacobs RR, Montesano PX: 1988 Volvo award in clinica

Oh WS, Shim JC: A randomized controlled trial of radiofrequency c

Slipman CW et al: A critical review of the evidence for the use of z

van Wijk RM et al: Radiofrequency denervation of lumbar facet joi

STENOSIS OF THE LUMBAR SPINE

Stenosis of the lumbar spine is a clinical entity responsible for a va

Pathophysiology

Some physiologic narrowing of the canal occurs with age. There ar facets. Degeneration of the intervertebral disk causes increased st advanced degenerative stenosis.

The cause of pain experienced by patients with stenosis is perplex fibers are nutritionally deprived by compression of the small nutrie perfusing the root tissues. This can compromise the metabolism o

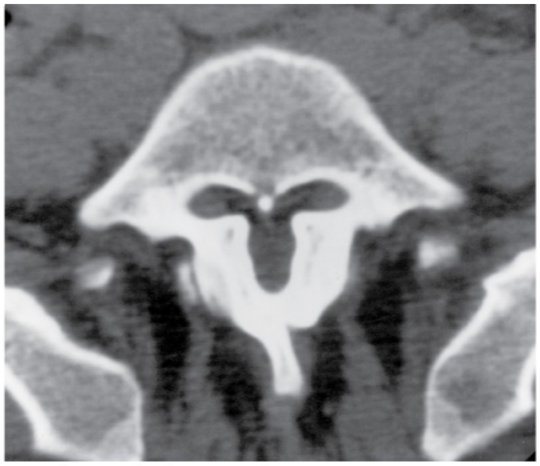
According to a vascular and nutritional explanation for the onset o nutrients and the removal of noxious accumulations. The resulting

Gross morphologic changes include a compressed caudal sac, diffu either side of the compressed lesion.

Classification

Spinal stenosis is classified as congenital or acquired. The congenit trefoil, the trefoil shape is most commonly associated with stenosis

Figure 5–11.



CT scan showing severe stenosis and typical trefoil shape of the lu

The location of stenosis can be central or lateral. In central stenos

Clinical Findings

SYMPTOMS AND SIGNS

In degenerative spinal stenosis, which occurs primarily in elderly (
Nearly all patients report that their lower extremity pain is altered
ambulate in a more flexed position. These are the hallmarks of pse

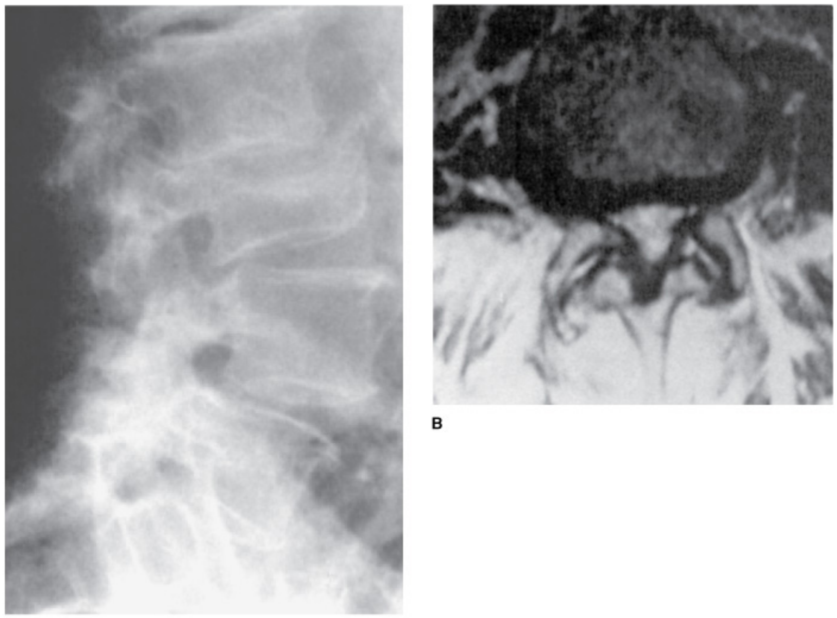
In a study of 172 patients who had symptoms of claudication, wer
ultrasound and arteriography, and six of these nine required addit

IMAGING STUDIES

Findings on plain radiographs include degenerative disk disease, os
measurement of the canal dimensions when combined with contras

MRI is comparable to contrast-enhanced CT scanning in its ability

Figure 5–12.



A

B

Imaging studies in a patient with degenerative stenosis of the lum

Differential Diagnosis

A complete physical examination is essential to exclude other caus

Psychologic factors of low back pain often give rise to symptoms ir

Treatment

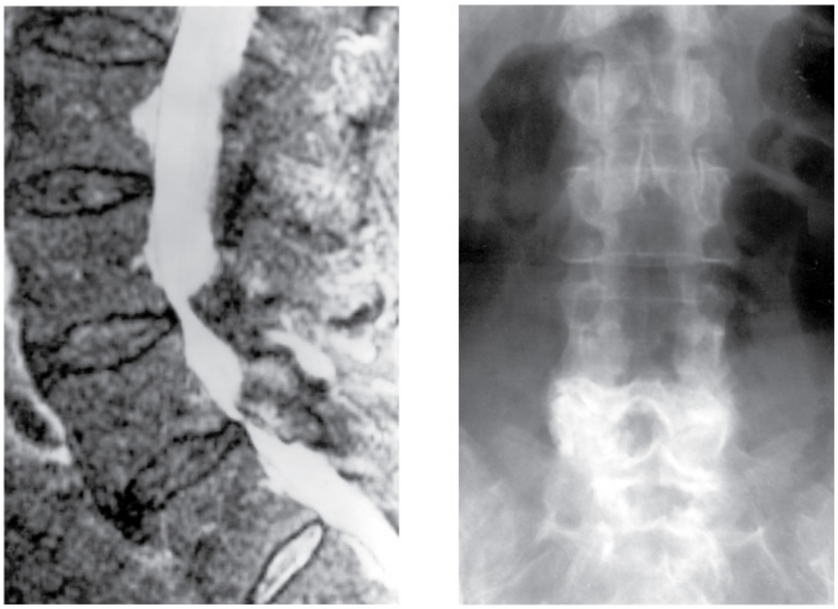
CONSERVATIVE TREATMENT

Initial management of the patient with symptoms suggestive of sp
25%.

SURGICAL TREATMENT

If conservative methods fail, the patient's quality of life must be a
coexisting morbid conditions (Figure 5–13).

Figure 5–13.



A B

Imaging studies in a patient with stenosis of the lumbar spine and

Postoperative instability is reported in approximately 10–15% of p

Atlas SJ et al: Long-term outcomes of surgical and nonsurgical ma

Chang Y et al: The effect of surgical and nonsurgical treatment on

Galiano K et al: Long-term outcome of laminectomy for spinal ster

Ghiselli G et al: Adjacent segment degeneration in the lumbar spir

Ikuta K et al: Short-term results of microendoscopic posterior dec

Knaub MA et al: Lumbar spinal stenosis: Indications for arthrodesi

Kornblum MB et al: Degenerative lumbar spondylolisthesis with sp

Lin SI, Lin RM: Disability and walking capacity in patients with lum

Palmer S, Turner R, Palmer R: Bilateral decompressive surgery in

Saint-Louis LA: Lumbar spinal stenosis assessment with computed

Sengupta DK, Herkowitz HN: Lumbar spinal stenosis. Treatment st

Shapiro GS, Taira G, Boachie-Adjei O: Results of surgical treatmen

Simotas AC: Nonoperative treatment for lumbar spinal stenosis. C

Truumees E: Spinal stenosis: Pathophysiology, clinical and radiolog

Yuan PS, Booth RE Jr, Albert TJ: Nonsurgical and surgical manager

OSTEOPOROSIS AND VERTEBRAL COMPRESSION FRAC

Osteoporosis is characterized by a decline in overall bone mass in
postmenopausal osteoporosis that occurs during the 15–20 years a

Vertebral compression fractures are one of the most frequent man

Clinical Findings

Patients with symptomatic vertebral compression fractures typicall
history of significant trauma or an inciting event.

Imaging

Plain radiographs and densitometric scans are the major imaging r
both the axial and appendicular skeleton. Other imaging modalities

Posterior/anterior and lateral radiographs of the affected area of th
remain symptomatic or progress after a course of conservative tre

Bone biopsy is indicated if a metabolic bone disease or a malignan

Treatment

Prevention still remains the best treatment for osteoporosis. Maxir
initiated. Calcitonin therapy can be used if estrogen therapy is con

The bisphosphonates, etidronate and alendronate, prevent osteocl

The initial treatment of symptomatic vertebral compression fractur

Surgical Treatment

Patients who have fractures that cause neurologic deficits or signif

Patients who have recalcitrant back pain from a nonunited vertebr
intrapedicularly or extrapedicularly (lateral to the pedicle) into the
pressure, and correct the wedge deformity. This technique has the

The mechanism of pain relief achieved through vertebroplasty and
currently under active investigation.

Coumans JV, Reinhardt MK, Lieberman IH: Kyphoplasty for vertebr

Diamond TH, Champion B, Clark WA: Management of acute osteop

Do HM et al: Prospective analysis of clinical outcomes after percut

Grohs JG et al: Minimal invasive stabilization of osteoporotic verte

Guglielmi G et al: Percutaneous vertebroplasty: Indications, contra

McGraw JK et al: Prospective evaluation of pain relief in 100 patie

Nussbaum DA, Gailloud P, Murphy K: A review of complications as

Phillips FM et al: Minimally invasive treatments of osteoporotic ver

Steinmann J, Tingey CT, Cruz G et al: Biomechanical comparison c

Uppin AA et al: Occurrence of new vertebral body fracture after pe

SCOLIOSIS

Scoliosis is an abnormal curvature of the spine as viewed in the co

Etiology, Classification, & Pathophysiology

Scoliosis is classified according to its cause, with the most commo
Proposed etiologies for idiopathic scoliosis include abnormalities in

Table 5–1. Classification of Scoliosis by Cause.

I. Idiopathic scoliosis	A. Infantile (under 3 years of age)	B. Juvenile (from 3 to 10 years of age)	C. Adolescent (from 10 years of age to skeletal maturity)	D. Adult	II. Neuromuscular scoliosis	A. Neuropa

Modified and reproduced, with permission, from Winter RB: Classi

Particularly in idiopathic cases, scoliosis can also be classified acco

The curvature is named according to the side of the convexity, as

The most common types of curves in cases of idiopathic scoliosis a
less flexible and rotation is evident, it may be difficult to determin

The natural history of spinal curvatures is affected by factors such
can become compromised, and a secondary restrictive lung diseas
years appears to be satisfactory for adults who have idiopathic sco

Principles of Diagnosis

HISTORY AND PHYSICAL EXAMINATION

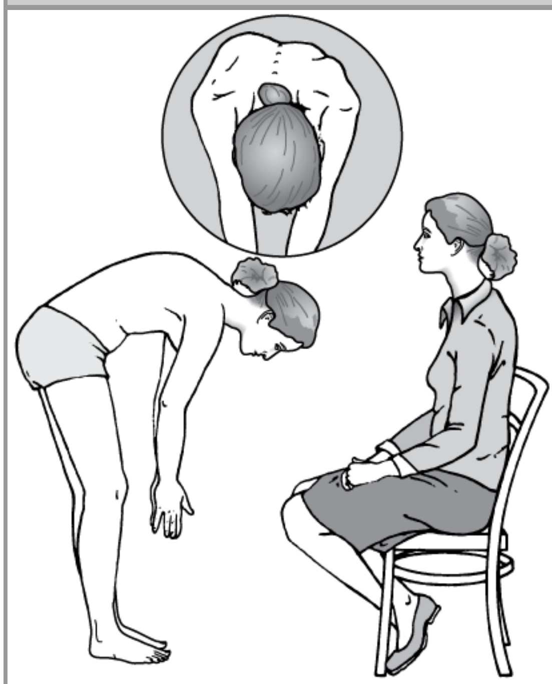
In a patient with a spine deformity, the history should include the
incidence of scoliosis in the general population is approximately 1%
more common in males.

In children and adolescents, the curvature is generally not painful.

The patient's skin, habitus, and back should be carefully inspected
examined for high-arched palate, cardiac murmur, and dislocated l

In patients with scoliosis, the shoulders or pelvis may not be level,
The rib hump can be quantified by direct measurement of its heigh

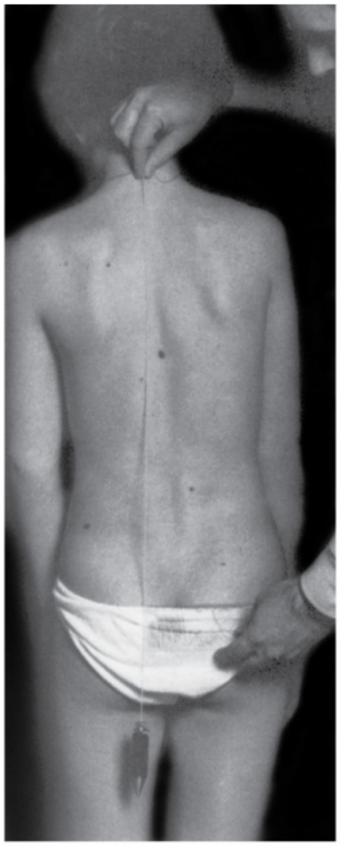
Figure 5–14.



The rotational deformity of scoliosis is manifested by a rib hump,

(Reproduced, with permission, from Day LJ et al: Orthopedics. In

Figure 5–15.



Use of a plumb bob to measure coronal decompensation in a patie

(Reproduced, with permission, from McCarthy RE: Evaluation of th

Flexibility of the curve can be qualitatively assessed by having the

NEUROLOGIC TESTS

Patients should demonstrate a normal gait and be able to walk on
Babinski sign, or a positive Hoffmann sign) should be noted and su

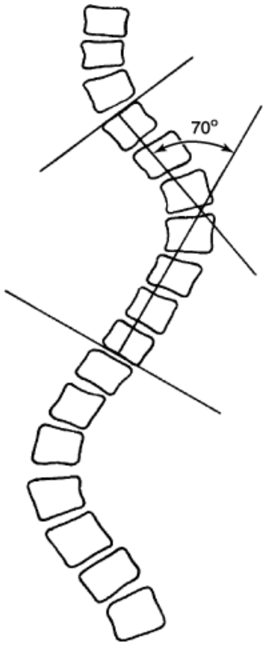
An asymmetric abdominal reflex is the most common neurologic al

Abnormal neurologic test results are an indication for further work

IMAGING STUDIES

AP and lateral radiographs of the entire length of the spine should

Figure 5–16.



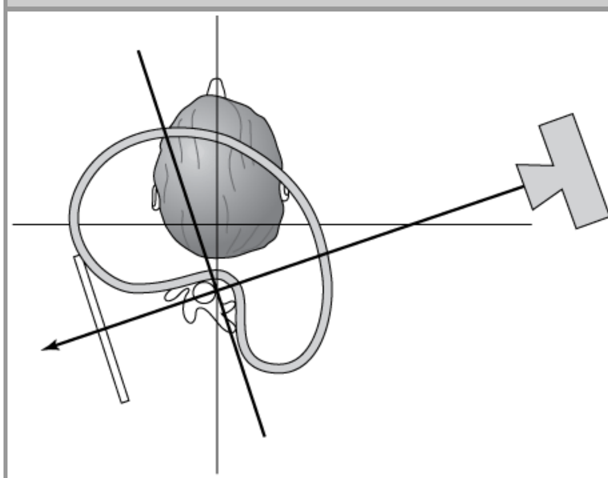
Use of the Cobb method to measure the scoliotic curve. First, line

(Reproduced, with permission, from Day LJ et al: Orthopedics. In

Views taken with the patient bending away from the concavity ma
the legs and arms or via application of a head halter.

For severe curves (more than 90 degrees), the rotational deformit

Figure 5–17.



In cases of severe curvature, the x-ray beam and cassette are po

(Reproduced, with permission, from Lonstein JE: Patient evaluatio

For patients with abnormal results in the neurologic examination, a
distally and can prevent the normal cephalad migration of the corc

OTHER STUDIES

If the patient has a finding of intracanal abnormalities, particularly

Patients with curves greater than 60 degrees, those with respirato
tracheostomy placement. We prefer, however, to caution patients a

Principles of Treatment

Although general principles of treatment are discussed here, addit

CONSERVATIVE TREATMENT

Mild curves (less than 20 degrees) can generally be managed cons

Although some skeletally immature patients with curves greater th
for certain patients in this group. Any skeletally immature patient

Several types of braces are available for the treatment of scoliosis
metal struts, applying pressure to the rib at the apex of the conve

Figure 5–18.

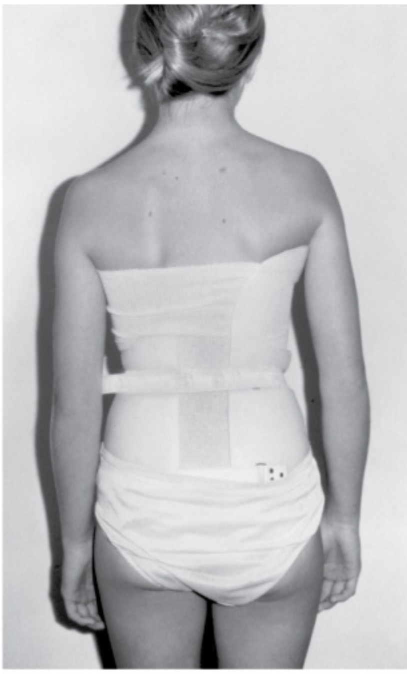
The Milwaukee brace, which is also known as the cervical thoracol

The thoracolumbosacral orthosis is a more cosmetically acceptable
at the most prominent area. A second pad can be applied over the

Because of the corrective forces being placed posteriorly, bracing r

For isolated lumbar curves, a lumbosacral orthosis can be used (Fi

Figure 5–19.



The underarm brace, which is also known as the lumbosacral orth

Although braces are designed to apply corrective forces to the spi

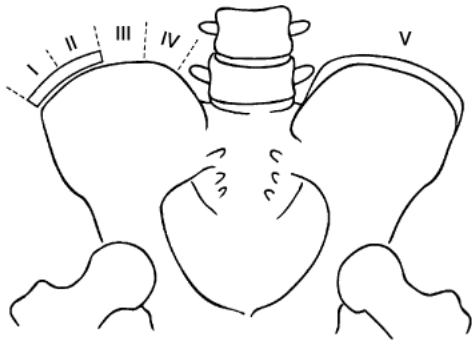
Unlike most braces, the Charleston night bending brace is worn or

Infants may require casting for management of severe curves. Wh

Patients who are wearing braces for the treatment of scoliosis sho
and some studies indicate that compliance with brace wear is corr

If an idiopathic curvature can be controlled with bracing, bracing s
(Risser sign, as shown in Figure 5–20) or by taking radiographs of
Some loss of correction should be expected; again, it is important

Figure 5–20.



The Risser sign for skeletal maturity. The iliac apophysis first appe
(Reproduced, with permission, from McCarthy RE: Evaluation of th

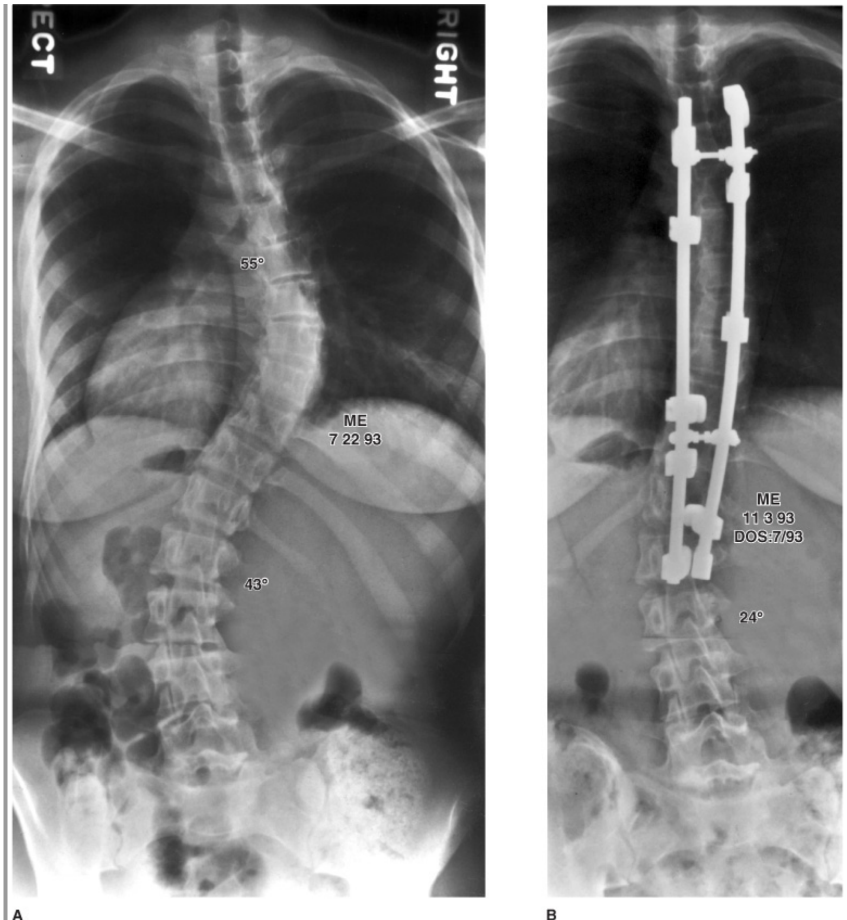
SURGICAL TREATMENT

Curves greater than 40 degrees are difficult to control with bracin

Posterior fusion and Harrington rod instrumentation was historicall
The sublaminar wiring technique is generally reserved for neuromu

Currently, variable hook-rod systems permit placement of hooks o
contours can also be corrected, if needed, by applying compressio
fixation so that postoperative brace wear is not needed for most y

Figure 5–21.



Imaging studies in a patient with scoliosis. **A:** Radiograph showing

For more rigid curves, such as may be found in older patients (ove
include rigid kyphosis, prior failed fusion, and the presence of seve

Some single curves, particularly thoracolumbar and lumbar curves
correction (Figure 5–22). They are generally not used lower than t

Figure 5–22.

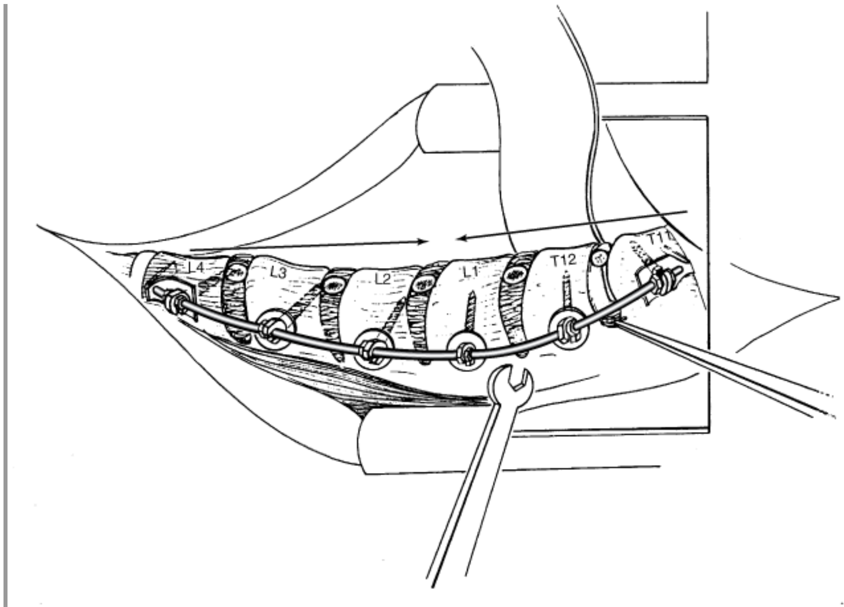


Illustration of the use of anterior instrumentation on a Thoracolum

Complications & Risks of Surgery

The incidence of complications in adolescent patients is quite low,

NEUROLOGIC COMPROMISE

Among the risks faced by patients who undergo major spine fusior better understood today, the risk appears to have decreased.

CARDIOPULMONARY PROBLEMS

Cardiopulmonary complications are unusual in adolescents, but the hypotension is used to minimize blood loss during many procedure

The risk of thromboembolic complications after spine surgery rang in high-risk patients. Although their efficacy is well documented wi

INFECTION

Although perioperative antibiotics should and usually are given, pa

PSEUDARTHROSIS

Rarely occurring in the adolescent but seen occasionally in adults i Instrumentation that is painful or broken may be an indication of p

DECOMPENSATION

In cases of decompensation, the patient leans with the trunk shifte

FLAT BACK SYNDROME

Seen less frequently now that contoured rods are used, flat back s Patients may need to hyperextend their hips to stand fully upright

LOW BACK PAIN

Lower distal levels of fusion appear to correlate with increasing ris

Ascher M et al: Safety and efficacy of Isola instrumentation and ar

Daneilsonn AJ, Nachemson AL: Back pain and function 22 years af

Daneilsson AJ, Nachemson AL: Back pain and function 23 years af

Danielsson AJ, Nachemson AL: Radiologic findings and curve progr

Davids JR et al: Indications for magnetic resonance imaging in pre

Dickson RA, Weinstein SL: Bracing (and screening)—Yes or no? J B

Gepstein R et al: Effectiveness of the Charleston bending brace in

Gruelich W, Pyle S: *Radiographic Atlas of Skeletal Development of*

Lenke LG: Lenke classification system of adolescent idiopathic scol

Lenke LG et al: Radiographic results of arthrodesis with Cotrel-Dul

Nachemson AL, Petersen P-E, and members of the Brace Study Gr

Parent S et al: Adolescent idiopathic scoliosis: Etiology, anatomy, r

Petersen L-E, Nachemson AL, and members of the Brace Study Gr

Rowe DE et al: A meta-analysis of the efficacy of nonoperative tre

Idiopathic Scoliosis in Adults

Indications for intervention in adults with scoliosis are pain and pro
be braced as a salvage measure. In an otherwise reasonably healt

The same surgical principles apply to adults as younger patients. A

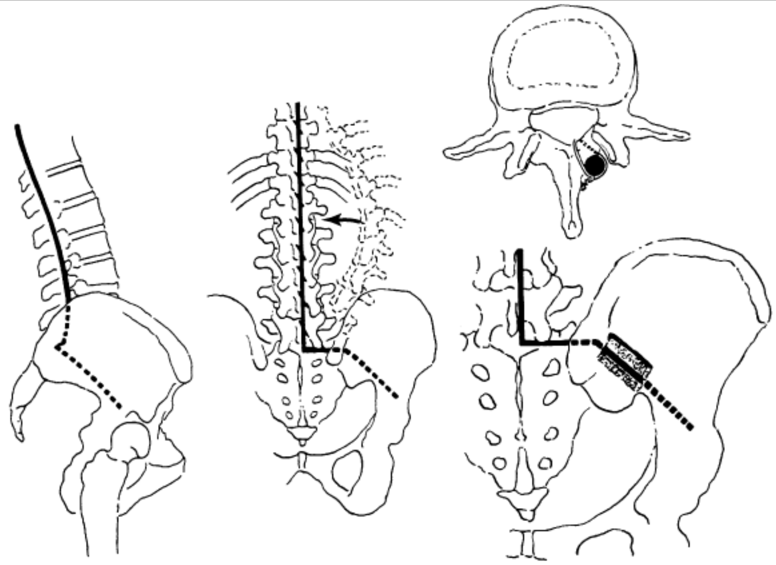
In adulthood, previously compensatory curves are often structural
addressed: If correction of the major curve or curves is achieved a

Another concern is the need to correct sagittal plane deformity, pa

Anterior release and fusion may be indicated prior to posterior inst
may affect the patient's ability to stand fully upright.

For older patients, particularly women, osteoporosis may prevent (
Use of iliac screws (Figure 5–23) should be considered for long fus
perioperative risks of surgery.

Figure 5–23.



Use of the Galveston technique to obtain pelvic fixation.

(Reproduced, with permission, from Shook JE, Lubicky JP: Paralyt

Postoperative care in the adult patient undergoing major reconstru

Fluid shifts can be significant after lengthy procedures, particularly

Bradford DS et al: Adult scoliosis: Surgical indications, operative n

Connolly PJ et al: Adolescent idiopathic scoliosis. J Bone Joint Surg

Dickson JH et al: Results of operative treatment of idiopathic scoli

Eck KR et al: Complications and results of long adult deformity fus

Grubb SA et al: Results of surgical treatment of painful adult scoli

Kim YJ et al: Pseudoarthrosis in primary fusions for adult idiopathi

Schwab F et al: Adult scoliosis: A health assessment analysis by S

Schwab FJ et al: Adult scoliosis: A quantitative radiographic and cl

Weinstein SL et al: Health and function of patients with untreated

Neuromuscular Scoliosis

Neuromuscular conditions frequently associated with scoliosis inclu
of ensuing growth. Although neuromuscular scoliosis can be subdiv

The assessment of patients should be detailed and include an eval
or can be secondary to the spinal deformity. The primary conditior

With neuromuscular scoliosis, as with idiopathic scoliosis, curvatur
balance in affected patients. Before treatment of neuromuscular s

Studies show, however, that in patients with Duchenne-type musc
functional vital capacity.

The neuromuscular condition associated with scoliosis in each case
function is also progressively lost in many neuromuscular conditior

Unlike patients with idiopathic scoliosis, patients with neuromuscul

If surgery is recommended in cases of neuromuscular scoliosis, sp
fusion to the pelvis is advisable. This may be performed with the C
those described here, it is usually necessary to extend the fusion p

The perioperative management of neuromuscular scoliosis can be
ataxia have a high incidence of cardiomyopathy and diabetes melli

With aggressive medical and surgical management and a supporti

Benson ER et al: Results and morbidity in a consecutive series of p

Jones KB et al: Longitudinal parental perceptions of spinal fusion f

Kannan S et al: Bleeding and coagulation changes during spinal fu

McCarthy RE: Management of neuromuscular scoliosis. Orthop Clir

Miller F et al: Pulmonary function and scoliosis in Duchenne dystro

Miller RG et al: The effect of spine fusion on respiratory function ir

Olafsson Y et al: Brace treatment in neuromuscular spine deformit

Yazici M et al: The safety and efficacy of Isola-Galveston instrumer

Neurofibromatosis

Spinal deformity associated with neurofibromatosis poses some sp

Dysplastic curves can be identified by evidence of dysplastic bone:

Dysplastic curves in patients with neurofibromatosis can progress

Surgery in patients with dysplastic curves is associated with a high extent of dural ectasia. Fusion levels are selected according to the

Akbarnia BA et al: Prevalence of scoliosis in neurofibromatosis. Sp

Funasaki H et al: Pathophysiology of spinal deformities in neurofib

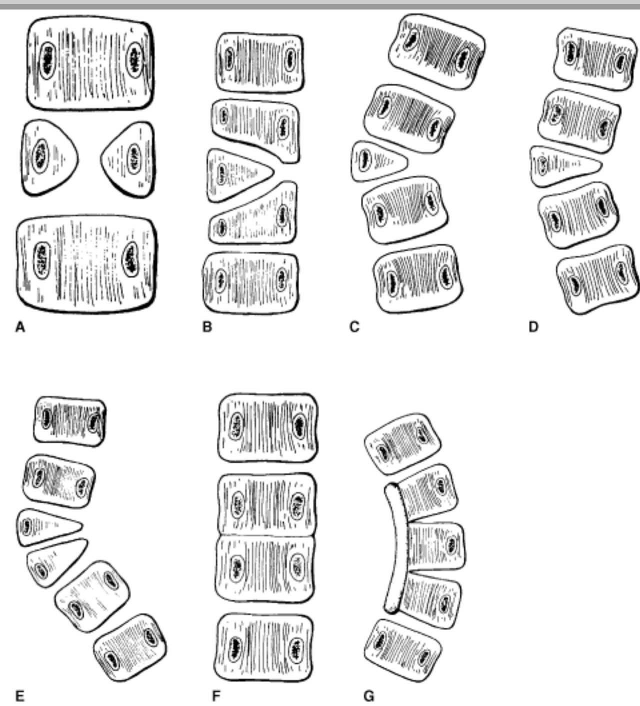
Vitale MG et al: Orthopaedic manifestations of neurofibromatosis i

Winter RB et al: Spine deformity in neurofibromatosis. A review of

Congenital Scoliosis

Congenital scoliosis is caused by one of two types of structural bor contralateral hemivertebrae have the greatest tendency for rapid

Figure 5–24.



The major types of congenital scoliosis are failure of formation, as
(Reproduced, with permission, from Hall JE: Congenital scoliosis. I

With respect to progression, hemivertebrae have a variable progn
spine above or below the abnormality cannot compensate. Hemive

Bracing is ineffective in treating congenital scoliosis because the cu

In patients with congenital scoliosis, the incidence of cardiac abnor
cord (presence of a tight filum terminale that does not permit the

If surgical intervention in patients with congenital scoliosis is indica
the fused posterior elements. For this reason, combined anterior a
skeletal maturity at risk for development of crankshaft.)

In some cases of hemivertebra, hemiepiphysiodesis may be perfor

In cases in which a hemivertebra is accompanied by significant cor
Hemivertebra excision may be the preferred option in the lumbar s

Bradford DS: Partial epiphyseal arrest and supplemental fixation f

Bradford DS, Boachie-Adjei O: One-stage anterior and posterior h

Deviren V et al: Excision of hemivertebrae in the management of c

Holte DC et al: Excision of hemivertebrae and wedge resection in t

Kim YJ, Otsuka NY, Flynn JM et al: Surgical treatment of congenita

Nakamura H, Matsuda H, Konishi S et al: Single-stage excision of

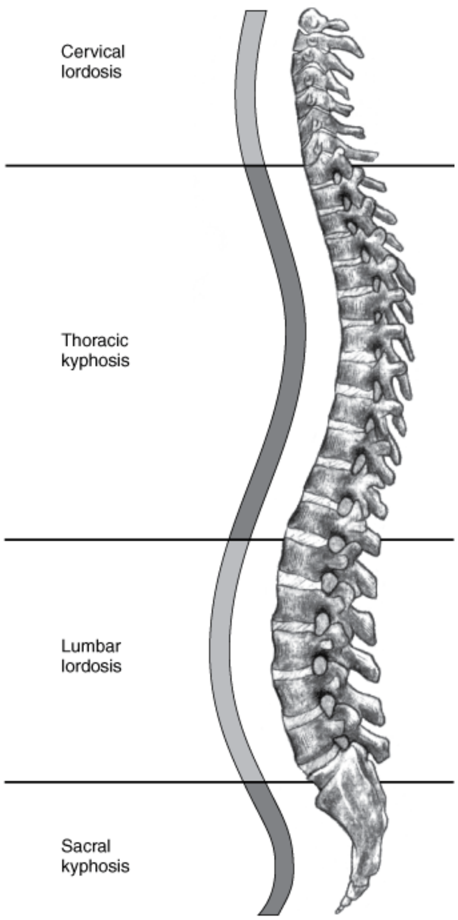
Prahinski JR, Polly DW Jr, McHale KA et al: Occult intraspinal anom

Thompson AG et al: Long term results of combined anterior and p

KYPHOSIS

The normal sagittal contour of the spine includes cervical lordosis,

Figure 5–25.



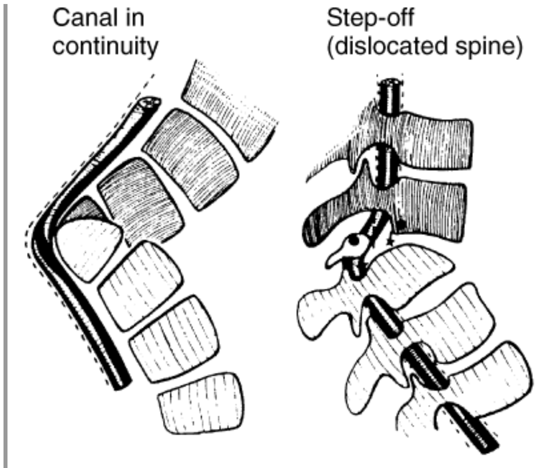
The normal sagittal contour of the spine.

(Reproduced, with permission, from Bullough PG, Boachie-Adjei O

Congenital Kyphosis

As in congenital scoliosis (see previous discussion), congenital kypl
neurologic problems. Severe deficiencies, however, may require ar

Figure 5–26.



Congenital kyphosis and congenital "dislocation" of the spinal colu
(Reproduced, with permission, from Dubousset J: Congenital kyph

Scheuermann's Kyphosis

Normal thoracic kyphosis ranges from 25 to 45 degrees. Postural k
material at the vertebral endplates, and increased thoracic kyphos
Cobb angle can be measured. Thoracic curves may cause pain and

Bracing can be instituted if the kyphosis measures more than 45 d
should be taken with the patient in the brace to confirm that adeq
Although some correction may be lost, proper use of the Milwauke

Surgical treatment of kyphosis may be indicated if the curve magn
hyperextension lateral radiograph, an anterior release and fusion p

Reports describe the natural history of Scheuermann kyphosis, sug

Arlet V, Schlenzka D: Scheuermann's kyphosis: Surgical managem

Lowe TG, Kasten MD: An analysis of sagittal curves and balance a

Murray PM et al: The natural history and long-term follow-up of Sc

MYELODYSPLASIA

Neural tube defects can result in complex spinal deformities secon
ventriculoperitoneal shunt because of hydrocephalus. The level of

Neurologic function in patients with myelodysplasia is static and sh

Orthopedic management includes maximizing the function of patie

As with many neuromuscular spinal deformities, curvatures may p

In many cases, the curvature eventually requires surgical stabiliza
instrumentation to the proximal thoracic spine is preferred, as with

The lack of posterior elements in the myelodysplastic spine can lea

Banit DM et al: Posterior spinal fusion in paralytic scoliosis and my

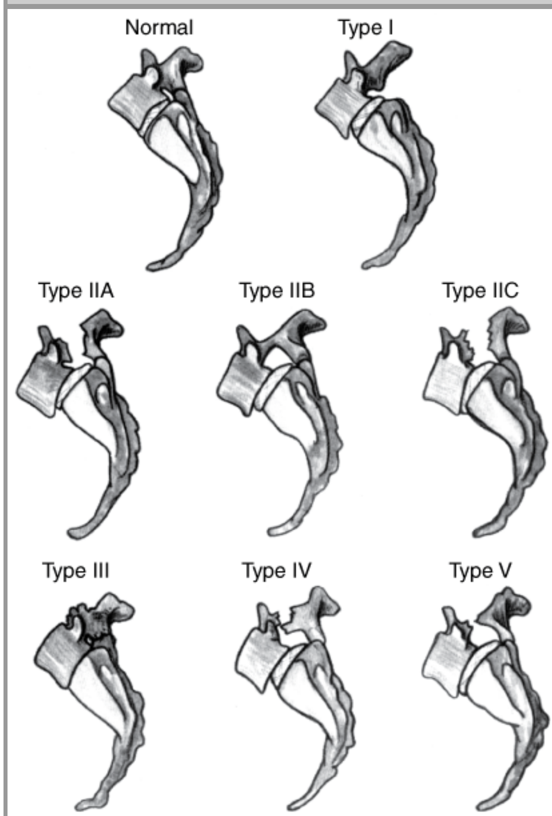
Parsch D et al: Surgical management of paralytic scoliosis in myel

SPONDYLOLISTHESIS & SPONDYLOLYSIS

Spondylolisthesis is the slipping forward of one vertebra upon anot

The classification system most commonly used in spondylolisthesis
younger (less than 15 years) patients and most likely to occur at t

Figure 5–27.



Classification of spondylolisthesis.

(Reproduced, with permission, from Bradford DS, Hu SS: Spondyl

Marchetti and Bartolozzi proposed a classification of spondylolisthe
based on clinical presentation and spinal morphology is now sugge

Bridwell KH, DeWal RL, eds: *The Textbook of Spinal Surgery,* 2nd

Herman MJ, Pizzutillo PD: Spondylolysis and spondylolisthesis in th

Marchetti PG, Bartolozzi P: Classification of spondylolisthesis as a g

Isthmic Spondylolisthesis

The cause of isthmic spondylolisthesis may be developmental, with suggest that the pars interarticularis is under the greatest stress i

Clinical Findings

Spondylolysis and spondylolisthesis may be asymptomatic, or they forward on the sacrum, is most commonly seen.

In young patients, regardless of the extent of slippage, there may crests (Figure 5–28).

Figure 5–28.

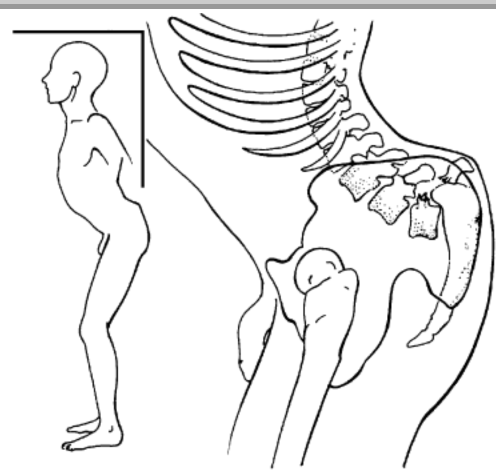
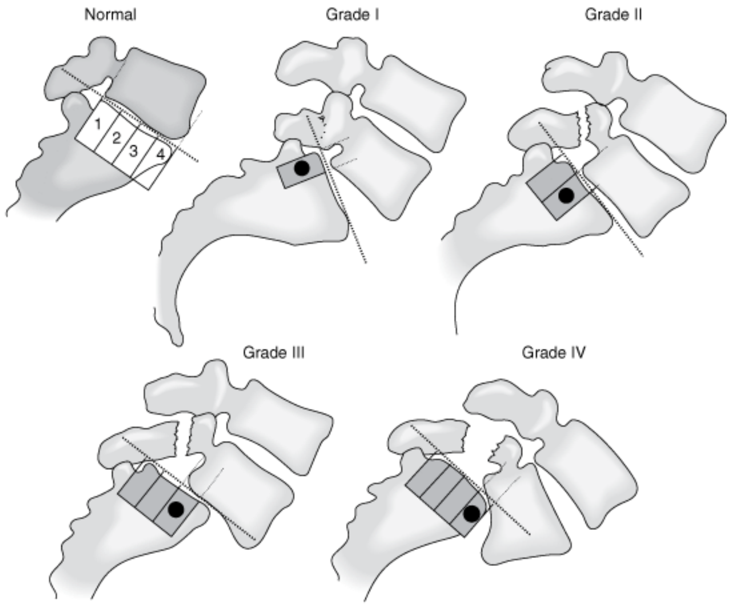


Diagram showing how high-grade spondylolisthesis results in a sh

(Reproduced, with permission, from Bradford DS, Hu SS: Spondyl

Radiographic examination shows the defect on the lateral view, wi findings are negative, bone scans may be useful. CT scanning sho

Figure 5–29.



Meyerding classification of degree of slippage in spondylolisthesis.
(Reproduced, with permission, from Bradford DS, Hu SS: Spondyl

Figure 5–30.

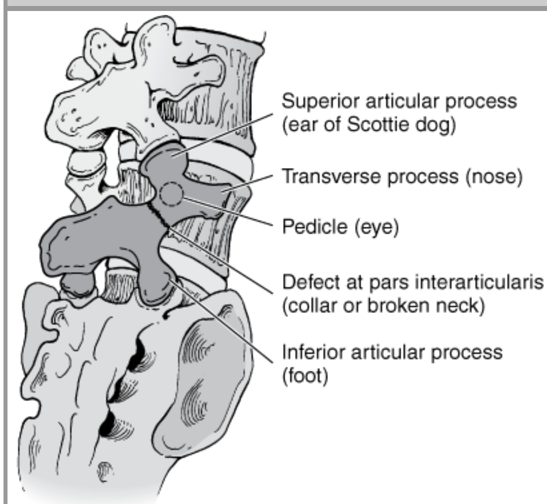
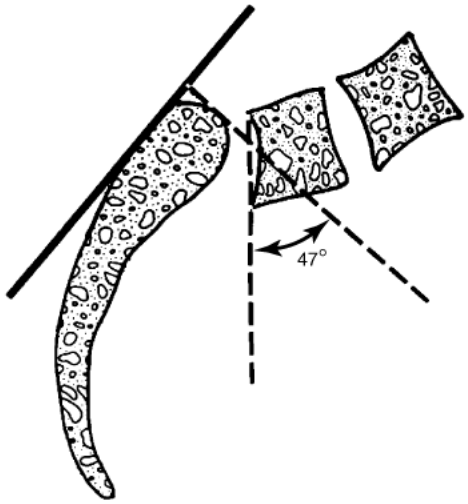


Diagram showing the "Scottie dog" (dark shaded area) seen on ot

The slip angle, a measure of lumbosacral kyphosis, is useful in det

Figure 5–31.



Measurement of the slip angle as a predictor of progression in spo
(Reproduced, with permission, from Bradford DS, Hu SS: Spondyl

In patients with radicular symptoms or bowel or bladder impairme

Treatment

CONSERVATIVE TREATMENT

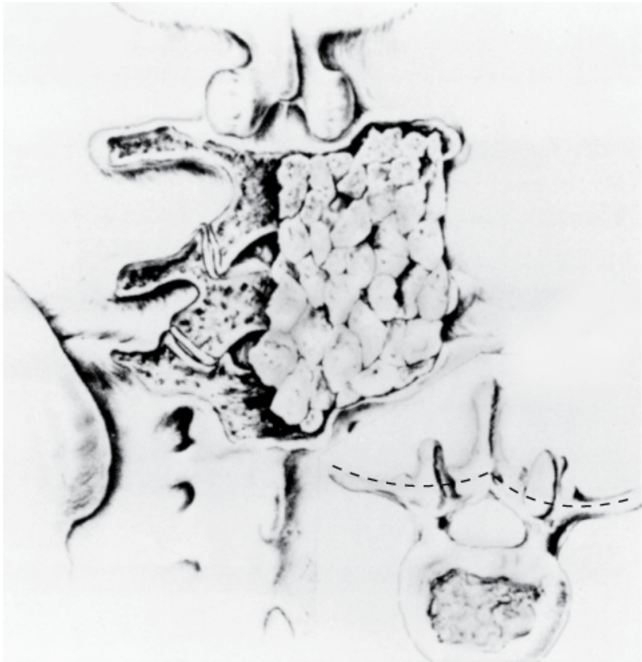
Low-grade spondylolisthesis (Meyerding grade I or II) can usually
activities that hyperextend the spine. Skeletally immature patients

SURGICAL TREATMENT:

Fusion and Decompression

Fusion is indicated for patients who fail to respond to conservative
95% and good to excellent clinical outcomes in 75–100% of patien
lamina are exposed and decorticated. Iliac crest bone graft is harv

Figure 5–32.



Schematic diagram of fusion for spondylolisthesis, as described by
(Reproduced, with permission, from Bradford DS, Hu SS: Spondyl

If neurologic findings such as numbness, leg pain, leg weakness, c
progression, so decompression should be combined with fusion. Sc

Bracing or casting may be indicated after fusion and may consist c

Pars Repair

Pars repair may be indicated for young (less than 18 years) patien

Figure 5–33.

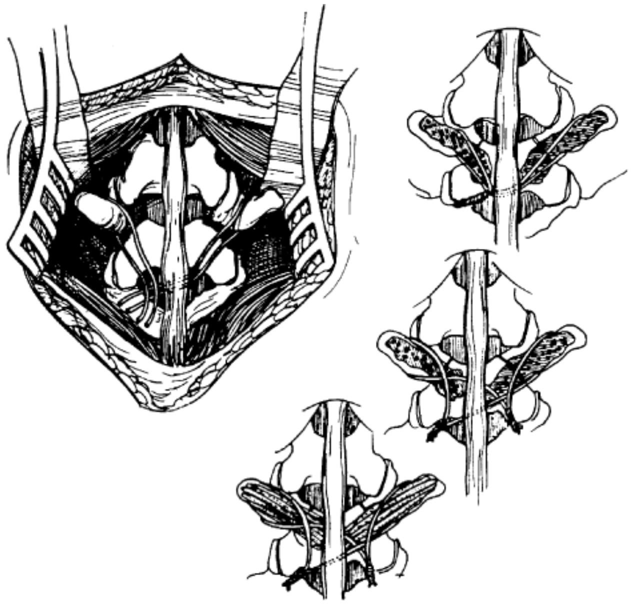


Illustration of pars repair, which can be performed in younger pati
(Reproduced, with permission, from Bradford DS, Hu SS: Spondyl

Fibular Strut Graft

Bohlman and Cook described a technique for one-stage posterior c
or allograft fibula is inserted and then countersunk to avoid dural i

Figure 5–34.

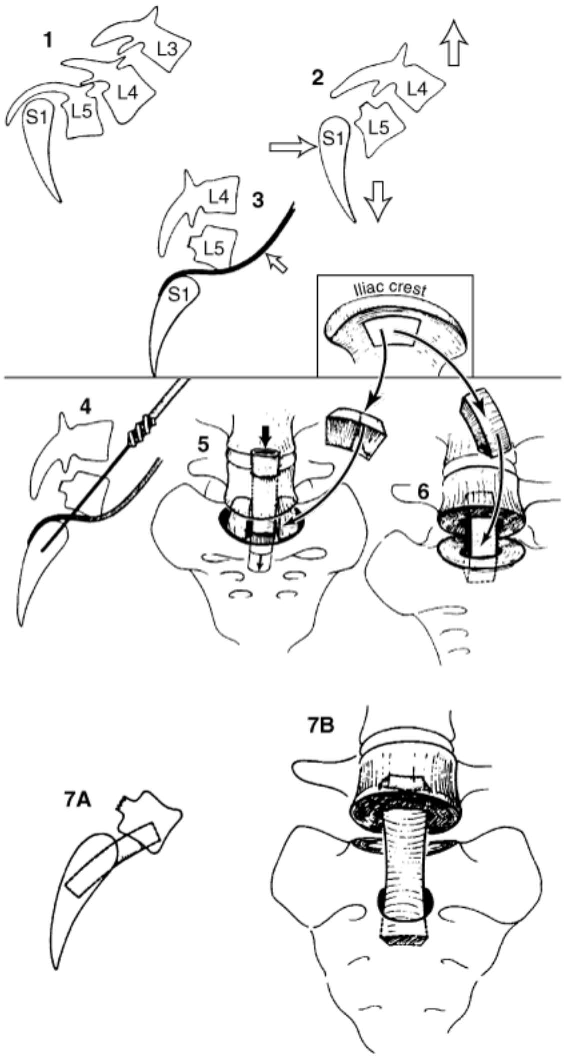


Diagram showing the steps involved in an anterior strut grafting p

(Reproduced, with permission, from Bradford DS, Hu SS: Spondyl

Anterior Fusion

Another option for achieving fusion is via an anterior transperitone
in male and female patients and the risk of retrograde ejaculation

Reduction

Reduction of high-grade spondylolisthesis remains controversial bu
spondylolisthesis. Improvement of the slip angle may prevent slip

Although even fusion in situ of high-grade slips can lead to neurolo
can be performed after traction is completed or initially at the tim

Pedicle screw instrumentation can be used by experienced surgeo

For severe slips, L5 vertebrectomy with reduction of L4 onto S1 is

Complications

As noted earlier, neurologic compromise sometimes results even a

Incomplete pain relief is rare in adolescents but is sometimes a co

Frennered AK et al: Natural history of symptomatic isthmic low-gr

Kakiuchi M: Repair of the defect in spondylolysis. J Bone Joint Sur

Labelle H et al: Spondylolisthesis, pelvic incidence, and spinopelvic

Laursen M et al: Functional outcome after partial reduction and 36

Minamide A et al: Transdiscal L5-S1 screws for the fixation of isthr

Ogilvie JW: Complications in spondylolisthesis surgery. Spine 2005

Petraco DM et al: An anatomic evaluation of L5 nerve stretch in sp

Degenerative Spondylolisthesis

Unlike isthmic spondylolisthesis, degenerative spondylolisthesis is motion. Other lumbar levels have more motion segments above ar spondylolisthesis rarely reaches the severity seen in severe isthmi

The narrowing at the disk level can lead to increased stresses at t

Most patients with degenerative spondylolisthesis demonstrate syr

If degenerative spondylolisthesis is refractory to conservative mea consolidates.

Boden SD et al: Orientation of the lumbar facet joints: Association

Fischgrund JS et al: Degenerative lumbar spondylolisthesis with sp

Herkowitz HN: Spine update. Degenerative spondylolisthesis. Spin

Kuntz KM, Snider RK, Weinstein JN et al: Cost-effectiveness of fus

Nork SE et al: Patient outcomes after decompression and instrume

Sengupta DK, Herkowitz HN: Degenerative spondylolisthesis: Revi

Thoracic Disk Disease

Disk herniation is found much less commonly in the thoracic spine

Patients with thoracic disk disease may present with radicular sym

In the absence of long-tract signs and paraparesis, conservative m

Surgical treatment is recommended for patients with signs of mye

When an anterior approach is used, 58–86% of patients show neu the cord and incomplete decompression of an inadequately visualiz

Bohlman H, Zdeblick T: Anterior excision of herniated thoracic disc

Brown CW et al: The natural history of thoracic disc herniation. Sp

Levi N, Gjerris F, Dons K: Thoracic disc herniation. Unilateral trans

Otani K et al: Thoracic disc herniation. Spine 1988;13:1262. [PMID

Regan JJ et al: A technical report on video-assisted thoracoscopy i

Vanichkachorn JS, Vaccaro AR: Thoracic disk disease: Diagnosis ar

Wood KB et al: Thoracic discography in healthy individuals. A cont

GENERAL CONSIDERATIONS

The cervical spine is the most mobile area of the spine, and as suc those between 15 and 35 years of age. Approximately 80% of all p

With the use of seat belts and air bags in motor vehicles and the a associated injuries are carried out. After the patient is stabilized, t

Identification & Stabilization of Life-Threatening Injur

Eighty-five percent of all neck injuries requiring medical evaluation spine should be presumed injured and thus immobilized. Approxim fractures. Appropriate diagnosis and fluid management are critical

History & General Physical Examination

Details of the history of the injury should be obtained. If the patie Were there any transient signs of paresis? Was the patient able to

The history taken from the patient or family members should also

It is helpful to question patients about what they are experiencing the forehead might indicate a hyperextension type injury. Observa screening examination because false-negative results are possible.

Neurologic Evaluation

A meticulous neurologic examination should be performed followin

NEUROLOGIC TESTS

The neurologic evaluation should start with documentation of the f commands, a motor examination should be fairly straightforward.

An extensive sensory examination should also be performed with c proprioception is tested by having the patient verify the position o

Reflexes should be checked bilaterally. In the upper extremity, the

The presence or absence of the four reflexes listed in Table 5–2 sh neuron lesion. The bulbocavernosus reflex has its root in the S3 ar scrotal sac, which should retract upward secondary to contraction

Table 5–2. Evaluation of Reflexes in Patients with Inj

Reflex	Root	Positive Response	Signif
Babinski	Upper motor neurons	Extension and spread of toes	Upper

The presence of spinal shock causes the absence of all reflexes an the patient is manipulated and treated.

ANATOMIC CONSIDERATIONS

The ability to interpret the results of a patient's neurologic examin

Peripheral nerves are a combination of afferent fibers, which carry the ventral root. The afferent fibers are often regrouped in variou peripheral nerve is demonstrated by a highly specific sensory loss

The spinal cord is a caudal continuation of the brain, extending in motor neurons. Headed from caudal to rostral, the spinal cord is h

The overall diameter of the spinal cord varies as a relative percent the gray matter increases relative to the white matter, whereas th

The gray matter, so called because it appears gray on unstained c

The white matter derives its name from the fact that the axons in

The two major ascending systems that relay somatic sensory infor cerebral cortex. The topography of the dorsal column is such that

Motor pathways originate in the cerebral cortex and travel distally both lower motor neurons traversing to the upper extremities and

The anatomy of the reflex arc and especially its relationship to spi centers. If all descending influence is interrupted, such as would o

RISK OF NEUROLOGIC DAMAGE

As mentioned earlier, the spinal cord varies in its diameter from ce

Cord compromise extends from two causes: mechanical destructio

CLASSIFICATION OF NEUROLOGIC STATUS

Intact

Approximately 60% of injuries to the cervical spine result in no ne

Nerve Root Injuries

Eight cervical nerve roots correspond to the seven cervical vertebr
injuries. Injury to the nerve root alone may result from a compres

Incomplete versus Complete Neurologic Injury

In the acute setting, any evidence of neurologic function distal to t

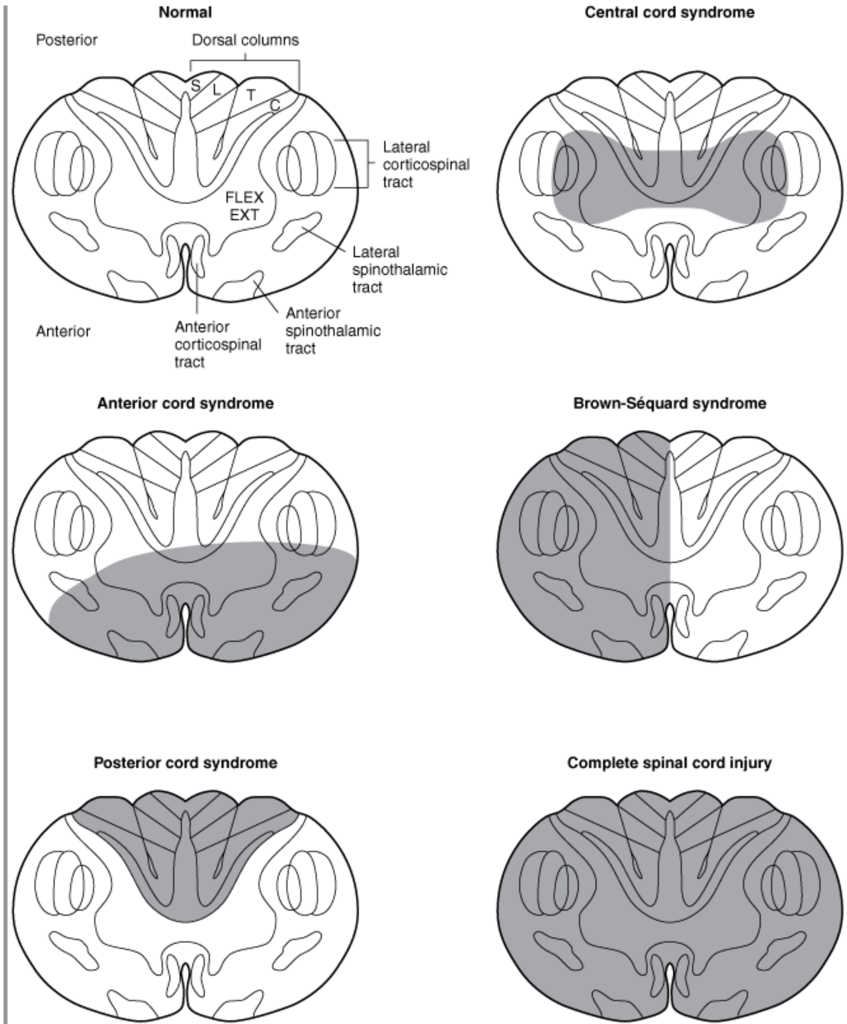
According to the Frankel system, which is the most widely used sy
function.

In the acutely injured spinal cord patient, the documentation of sa
spinal column. Because these patients can move their lower extrer

CLINICAL FEATURES OF SPINAL CORD SYNDROMES

Combining the findings on examination with knowledge of the cros

Figure 5–35.



Diagrams illustrating cross-sectional views of the normal and injur
cord injury, all areas are affected.

Central Cord Syndrome

The most common of the incomplete cord syndromes is the centra
"dissociation in degree of motor weakness with lower limbs strong
extremities, whereas a severe central cord syndrome includes mot
cord syndrome. In cases in which they are involved, they are the a

From 50% to 75% of patients with central cord lesions show some

Anterior Cord Syndrome

The patient with an anterior cord syndrome typically presents with
the younger (less than 35 years) trauma victim. The mechanism o
function is present early.

Brown-Séquard Syndrome

Patients with this syndrome have a motor weakness on the ipsilate
This tract carries pain and temperature fibers from the contralater

Brown-Séquard syndrome may result from a closed rotational inju

Posterior Cord Syndrome

The posterior cord syndrome is the least common of the incomplet

Complete Spinal Cord Injury

A complete neurologic deficit is characterized by a total absence of
complete and there is virtually no likelihood of functional spinal cor
upper extremities may be regained.

Imaging Studies

RADIOGRAPHY

Screening Radiograph

A lateral radiograph of the cervical spine may be the only screenin
through Gardner-Wells tongs. Once the patient is fully evaluated a

Subsequent Plain Radiographs

Full radiographic evaluation of the cervical spine with plain radiogr
be done with axial traction on the upper extremities caudally to at

When evaluating a lateral cervical spine radiograph, the clinician sl
the foramen magnum connecting the anterior cortex of each succe
process. After the clinician examines the radiograph in terms of th

Figure 5–36.

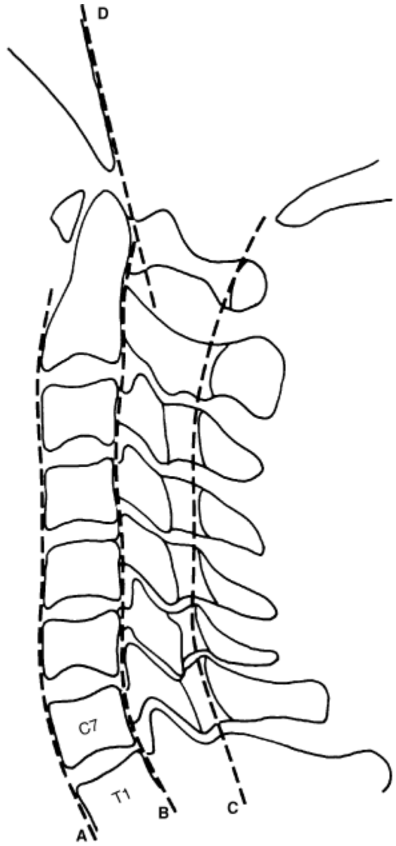


Diagram illustrating normal lines and curves in the bony anatomy

(Reproduced, with permission, from El-Khoury GY, Kathol MH: Rac

The evaluation of soft tissues can also prove valuable diagnosticall

The AP view of the cervical spine is at first a confusing projection t instability. Abrupt malalignment of the spinous processes suggests rotational malalignment of the facet.

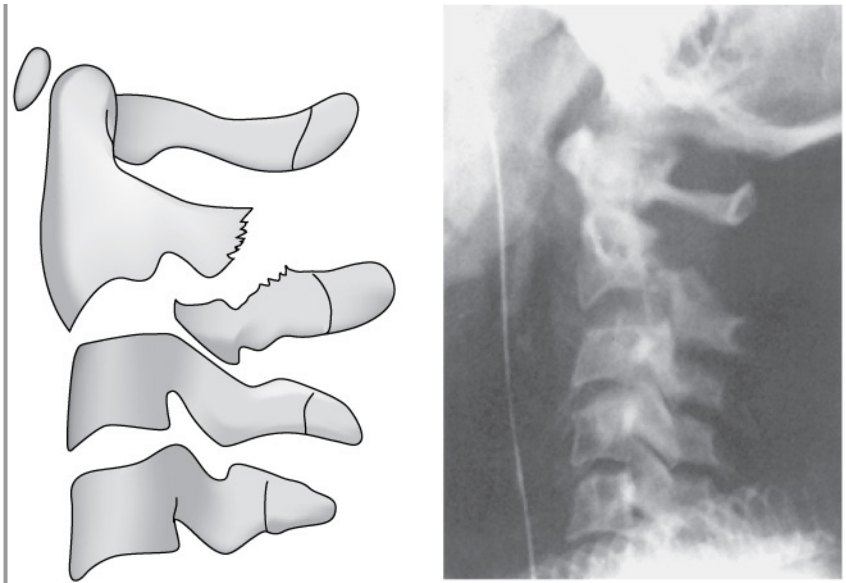
The open-mouth (odontoid) view is the projection most useful for

The right and left oblique views can be taken of the cervical spine

Stress Radiographs

Two techniques are used in obtaining cervical stress radiographs. T approximately a third of body weight or 30 kg, depending on the l

Figure 5–37.



A: Diagram illustrating an increase of the C2-C3 interdisk space ir
(Reproduced, with permission, from Levine AM, Rhyne AL: Trauma

The second technique, which should only be performed in a fully a
facet subluxation, forward subluxation of 3.5 cm of one vertebral I

COMPUTED TOMOGRAPHY

CT scanning is the most useful means for definitive delineation of I
construct for excellent visualization of the bony anatomy.

MAGNETIC RESONANCE IMAGING

MRI is the most effective way to evaluate the soft-tissue compone
close monitoring of the acutely ill patient difficult.

Diagnostic Checklist of Spinal Instability

The concept of spinal stability is central to the understanding and
White and Panjabi's diagnostic checklist of spinal instability (Table

Table 5–3. White and Panjabi's Diagnostic Checklist o

Checklist Category	Description
1	Disruption of the anterior elements, with greater loss of height

[a]If a total of 5 points is present in a given patient, the injury is de

Modified and reproduced, with permission, from White AA III, Pan

Holdsworth's two-column theory of spine stability, as well as Denis

General Principles of Managing Acute Injuries of the C

Management of acute cervical spine injury is predicated on two pri center. The equipment for initial immobilization should not be remo definitive cervical spine injury is identified and deemed unstable, s

Among the various agents that show potential benefits in laborato treated between hours 3 and 8 only did better by extending to 48 of the injury. The recommended dosage of methylprednisolone in a benefit."

Bracken MB et al: Administration of methylprednisolone for 24 or

Denis F: The three-column spine and its significance in the classifi

Nesathurai S: Steroids and spinal cord injury: revisiting the NASC

White AA III, Panjabi MM: Update on the evaluation of instability c

INJURIES OF THE UPPER CERVICAL SPINE

With the exception of occipitoatlantal dissociation, traumatic injuri

Occipitoatlantal Dissociation

Occipitoatlantal dissociation is a disruption of the cranial vertebral translation of the skull on the vertebral column is a common prese

When the dissociation is a frank dislocation, the findings are clear dens. If the dens penetrates this line, anterior translation of the cr to AO is greater than 1:1, anterior occipitoatlantal dissociation is p

Figure 5–38.

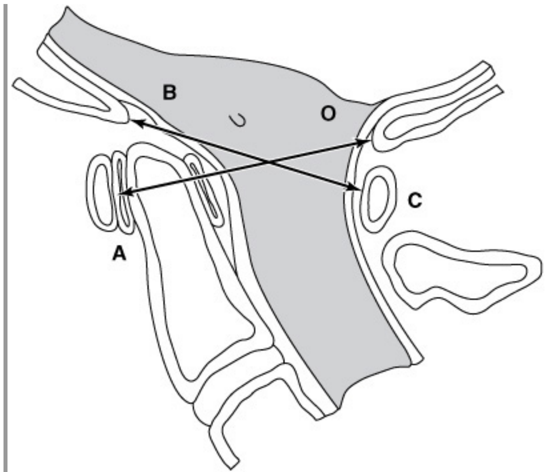


Diagram showing lines used in the calculation of the Powers ratio,

Early recognition and surgical stabilization are the mainstays of tre

Fractures of Vertebra C1 (Atlas Fractures)

The mechanism of injury in the fracture of the atlas is most typica being driven into the interior portions of the ring of the atlas and c the more common posterior arch fracture is typically the result of

A fracture of the atlas is typically diagnosed on plain radiographs. ligament disruption can also be seen on the lateral radiograph if th

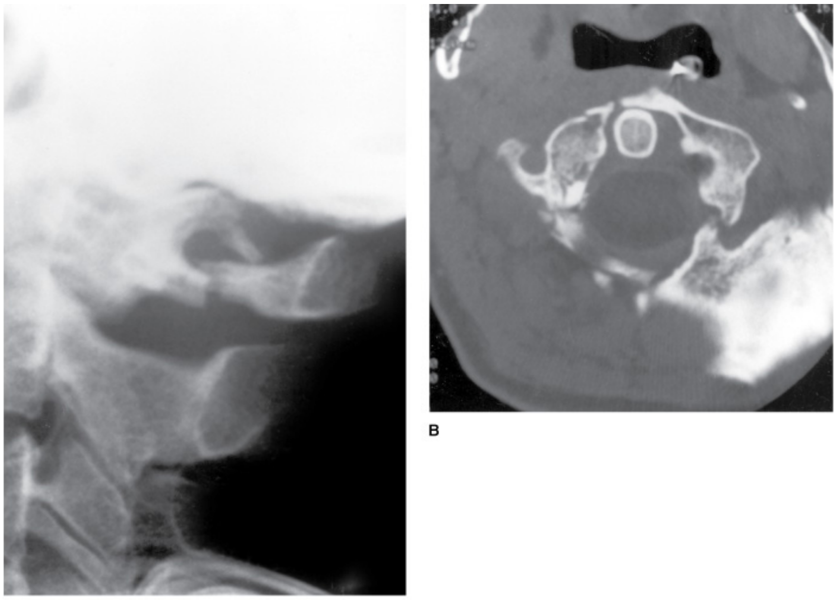
Figure 5–39.

Open-mouth (odontoid) radiographic view demonstrating asymme

(Reproduced, with permission, from El-Khoury GY, Kathol MH: Rac

The treatment for fractures of the atlas as isolated injuries is typic minimally displaced fracture of the atlas. At completion of bony un

Figure 5–40.



A

B

Imaging studies in a patient who was in a motor vehicle accident a

Dislocations & Subluxations of Vertebrae C1 & C2

ATLANTOAXIAL ROTATORY SUBLUXATION

Atlantoaxial rotatory subluxation is most common in children and r
50% of cases, cervical spine rotation occurs at the C1-C2 junction,

The diagnosis of atlantoaxial rotatory subluxation is typically suspe
rotation can demonstrate a fixed deformity.

There are four types of atlantoaxial rotatory subluxations. In type
dislocation of the atlas on the axis, a finding typically associated w

Treatment of atlantoaxial subluxation is typically conservative, con

DISRUPTION OF THE TRANSVERSE LIGAMENT

The transverse ligament and secondarily the alar ligament are the
of anterior dislocation of dens fractures still holds true.

The mechanism of disruption is typically a flexion injury, and the d

High-resolution CT scan can be used to categorize this injury into t
a reasonable alternative. A 74% success rate can be anticipated, w

FRACTURE OF THE ODONTOID PROCESS

Fracture of the odontoid process is typically associated with high-v
odontoid process, Anderson and D'Alonzo reported that 15 had sor

Odontoid fractures may be suspected on the basis of clinical prese

Both the risk of nonunion with delayed instability and the method

Figure 5–41.

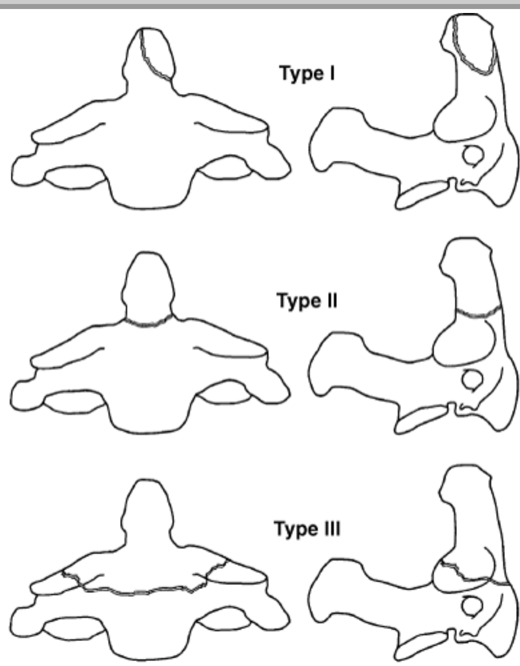
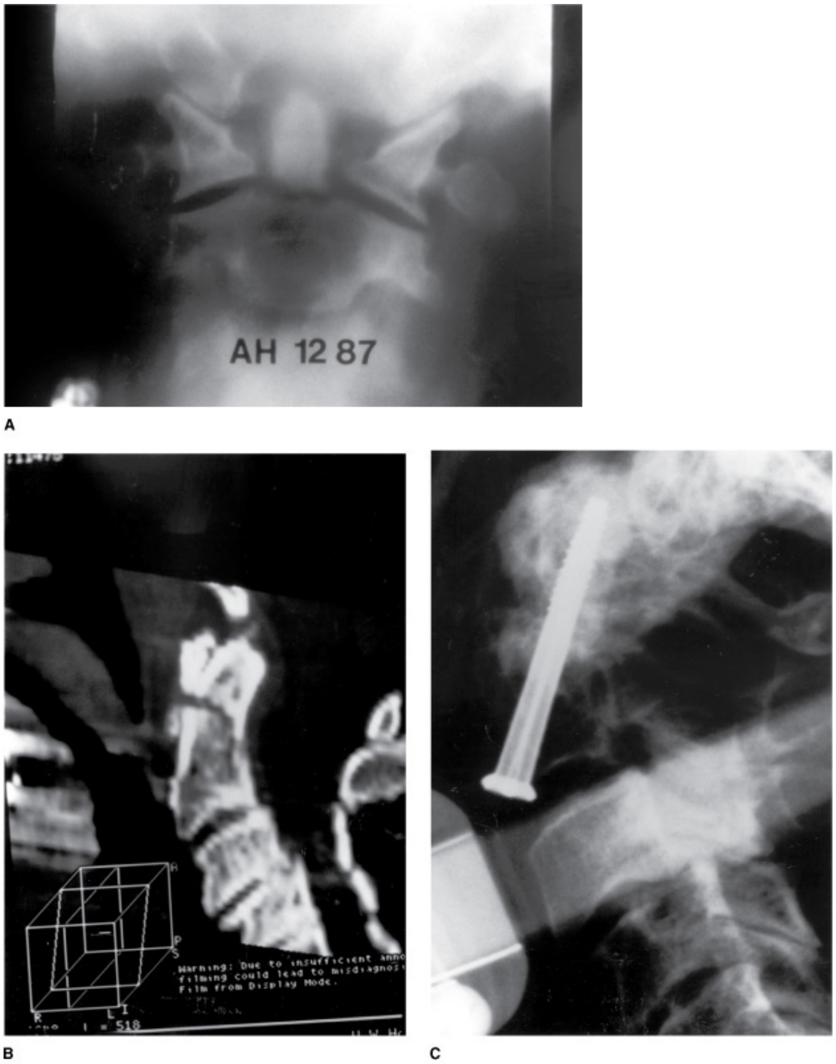


Diagram showing the three types of fractures of the odontoid proc

Type I is a fracture through the tip of the odontoid process. In this

Type II, the most common type, is a fracture through the base of
primary surgical treatment may be indicated. Anterior screw fixati

Figure 5–42.



Imaging studies in a patient with a type II odontoid fracture nonu

Type III is a fracture through the body of the axis. The blood supp

HANGMAN'S FRACTURE (TRAUMATIC SPONDYLOLISTHESIS

Hangman's fracture occurs when a fracture line passes through th
reported that traumatic spondylolisthesis was second only to occip

According to the scheme proposed by Levine and Rhyne, hangmar

Figure 5–43.

A

B

Imaging studies in a patient who was in a motor vehicle accident a

Type I is typically caused by hyperextension with or without additi

Type II is thought to be caused by hyperextension and axial load w
potentially resulting in cord compromise as the anterior aspect of t

Type IIA has the same fracture pattern as type II but with a comp

Type III includes a fracture through the neural arch, a facet disloca
posterior fusion is indicated.

Anderson LD, D'Alonzo RT: Fractures of the odontoid process of th

Govender S et al: Fractures of the odontoid process. J Bone Joint

Powers B et al: Traumatic anterior atlanto-occipital dislocation. Neu

Vieweg U, Schultheiss R: A review of halo vest treatment of upper

Ziai WC, Hurlbert RJ: A six year review of odontoid fractures: The

INJURIES OF THE LOWER CERVICAL SPINE

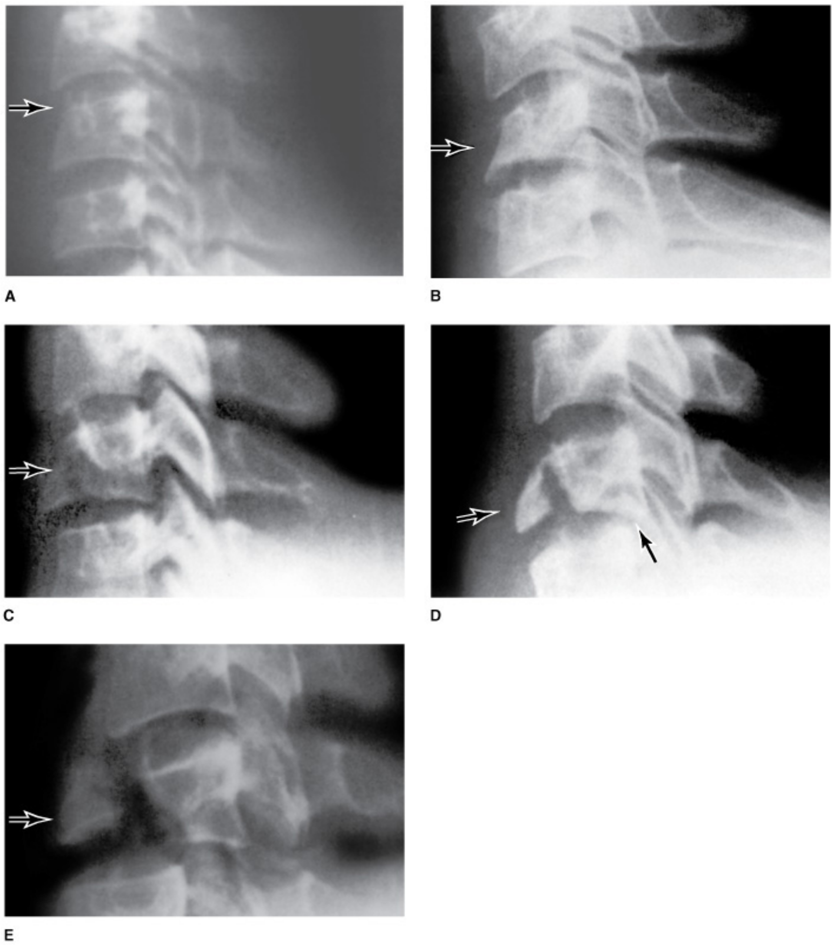
As stated earlier, fractures and dislocations of the lower cervical sp

In 1982, Allen and colleagues developed a classification system for
compression, distractive flexion, compressive extension, distractive

Compressive Flexion Injury

There are five stages of compressive flexion injuries, which are lab
anterior surface of the vertebral body through to the inferior subcl

Figure 5–44.



Radiographs showing the five stages of compressive flexion injury

(Reproduced, with permission, from Allen BL et al: A mechanistic

Within the compressive flexion category are two types of fractures
these require anterior decompression and stabilization. All patients

Vertical Compression Injury

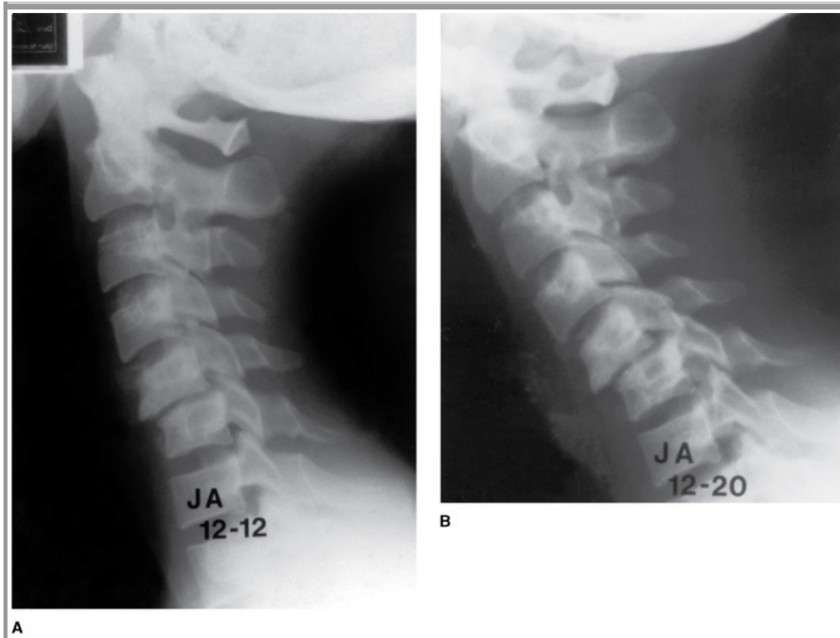
Vertical compression spinal (VCS) injuries occur secondary to axial

The treatment for VCS injuries is typically nonoperative. Traction is

Distractive Flexion Injury

The category of distractive flexion spinal (DFS) injury was the mos
initial evaluation and therefore result in late symptomatic instabilit
anterior dislocation at the affected level. DFS IV, which is also tern

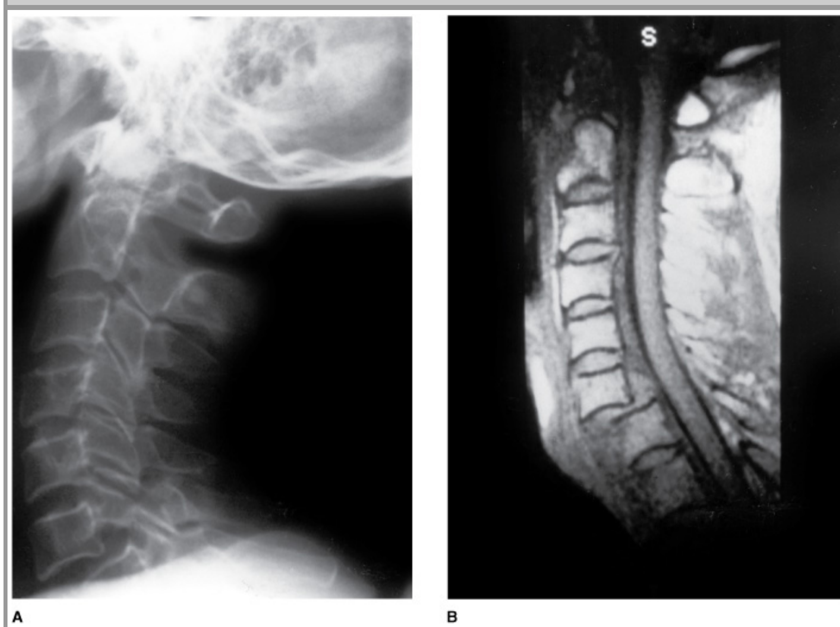
Figure 5–45.



Imaging studies in a patient with a distractive flexion injury of the

Treatment of DFS injuries depends on the severity of the injury. A
injury and instability. Treatment consisting of closed reduction and

Figure 5–46.



Imaging studies in a man who fell from a height and suffered a C6

Another fracture pattern that should be included in the discussion

Compressive Extension Injury

The category of compressive extension (CES) injury was the secor
fracture of the vertebral arch articular processes, lamina, or pedic

Treatment of CES injuries is related to the three-column theory. St

Distractive Extension Injury

Distractive extension (DES) injuries are typically soft-tissue lesions
upper vertebral body into the spinal canal. This lesion is often redu

The DES injury is usually stable and does not require surgical inter

Lateral Flexion Injury

Allen and colleagues included the injuries of five patients in the cat
mechanism can lead to brachial plexus injuries of varying degrees

Because of the rarity of LFS injuries, treatment protocols are not w

Treatment Decisions

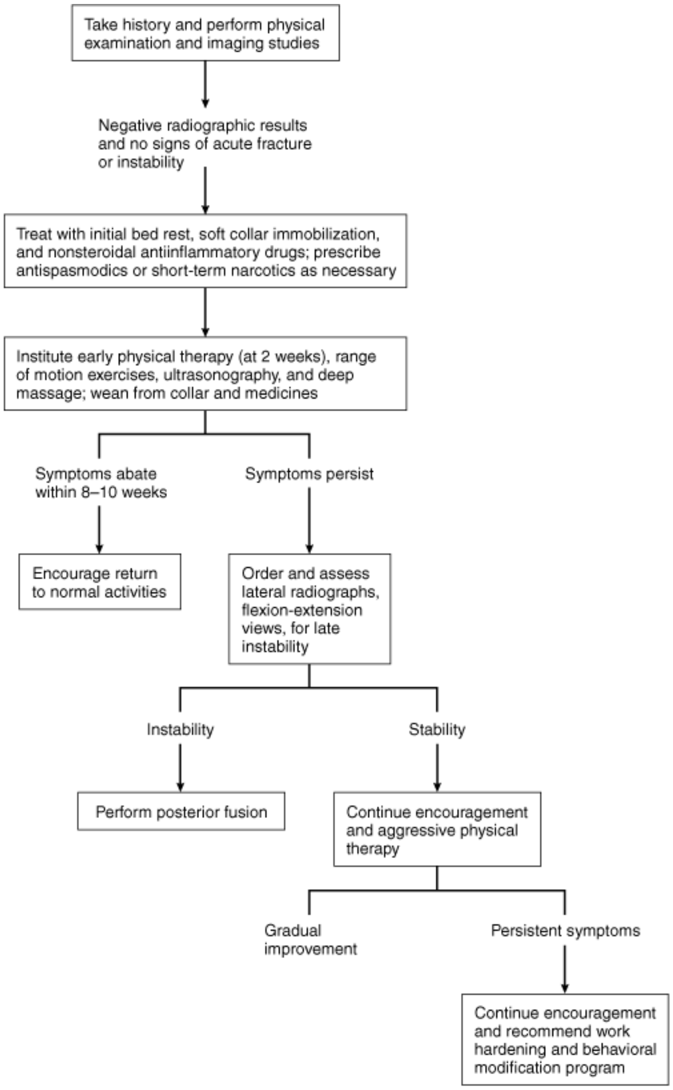
Ultimately the treating physician must decide on a treatment plan.
a clear operative indication either through an anterior, posterior, or

Cervical Strains & Sprains (Whiplash Injury)

Cervical strains and sprains, which are commonly referred to as a
and even vertigo. It is often difficult for the physician to correlate
spasm of the scalenus muscle, and certainly symptoms such as ho

Figure 5–47 presents an algorithm for management of cervical stra
prevertebral soft-tissue window should be within normal limits to r

Figure 5–47.



Algorithm for management of patients with cervical strain.

Once the stability of the spine is ensured, the care of the cervical s
lasting.

Approximately 42% of patients have persistent symptoms beyond
prognosis than hyperflexion injuries.

Hartling L et al: Prognostic value of the Quebec classification of wh

McNabb I: The "whiplash syndrome." Orthop Clin North Am 1971;2

Siegmund GP et al: Mechanical evidence of facet capsule injury du

Yoganandan N et al: Whiplash injury determination with conventio

MUSCULOSKELETAL ONCOLOGY: INTRODU

Tumors of the musculoskeletal system are an extremely heteroger

Neoplastic processes arise in tissues of mesenchymal origin far les younger than 15 years and 40% percent affecting persons older th

ETIOLOGY OF MUSCULOSKELETAL TUMORS

Tumorigenesis is a complex multiple-step process by which healthy

To appreciate how bone or soft-tissue tumors develop, one must h

Control of the cell cycle is a function of numerous regulatory prote

Oncogenes, encoding a variety of growth factors, promote progres of the amount of genomic instability that arises with each subsequ

Factors that influence these mechanisms include both inheritable g

The neoplastic process may arrest in the so-called benign state, w

Although a plethora of molecular markers are being studied, under

EVALUATION & STAGING OF TUMORS

History & Physical Examination

When evaluating a new patient with a possible tumor, the workup

The clinical history is of paramount importance (Table 6–1). The ag

Table 6–1. Questions That Must Be Asked in the Work

1. **The patient's age.** Certain tumors are relatively specific to particular age groups.	2. **Duration of c** (years). Malignar

Table 6–2. Distribution of Bone Tumors by Age (Years

A thorough physical exam is also critical (Table 6–3). The clinician

Table 6–3. Aspects of Physical Exam That Should Be D

1. **Skin color**			

2. **Warmth** 3. **Location** 4. **Swelling.** Swelling, in

a *Note:* These findings assume the absence of trauma.

The clinician must also consider pseudotumors in addition to true r

Imaging Studies

RADIOGRAPHY

Initial evaluation should begin with plain radiography. In every pat

The initial radiographic images must be scrutinized. For bone lesio

Terms such as *geographic, well circumscribed, permeative,* and ar

Figure 6–1.

Radiograph of an enchondroma of the second metacarpal. Notice i

Figure 6–2.

Radiograph of a proximal fibular osteosarcoma demonstrating the

Figure 6–3.

Radiograph of a giant cell tumor of the thumb. This is a typical mo

With a careful history, physical, and appropriate radiographs, the p
femur. The likely benign tumors are giant cell tumor, nonossifying

Table 6–4. Skeletal Distribution of Bone Tumors, Rank

Type of Tumor	Femur	Tibia	Foot or Ankle	Humerus	Radius	Ulna
Benign bone tumors						

Table 6–5. Bone Tumors: Imaging Characteristics, Lo

	Imaging Characteristics			Location in a Long Bone					Beneficial Studies					Type of Tumor	Geograph
Benign bone tumors														Osteoid osteoma	1

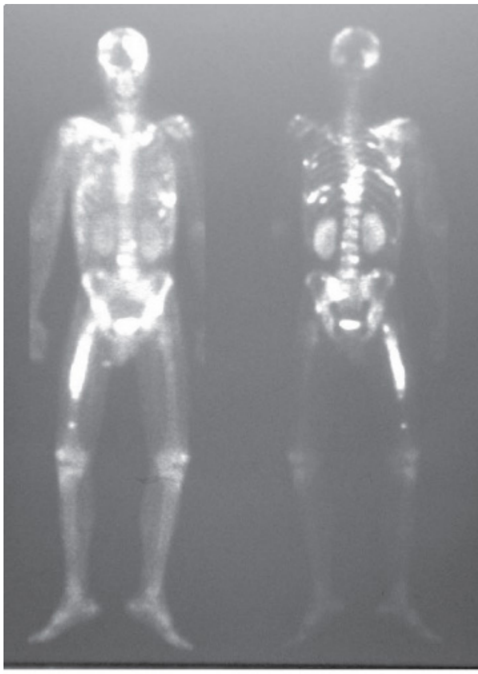
Table 6–6. Distribution of Soft-Tissue Tumors by Age

MFH = malignant fibrous histiocytoma.

ISOTOPE BONE SCANNING

Technetium-99 radioisotope scans are used to assess the degree o

Figure 6–4.



Technetium-99 scan demonstrating extensive osteoblastic activity

Isotope scanning is also used in the staging process of a primary s

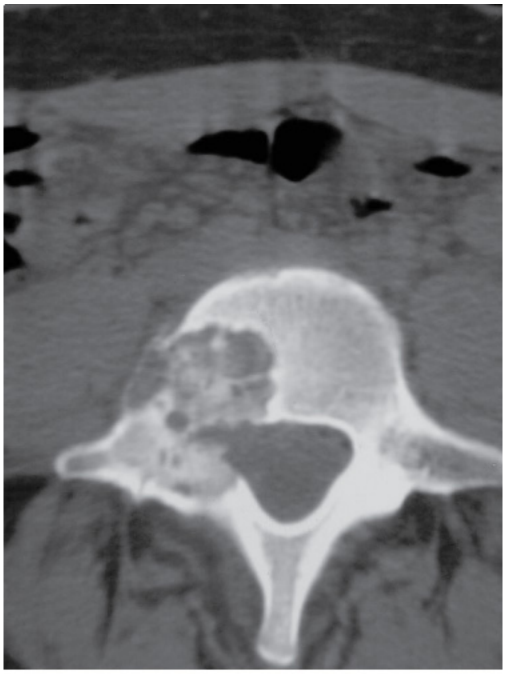
COMPUTED TOMOGRAPHY AND MAGNETIC RESONANCE IMA

Computed tomography (CT) remains a standard imaging procedur

Figure 6–5.

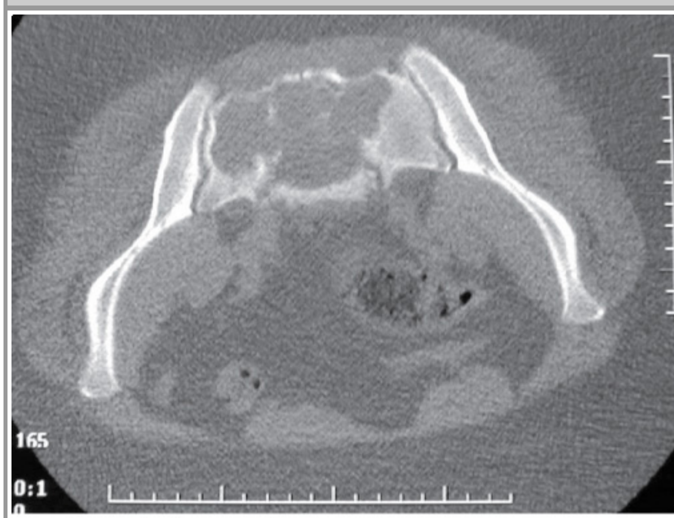
	40	50	60	70	80
Leiomyosarcoma					
Myxoid liposarcoma					
Round cell and pleomorphic liposarcoma					
Embryonal rhabdomyosarcoma					
Alveolar rhabdomyosarcoma					
Pleomorphic rhabdomyosarcoma					
Synovial sarcoma					
Solitary malignant schwannoma					
Multiple malignant schwannoma					
Alveolar soft part sarcoma					
Epithelioid sarcoma					
Clear cell sarcoma					

MFH = malignant fibrous histiocytoma.



CT scan of an osteoblastoma arising from the right pedicle of a lur

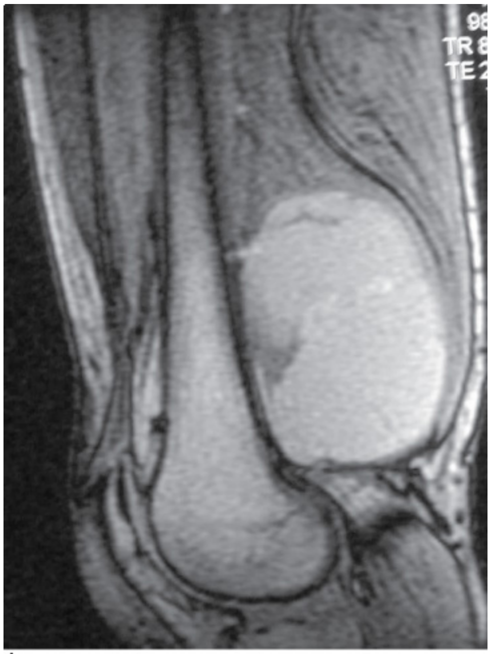
Figure 6–6.



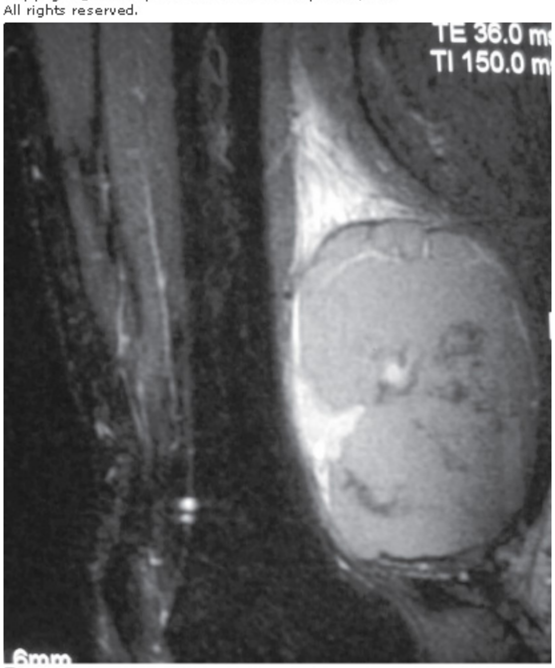
Pelvic CT demonstrating the bony destruction of the sacrum cause

MRI is the imaging modality of choice for evaluating bone marrow

Figure 6–7.



A



B

Synovial sarcoma involving the popliteal fossa. (**A**) T_1 weighted. (I

Laboratory Studies

BIOPSY

The biopsy should usually be the final staging procedure. Although
Obtaining an adequate specimen is critical. A frozen section deterr

The placement of the biopsy site is a major consideration. If the su

Transverse incisions should be avoided because removing the entir

Needle biopsies, either core or fine needle, can be used by experie

In general, excisional biopsies are discouraged unless the lesion is

CULTURES AND SPECIAL STUDIES

The damage of biopsy specimens after retrieval can make it impos

Molecular diagnostics is on the verge of revolutionizing sarcoma di

Table 6–7. Common Translocations Seen in Sarcomas
Ewing/primitive neuroectodermal tumor: t(11;22) (q24; q12), (t2

Staging Systems

After the appropriate studies are completed, staging begins. *Stagi*

SYSTEM OF THE AMERICAN JOINT COMMITTEE ON CANCER

The American Joint Committee on Cancer (AJCC) system (5th editi

SYSTEM OF THE AMERICAN MUSCULOSKELETAL TUMOR SOC

Orthopedic oncologists generally prefer the Enneking system, whic

The Enneking system further classifies tumors on the basis of whe

A low-grade fibrosarcoma located inside the fascial plane of the bi

Enneking WF: A system of staging musculoskeletal neoplasms. Cli

Mankin HJ et al: The hazards of the biopsy, revisited. J Bone Joint

Miettinen M et al: Gastrointestinal stromal tumors—Definition, clin

Moley JF et al: Soft-tissue sarcomas. Surg Clin North Am 2000;80

Oliveira AM et al: Grading in soft tissue tumors: Principles and pro

Reddick WE et al: Dynamic MR imaging (DEMRI) of microcirculatio

Simon MA et al: Diagnostic strategy for bone & soft tissue tumors

Skrzynski MC et al: Diagnostic accuracy and charge savings of out

Zahm SH et al: The epidemiology of soft tissue sarcoma. Semin O

BENIGN BONE TUMORS

Benign bone tumors have certain characteristics that favor their d
and are less well demarcated than stage 1 lesions. They frequently

The more common types of benign bone tumor seen by the practi

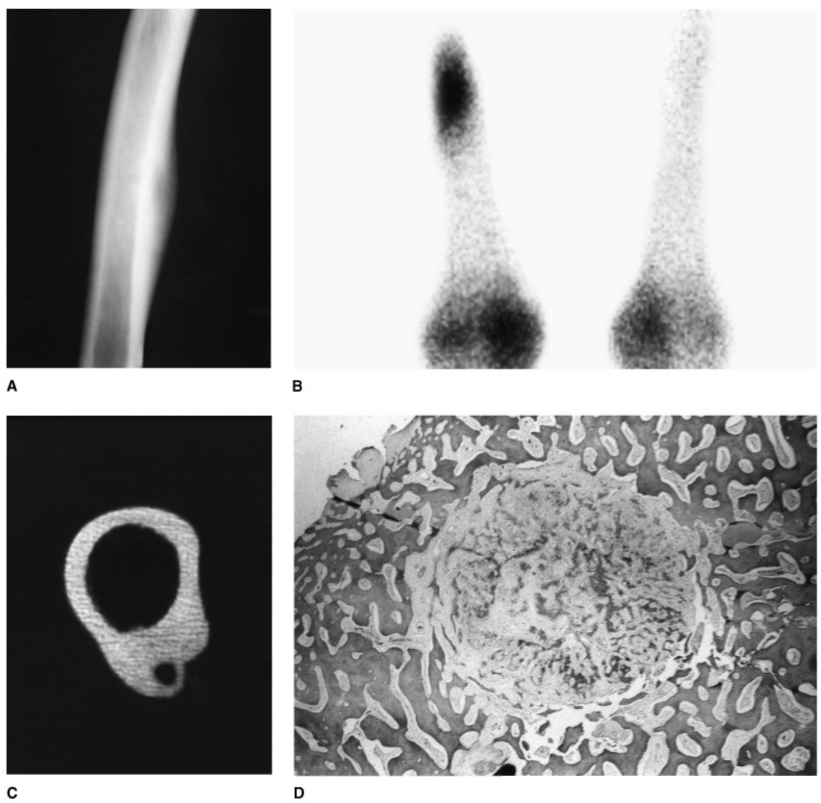
Benign Osteoid-Forming Tumors

OSTEOID OSTEOMA

The most common benign osteoid-forming tumor is the osteoid ost

The characteristic radiographic feature of the osteoid osteoma is t

Figure 6–8.



Radiograph (**A**), isotope bone scan (**B**), CT scan (**C**), and photomi

In the spine, the typical location for an osteoid osteoma is in the p

Previously, some investigators believed that the osteoid osteoma w

Most cases of osteoid osteoma are stage 1 lesions and can be trea
radiofrequency ablation (RFA) is reported as an effective, less inva

OSTEOBLASTOMA

Osteoblastoma is a large osteoid osteoma that demonstrates a pro
Radiographically, the osteoblastoma has a more lytic and destructi
In the spine area, the effects of osteoblastoma are similar to those

Figure 6–9.

Radiograph of osteoblastoma in the pedicle area of the C3 vertebr

In patients with osteoblastomas, treatment usually consists of a vi

OSTEOFIBROUS DYSPLASIA

Osteofibrous dysplasia is a rare condition that is seen almost exclu
In osteofibrous dysplasia (Figure 6–10), the lytic changes seen in t

Figure 6–10.

Radiograph of osteofibrous dysplasia in the tibia of an 8-year-old l

In a report of experience with 35 cases of osteofibrous dysplasia, i

Benign Chondroid-Forming Tumors

ENCHONDROMA

Enchondroma refers to a centrally located chondroma of bone. The

Radiographs of enchondromas show geographic lysis with sharp m

Figure 6–11.

Radiograph of an enchondroma of the proximal phalanx of the ring

Multiple enchondromatosis, or Ollier disease (Figure 6–12), is a ra

Figure 6–12.

Radiograph of Ollier disease of the upper and lower extremities.

A large solitary enchondroma in a large bone converts to a low-gra

There is no need to treat an asymptomatic patient with a solitary e

PERIOSTEAL CHONDROMA

A benign chondroma seen on the surface of a bone is called a peri

Figure 6–13.

Radiograph of a periosteal chondroma of the distal femur.

Management of periosteal chondromas generally consists of obser

OSTEOCHONDROMA

The nonossifying fibroma of bone is the most common benign tum

The bony base of an osteochondroma is in direct communication w

Figure 6–14.

Radiograph of an osteochondroma of the distal femur.

A familial form of osteochondroma, called hereditary multiple exos

Figure 6–15.

Radiograph of multiple exostoses of both hips.

Figure 6–16.

Radiograph of multiple exostoses in the knee.

Conversion of solitary osteochondroma to chondrosarcoma occurs

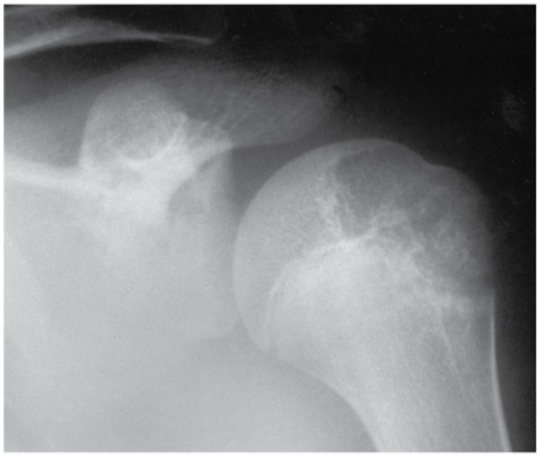
Osteochondromas are stage 1 lesions. Most children and adults wi

CHONDROBLASTOMA

The term *chondroblastoma* suggests a benign cartilage-forming tu

In cases of chondroblastoma, the radiograph demonstrates a lytic

Figure 6–17.



Radiograph of a chondroblastoma in the proximal humeral epiphys

The spontaneous conversion of chondroblastoma to a malignant tu

Treatment for chondroblastoma consists of aggressive intralesiona

CHONDROMYXOID FIBROMA

The chondromyxoid fibroma, a very rare tumor, generally affects r

Radiographs of chondromyxoid fibroma show a lytic tumor with sh

Figure 6–18.

Radiograph of a chondromyxoid fibroma in the proximal tibia of ar

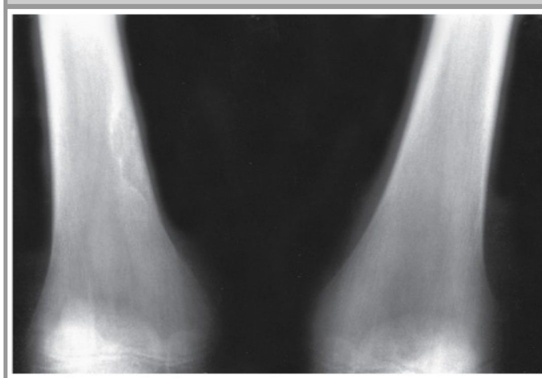
Benign Fibrous Tumors of Bone

FIBROUS CORTICAL DEFECT

Fibrous cortical defects, or cortical desmoids, are small hamartoma

In the case of fibrous cortical defects, microscopic studies show be

Figure 6–19.



Radiograph of a metaphyseal fibrous defect in a 15-year-old boy.

NONOSSIFYING FIBROMA

Just as the osteoblastoma is considered a larger or more extensive

With nonossifying fibroma, multiple lesions may take on the appea

Figure 6–20.

Radiograph of a nonossifying fibroma of the distal tibia.

FIBROUS DYSPLASIA

Fibrous dysplasia can present in a variety of ways: monostotic, po

Figure 6–21.

Radiograph of polyostotic fibrous dysplasia of the pelvis.

In addition to bony involvement, patients can demonstrate café au

In fibrous dysplasia, microscopic findings include an alphabet-soup

The molecular basis for fibrous dysplasia is associated with mutati

Fibrous dysplasia tends to be active during the growing years and

In pediatric patients with active disease, curettage and grafting sh

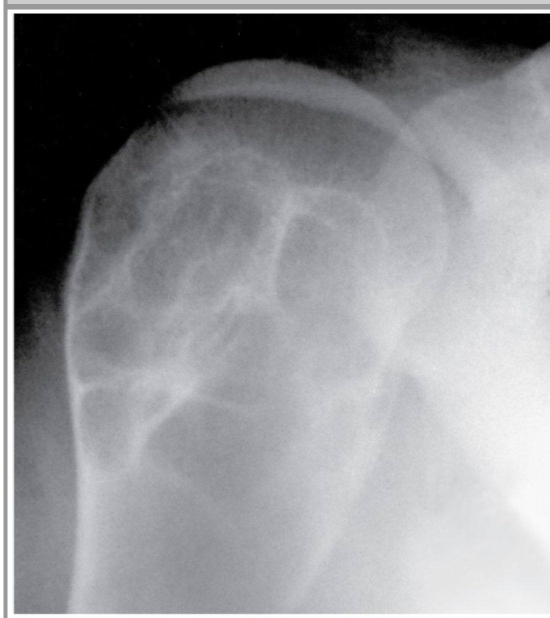
Cystic Lesions of Bone

SIMPLE BONE CYST

Simple bone cysts are a common pseudotumor of bone and the m

Radiographs typically show a solitary cyst that is centrally located

Figure 6–22.



Radiograph of a solitary bone cyst on the proximal humerus of a 1

The cyst cavity, lined with a fibrinous membrane that contains gia

Before the mid-1970s, the standard treatment for a solitary bone
cyst lining. Curettage and bone grafting may also be an effective r

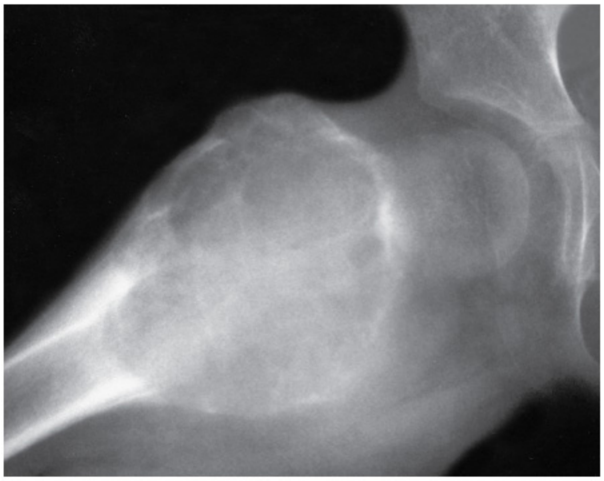
Physicians should note that sarcomas can take on the radiographic

ANEURYSMAL BONE CYST

Aneurysmal bone cyst is a hemorrhagic lesion with many characte

Initially, the aneurysmal bone cyst appears on radiograph as an ag

Figure 6–23.



Radiograph of an aneurysmal bone cyst on the proximal femur of

At the time of biopsy, the aneurysmal bone lesion demonstrates la
Specifically, a t(16,17) translocation resulting in a CDH11-USP6 fu

If an aneurysmal cyst is left untreated, it may involute spontaneou

EPIDERMOID CYST

The least common bone cyst is the epidermoid bone cyst. This lesi

Figure 6–24.

Radiograph of an epidermoid cyst in the distal phalanx.

Giant Cell Tumor of Bone

Numerous types of tumors contain giant cells but are not true ben
Between 5% and 10% of all benign bone tumors are true giant ce

Figure 6–25.

Radiograph of a giant cell tumor on the proximal tibia of a 22-yea

Like the chondroblastoma, the benign giant cell tumor has a 1–2%

Until recent years, the standard treatment for giant cell tumor wa
investigators are developing experimental medical protocols. Close

Hemangioma

Hemangioma of bone is a hamartomatous process that occurs mor

Figure 6–26.

Radiograph of a hemangioma of the tibia in a 14-year-old boy.

Gorham disease, characterized by massive osteolysis in children o

Baruffi MR et al: Aneurysmal bone cyst with chromosomal change

Bottner F et al: Cyclooxygenase-2 inhibitor for pain management i

Boutou-Bredaki S et al: Prognosis of giant cell tumor of bone. Hist

Bovee JV et al: Malignant progression in multiple enchondromatos

Cantwell CP et al: Current trends in treatment of osteoid osteoma

Cheung P et al: Etiological point mutations in the hereditary multip

Flemming DJ et al: Primary tumors of the spine. Semin Musculosk

Gallazzi MB et al: Percutaneous radio-frequency ablation of osteoi

Kivioja A et al: Chondrosarcoma in a family with multiple heredita

Komiya S et al: Increased concentrations of nitrate and nitrite in t

Lindner NJ et al: Percutaneous radiofrequency ablation in osteoid

Maki M et al: Comparative study of fibrous dysplasia and osteofibr

Marie PJ: Cellular and molecular basis of fibrous dysplasia. Histol H

Nakase T et al: Involvement of BMP-2 signaling in a cartilage cap

Oliveira AM et al: USP6 (Tre2) fusion oncogenes in aneurysmal bor

Ramappa AJ et al: Chondroblastoma of bone. J Bone Joint Surg Ar

Randall RL et al: Aggressive aneurysmal bone cyst of the proximal

Robinson P et al: Periosteal chondroid tumors: Radiologic evaluatic

Rougraff BT et al: Treatment of active unicameral bone cysts with

Safar A et al: Recurrent anomalies of 6q25 in chondromyxoid fibrc

Soder S et al: Cell biology and matrix biochemistry of chondromyx

Yanagawa T et al: The natural history of disappearing bone tumou

MALIGNANT BONE TUMORS

Osteoid-Forming Sarcomas

Aside form multiple myeloma, osteosarcoma of bone is the most c
The molecular pathobiology of osteosarcoma is a subject of intens
This discussion begins with the more common, central form of sar

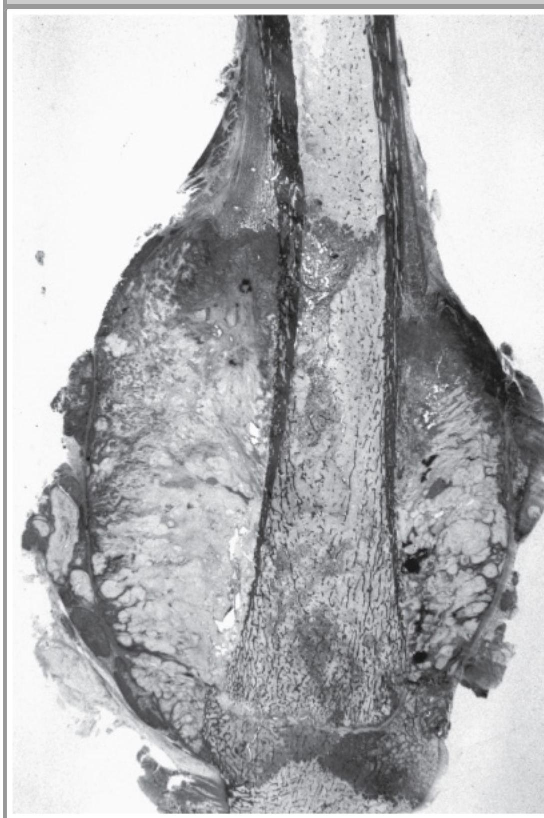
CLASSIC OSTEOSARCOMA

The classic form of osteosarcoma is typically seen in patients in th

Figure 6–27.

Osteosarcoma of the distal femur of a 15-year-old female patient.

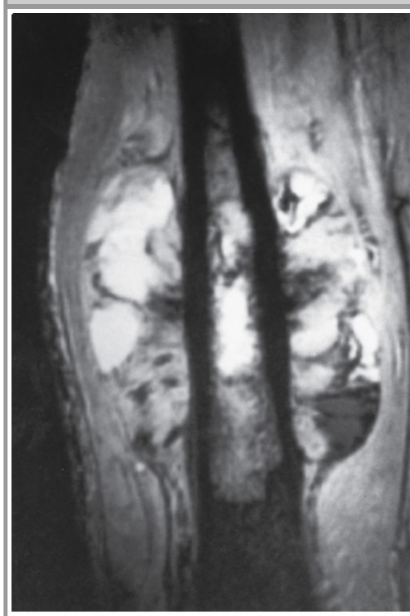
Figure 6–28.



Gross surgical specimen from Figure 6–27. Notice the sharp upper

Most patients with classic osteosarcoma have symptoms of pain be
In less than 2–25% of cases, an additional lesion may be found at
Staging of osteosarcoma must include an MRI of the involved extr

Figure 6–29.



Fat-subtraction (STIR [short tau inversion recovery]) MRI of a fem

Before the advent of adjuvant multidrug chemotherapy, the treat
The drugs commonly used today include high-dose methotrexate,
In extremity osteosarcoma, limb-sparing surgery, with wide resect
fracture, especially in the immunosuppressed patient receiving che

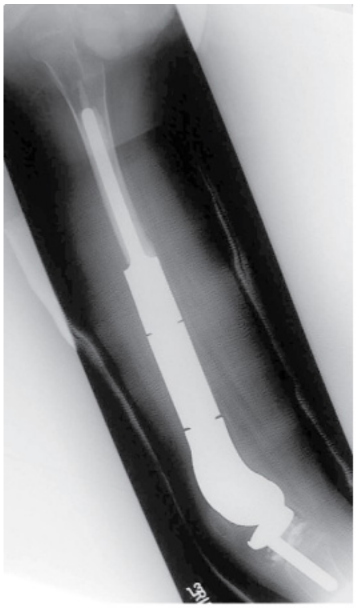
Figure 6–30.

A

B

A: Two examples of distal femoral replacement systems. **B:** Modu

Figure 6–31.



Lateral radiograph of distal femoral replacement system in skeleta

Prior to the introduction of chemotherapy, the finding of a pulmona

Molecular oncologic evaluation of osteosarcoma specimens is begin

HEMORRHAGIC OR TELANGIECTATIC OSTEOSARCOMA

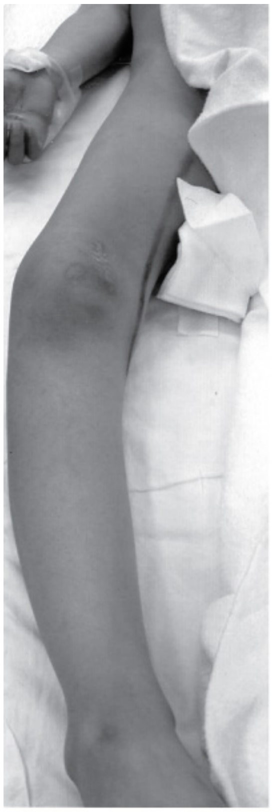
Telangiectatic osteosarcoma, an extremely lytic and destructive va

Figure 6–32.

Radiograph of hemorrhagic osteosarcoma in a 6-year-old girl.

Because hemorrhagic osteosarcoma is a high-grade, purely lytic tu

Figure 6–33.



Clinical photograph of patient that sustained a pathologic fracture

PAROSTEAL OSTEOSARCOMA

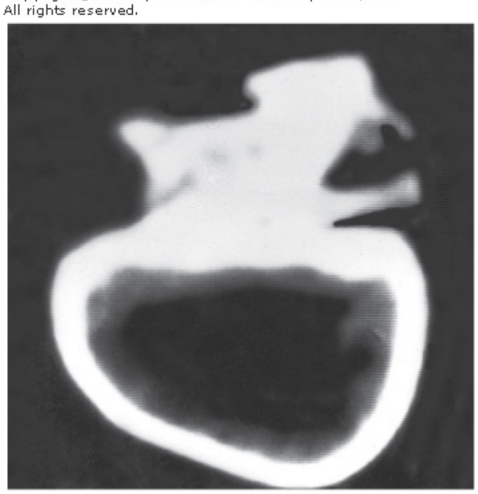
Parosteal osteosarcoma is a low-grade variant arising in an exophy

The tumor is composed of a spindle-cell fibroblastic component wit

Parosteal osteosarcoma is more common in females than in males

Figure 6–34.

A



B

Radiograph (**A**) and CT scan (**B**) of a parosteal osteosarcoma of th

Because the parosteal osteosarcoma is low grade, it does not resp

On occasion, low-grade parosteal osteosarcoma can dedifferentiate

PERIOSTEAL OSTEOSARCOMA

Periosteal osteosarcoma is another surface osteosarcoma of low to

Figure 6–35.

Radiograph of a periosteal osteosarcoma of the distal tibia in a 15

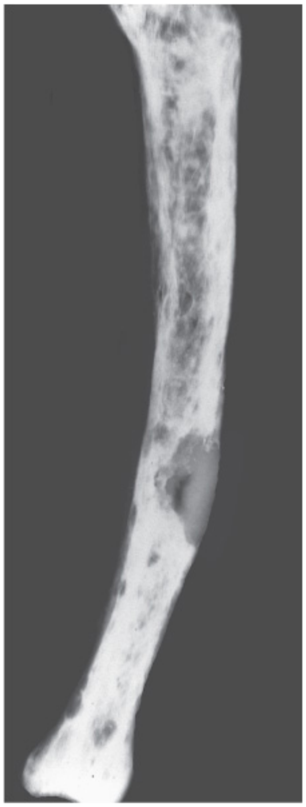
Because of its low to intermediate grade, periosteal osteosarcoma

SECONDARY OSTEOSARCOMA

Osteosarcoma can arise from benign disease through a process th

The classic example of a secondary osteosarcoma is seen in a sma

Figure 6–36.



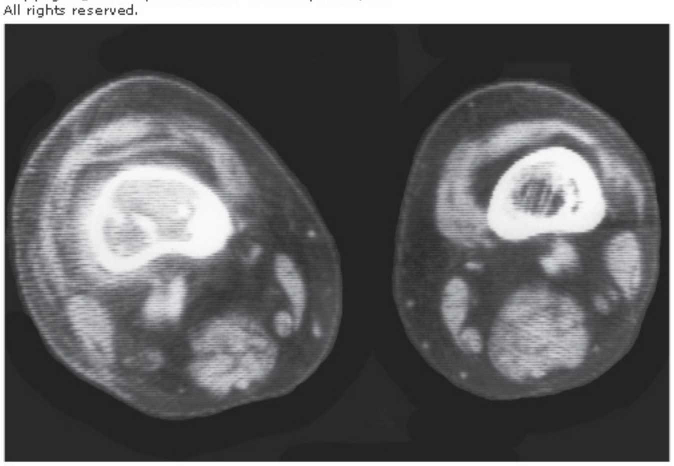
Radiograph of a pagetic osteosarcoma of the tibia.

LOW-GRADE INTRAMEDULLARY OSTEOSARCOMA

Another rare and low-grade osseofibrous variant of osteosarcoma

Figure 6–37.

A



B

Radiograph (**A**) and CT scan (**B**) of a low-grade intramedullary ost

IRRADIATION-INDUCED OSTEOSARCOMA

Radiation-induced osteosarcoma may arise after any form of signif

Figure 6–38.

Radiograph of irradiation-induced osteosarcoma of the peritrochar

MULTICENTRIC OSTEOSARCOMA

Multicentric osteosarcoma has two clinical presentations: (I) synch

Figure 6–39.

Isotope bone scan of multicentric osteosarcoma in an 8-year-old g

SOFT-TISSUE OSTEOSARCOMA

Osteosarcoma can occur in muscle tissue outside bone and accoun

Figure 6–40.

Radiograph of a soft-tissue osteosarcoma in the calf area of a 67-

Soft-tissue osteosarcoma must be differentiated from the more co

The treatment of the soft-tissue form of osteosarcoma is the same

Chondroid-Forming Sarcomas

Chondroid-forming sarcomas are a heterogenous group of neoplas

PRIMARY OR CENTRAL CONVENTIONAL CHONDROSARCOMA

The typical primary chondrosarcoma is a low-grade tumor seen in

Approximately 85% of central chondrosarcomas are low-grade lesi

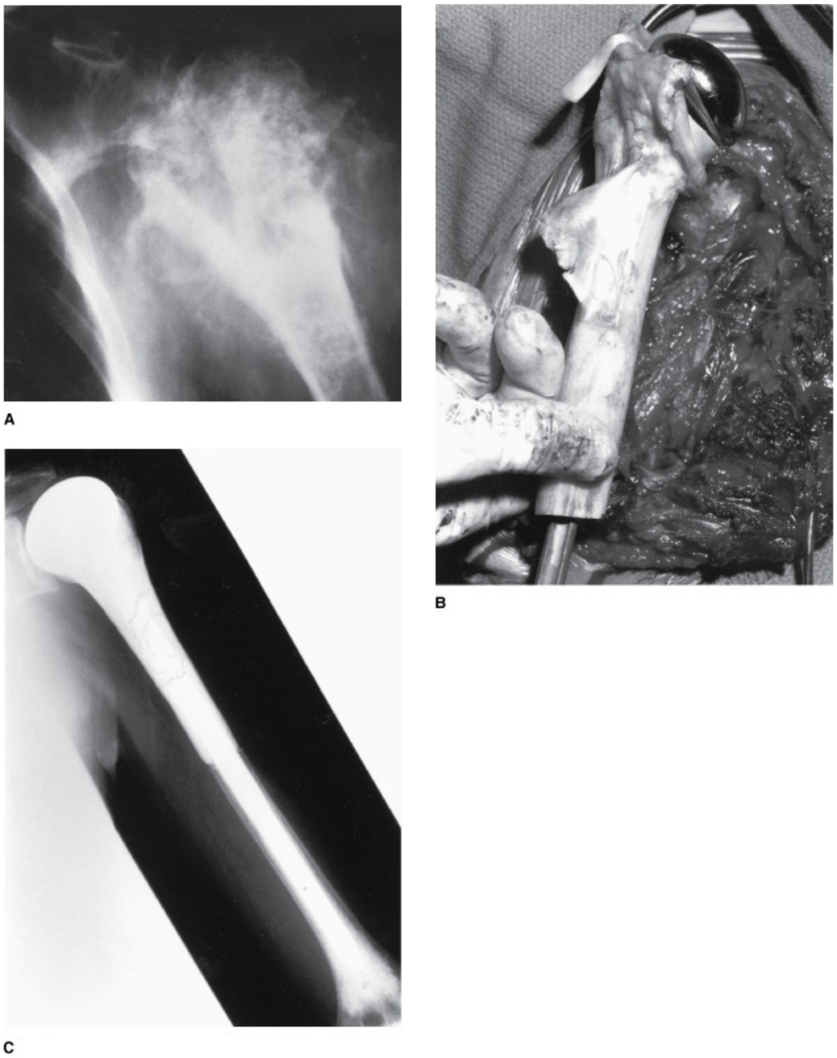
The radiologic feature that clearly separates this lesion from a ben

Figure 6–41.

Radiograph of a low-grade primary chondrosarcoma in the distal f

In general, the prognosis for low-grade central chondrosarcoma is

Figure 6–42.

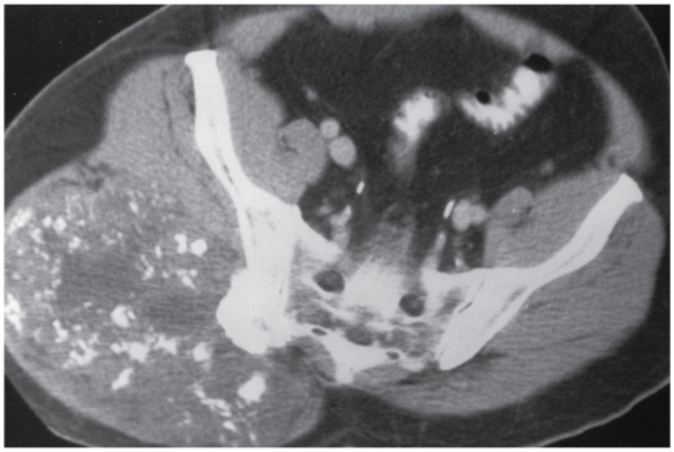


Preoperative radiograph of a large central chondrosarcoma in the

SECONDARY CHONDROSARCOMA

The vast majority of secondary chondrosarcomas arise from osteo
primary or central chondrosarcoma. Surgical removal, without viol

Figure 6–43.

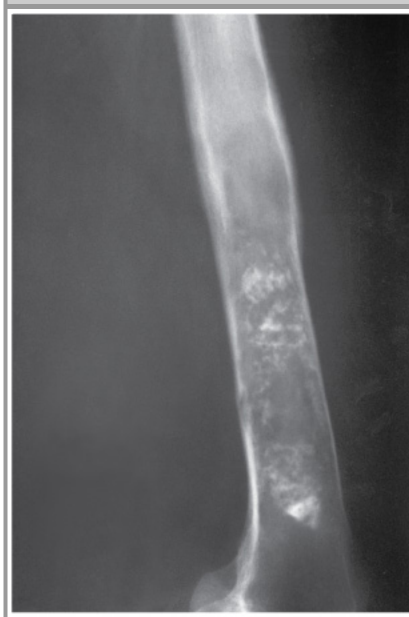


CT scan of a secondary peripheral chondrosarcoma in the ilium of

DEDIFFERENTIATED CHONDROSARCOMA

Dedifferentiated chondrosarcoma is the most malignant variant of

Figure 6–44.



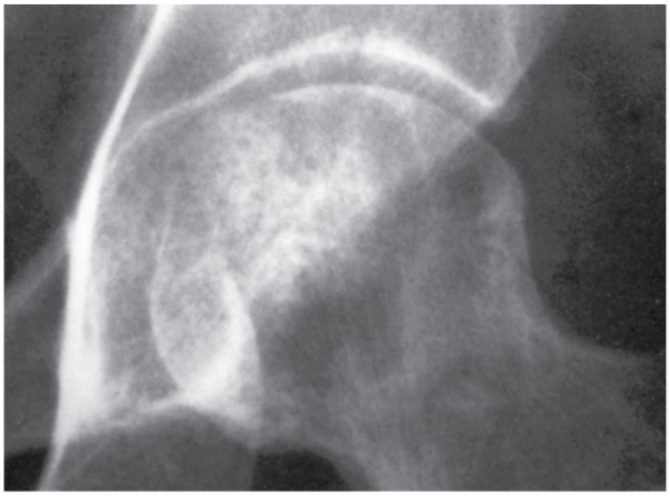
Radiograph of dedifferentiated chondrosarcoma in the distal femu

The prognosis in dedifferentiated chondrosarcoma is bleak, with th

CLEAR CELL CHONDROSARCOMA

Clear cell chondrosarcoma is a rare low-grade variant of chondrosa
with prognosis.

Figure 6–45.



Radiograph of clear cell chondrosarcoma of the femoral head in a

The treatment for clear cell chondrosarcoma is a wide excision anc

MESENCHYMAL CHONDROSARCOMA

Another rare variant of chondrosarcoma is the mesenchymal chon

Mesenchymal chondrosarcoma is a high-grade tumor with histolog

Treatment consists of resection, with a wide margin if possible, an

Round Cell Sarcomas

This so-called group of tumors is composed of distinct tumors that

THE EWING FAMILY OF TUMORS

Ewing Sarcoma

Ewing sarcoma is a well-known clinical entity originally described b
are also described in Ewing/PNET: t(21:22) and t(7:22).

In 90% of cases, Ewing sarcoma is found in patients between 5 ar

Ewing sarcoma appears radiographically as a central lytic tumor of

Figure 6–46.

Radiograph of periosteal response in Ewing sarcoma of the femur

Ewing sarcoma can frequently masquerade as osteomyelitis becau

Microscopically, small roundlike cells predominate in densely packe

Ewing sarcoma is an aggressive malignancy with a high local recur

Ewing sarcoma is a radiosensitive tumor. Historically, this was a m

Primitive Neuroectodermal Tumor

PNET is the less common relative to Ewing sarcoma. Like Ewing, th

By strict criteria, PNET is a rare tumor, representing approximately

LYMPHOMA

Lymphoblastic tumors are considered systemic neoplasms of the ly

There are two main types of non-Hodgkin lymphomas. The type e

Primary lymphoma of bone, which was formerly called reticulum ce

Radiographic findings in primary lymphoma include extensive lytic

Figure 6–47.

Radiograph of a lymphoma in the proximal humerus of a 64-year-

The most common histologic types of lymphoma of bone are the la

In primary lymphoma of bone, as in Ewing sarcoma, multidrug che

PLASMA CELL TUMOR

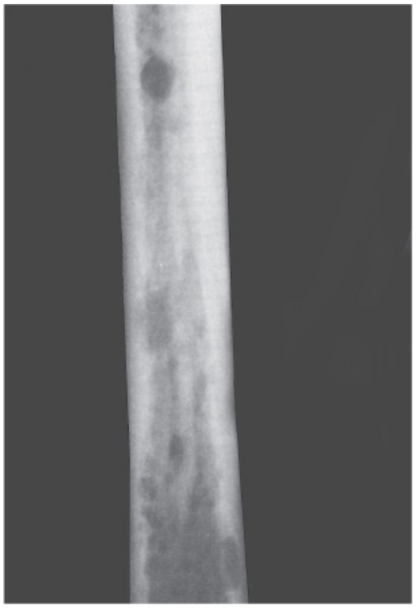
A bone tumor composed of malignant monoclonal plasma cells is re

Myeloma

Multiple myeloma, which is the most common primary tumor of bo

The disease is characterized by a triad of osteolytic punched-out le

Figure 6–48.



Radiograph of multiple myeloma in the femoral shaft of a 72-year

Lesions are rarely found distal to the knee or elbow. Approximately

A marrow aspirate usually demonstrates the abnormal plasma cells

Plain radiographs show myeloma lesions to be sharply demarcated

Less than 2% of myeloma cases demonstrate the POEMS syndrom

Although treatment and prognosis have improved, myeloma remai

Local treatment of myeloma is similar to that of metastatic disease

Solitary Myeloma

Solitary lesions are rare (Figure 6–49). By definition, there must b

Figure 6–49.

Radiograph of a solitary plasmacytoma in the proximal femur of a

Fibrous Sarcomas of Bone

Malignant fibrous tumors of bone are clinically similar to the osteos

FIBROSARCOMA OF BONE

Fibrosarcoma of bone is a malignant spindle-cell tumor seen in an

On radiograph, fibrosarcomas appear to be almost purely osteolyti

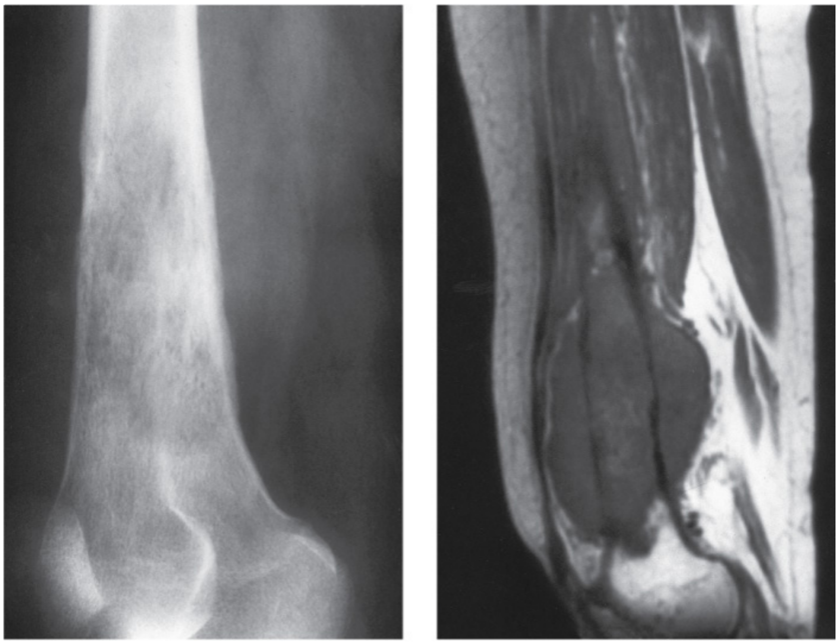
The prognosis and treatment are directly related to the histologic g

MALIGNANT FIBROUS HISTIOCYTOMA OF BONE

Prior to 1970, MFH was rarely diagnosed in bone but was common

MFH is a purely lytic tumor that shows aggressive permeation of n

Figure 6–50.



A

B

Radiograph (**A**) and T_1-weighted MRI (**B**) of malignant fibrous hist

Because MFH is closely related to the high-grade fibrosarcoma, it c

Adamantinoma of Bone

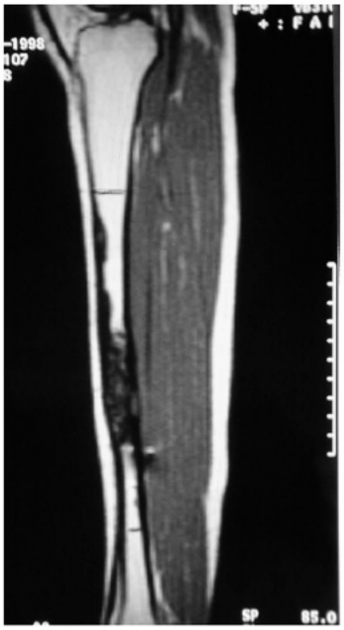
Adamantinomas account for only 0.33% of all malignant bone tum

In patients with adamantinoma, the radiograph shows a benign tu

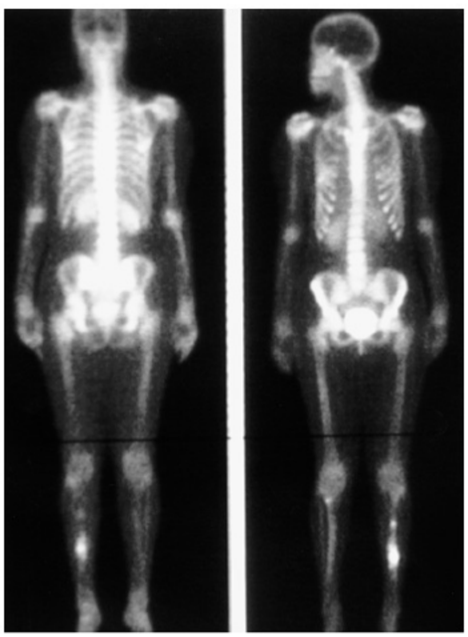
Figure 6–51.

A

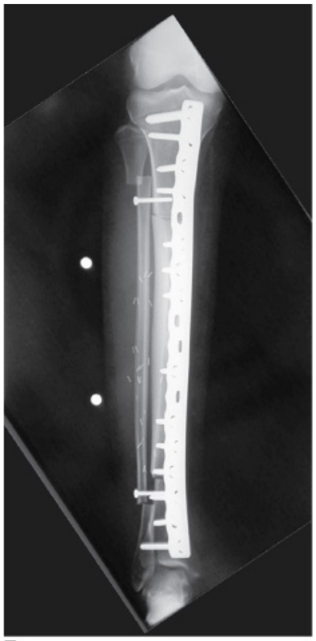
B



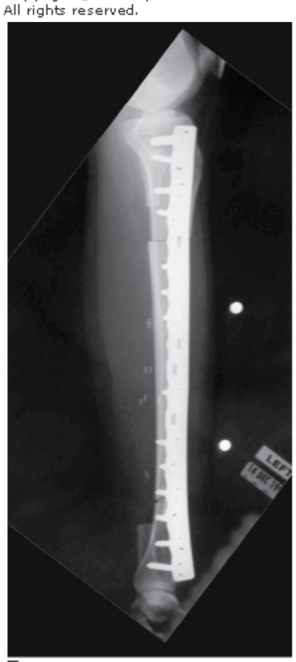
C



D



E



F

G

H

I

J

K

Adamantinoma of the tibia. Initial anteroposterior radiograph (**A**),

Microscopic findings include nests or cords of epithelial or angioid t

Adamantinoma grows extremely slowly, over many years, but on c

Vascular Sarcomas of Bone

Vascular sarcomas are relatively rare. They include the hemangioe

HEMANGIOENDOTHELIOMA

The hemangioendothelioma, which is more common in males than

Radiographically, the lesion appears lytic, with surrounding sclerot

Treatment depends on the histologic grade. The low-grade lesions

HEMANGIOPERICYTOMA

The hemangiopericytoma is an extremely rare form of vascular sa

Chordomas

Chordoma of bone is rare and accounts for 4% of malignant bone

On radiograph, the chordoma appears as a centrally located lytic p

Figure 6–52.

A

B

Sacral chordoma in middle-age woman: T_2 sagittal image (**A**), T_2 t

Treatment for the sacral lesions is an aggressive wide resection, w

Anthouli-Anagnostopoulou FA et al: Juxtacortical osteosarcoma. A

Bacci G et al: Neoadjuvant chemotherapy for osteosarcoma of the

Bacci G et al: Histologic response of high-grade nonmetastatic ost

Bacci G et al: Telangiectatic osteosarcoma of the extremity: Neoac

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Berend KR et al: Adjuvant chemotherapy for osteosarcoma may n

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Gokgoz N et al: Comparison of p53 mutations in patients with loca

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Hoang BH et al: Expression of LDL receptor-related protein 5 (LRP

Hoang MP et al: Mesenchymal chondrosarcoma: A small cell neopla

Kanamori M et al: Extra copies of chromosomes 7, 8, 12, 19, and

Kaste SC et al: Thallium bone imaging as an indicator of response

Kaya M et al: Vascular endothelial growth factor expression in untr

Khanna C et al: The membrane-cytoskeleton linker ezrin is necess

Kilpatrick SE et al: Clinicopathologic analysis of HER-2/neu immuno

Kloen P et al: Expression of transforming growth factor-beta (TGF

Lewis VO et al: Parosteal osteosarcoma of the posterior aspect of

Maitra A et al: Aberrant expression of tumor suppressor proteins i

Mandahl N et al: Cytogenetic aberrations and their prognostic imp

Oberlin O et al: Study of the French Society of Paediatric Oncology

Ogose A et al: Elevation of serum alkaline phosphatase in clear cel

Park YK et al: Overexpression of p53 and absent genetic mutation

Pring ME et al: Chondrosarcoma of the pelvis. A review of sixty-fo

Reddick WE et al: Dynamic MR imaging (DEMRI) of microcirculatio

Rizzo M et al: Chondrosarcoma of bone: Analysis of 108 cases and

Roland Durr H et al: Multiple myeloma: Surgery of the spine: Retr

Scully SP et al: Pathologic fracture in osteosarcoma: Prognostic im

Sluga M et al: The role of surgery and resection margins in the tre

Smith SE et al: Primary musculoskeletal tumors of fibrous origin. S

Tallini G et al: Correlation between clinicopathological features and

Tian E et al: The role of the Wnt-signaling antagonist DKK1 in the

Weisstein JS et al: Detection of c-fos expression in benign and ma

Zhou H et al: Her-2/neu staining in osteosarcoma: Association witl

BENIGN SOFT-TISSUE TUMORS

Soft tissue can be defined as nonepithelial, extraskeletal mesench
Benign soft-tissue tumors, by definition, represent a differentiated

Lipomas

The lipoma is by far the most common soft-tissue tumor and has a

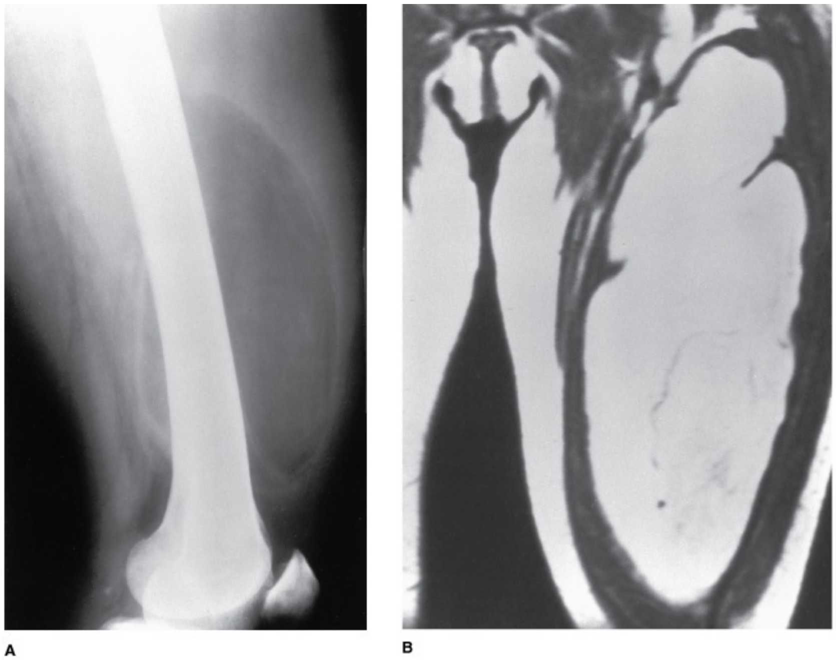
SUPERFICIAL SUBCUTANEOUS LIPOMA

The most frequently seen type of lipoma is the superficial subcutai
On palpation this tumor is soft and ballotable. Although it is found

INTRAMUSCULAR LIPOMA

The deep intramuscular lipoma is seen in adults between 30 and 6
caused it to be classified as a mesenchymoma in the past. In othe

Figure 6–53.



Radiograph (**A**) and coronal view T_1-weighted MRI (**B**) of an intrar

A marginal surgical excision is indicated for treatment of intramus

SPINDLE-CELL LIPOMA

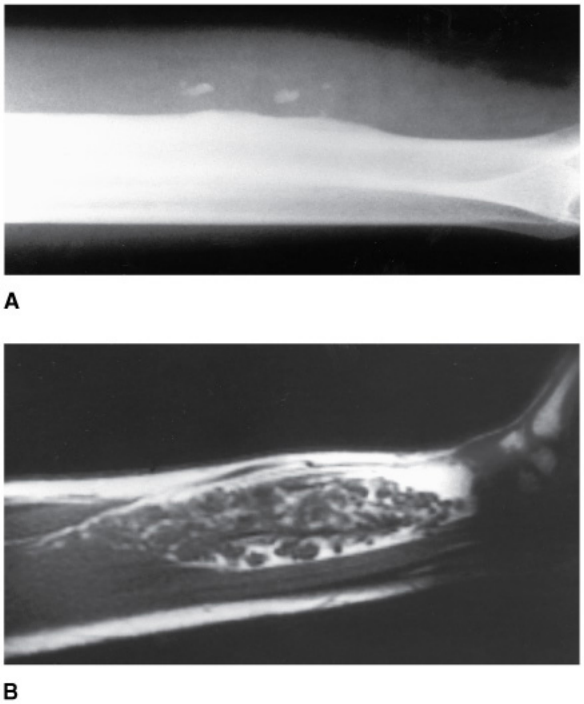
The spindle-cell lipoma is seen typically in the posterior neck and s

The treatment for this lesion is a simple marginal resection. The c

ANGIOLIPOMA

The angiolipoma (Figure 6–54) is a subcutaneous lesion seen in yo

Figure 6–54.



Radiograph (**A**) and T_1-weighted MRI (**B**) of a soft-tissue angiolipc

Treatment of angiolipoma consists of marginal excision.

DIFFUSE LIPOMATOSIS

An extremely rare variant of the lipoma is diffuse lipomatosis, chai

LUMBOSACRAL LIPOMA

The lumbosacral lipoma occurs in the lumbosacral area posterior to

Figure 6–55.

T_1-weighted MRI of a lumbosacral lipoma.

Surgical treatment consists of a marginal resection of the entire lip

BENIGN LIPOBLASTOMA AND DIFFUSE LIPOBLASTOMATOSI

The benign and diffuse types of lipoma are seen in the extremities

HIBERNOMA

Hibernoma, a rare lipoma usually seen in young (see Table 6–6) ac

Benign Vascular Tumors

Benign vascular proliferative tumors are the second most common

Like lipomas, angiomas occur in a wide variety of clinical condition: role in the regulation of angiogenesis.

HEMANGIOMA

Hemangiomas are the most frequently seen tumors of childhood a

Solitary Capillary Hemangioma

The most common type of hemangioma is the solitary capillary typ

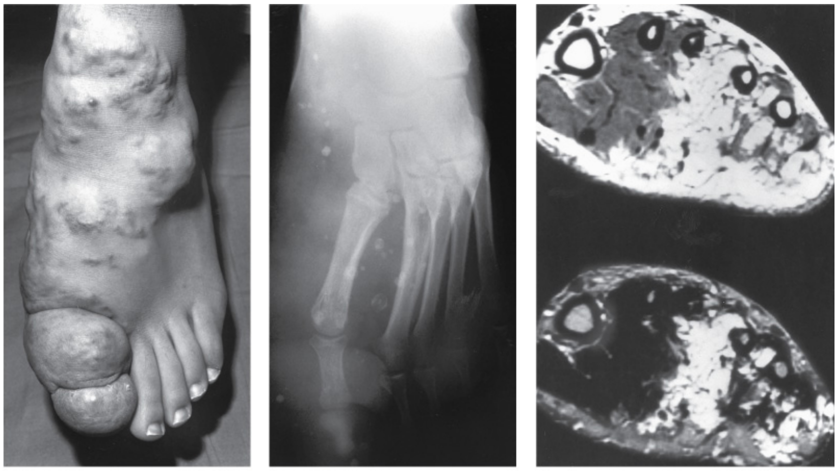
Because of the spontaneous regression, no treatment is needed in

Cavernous Hemangioma

The cavernous hemangioma is larger and less common than the ca

Imaging may be characteristic (Figure 6–56). In some patients wit

Figure 6–56.



Clinical appearance (**A**) and radiographic appearance (**B**) of a cave

The muscle lesions are usually asymptomatic until intralesional her

Arteriovenous Hemangioma

The arteriovenous hemangioma is seen in young patients (see Tab

If shunting is excessive, surgical removal of the hemangioma may

Epithelioid Hemangioma (Kimura Disease)

This cutaneous hemangioma is found on the head or neck in wome

Pyogenic Granuloma

The pyogenic granuloma is a polypoid capillary hemangioma that a

LYMPHANGIOMA

The lymphangioma is nothing more than an angioma composed of

Figure 6–57.

Radiograph of a lymphangioma in the forearm and hand of a 23-y

GLOMUS TUMOR

The glomus tumor arises from the hemangiopericyte, which is a ce

The glomus tumor is a pink lesion that measures less than 1 cm in

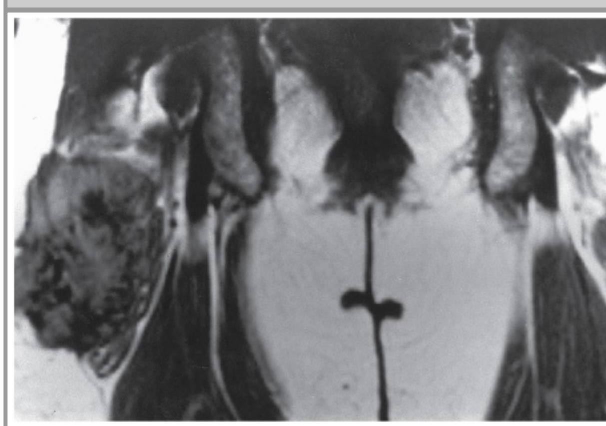
Extraabdominal Desmoid Tumors (Aggressive Fibroma

In comparison with the infantile fibrous lesions mentioned earlier, t

Desmoids are deep-seated tumors that arise from muscle fascial p

On gross examination, a desmoid tumor is firm and heavily collage

Figure 6–58.



T_1-weighted MRI of a desmoid tumor in the gluteal area of a 45-y

Desmoids are usually treated surgically with an aggressive wide re

Based on clinical and experimental evidence, estrogen may play a

Benign Tumors of Peripheral Nerves

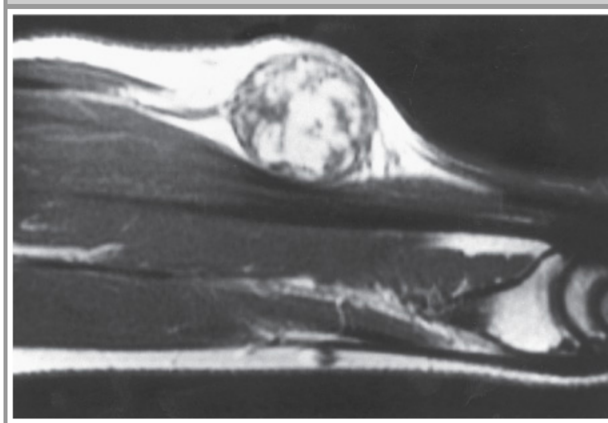
Benign tumors of peripheral nerve sheaths are common and take t

NEURILEMOMA

The neurilemoma (neurinoma or benign schwannoma) is the least

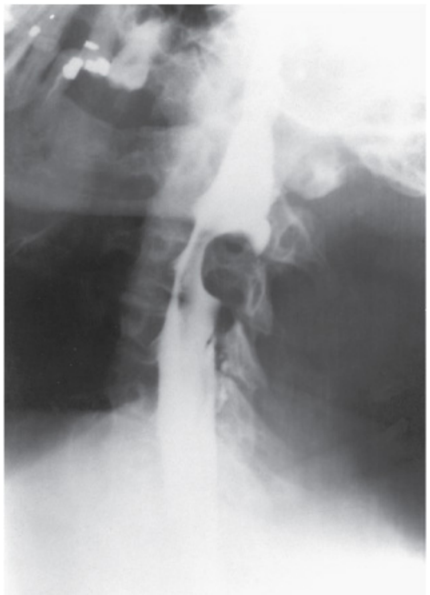
Unlike the neurofibroma, which has a fusiform appearance, the ne

Figure 6–59.



T_1-weighted MRI of a neurilemoma of the ulnar nerve in a 69-year

Figure 6–60.



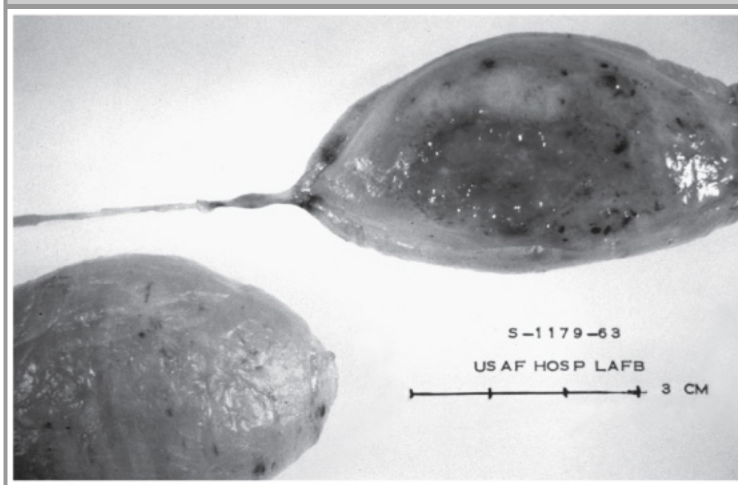
Myelogram of a neurilemoma in the cervical spine.

In some cases, simple excision of the neurilemoma is clinically indi

SOLITARY NEUROFIBROMA

The solitary neurofibroma is a fusiform fibrotic tumor arising centr

Figure 6–61.



Photographic appearance of a solitary neurofibroma.

Treatment of the solitary neurofibroma consists of simple excision.

NEUROFIBROMATOSIS (RECKLINGHAUSEN DISEASE)

Recklinghausen disease is a familial dysplasia, inherited as an autc

Later in life, the patient develops multiple neurofibromas, each of

Figure 6–62.

Cutaneous manifestations of neurofibromatosis.

A major threat to the patient's life is that a malignant schwannoma

Intramuscular Myxomas

The intramuscular myxoma is a rare tumor seen in patients older t

The intramuscular myxoma can be resected marginally. After this

Azzarelli A et al: Low-dose chemotherapy with methotrexate and v

Bertario L et al: Genotype and phenotype factors as determinants

Chun YS et al: Lipoblastoma. J Pediatr Surg 2001;36(6):905. [PMI

Kang HJ et al: Schwannomas of the upper extremity. J Hand Surg

Richards KA et al: The pulsed dye laser for cutaneous vascular and

Shields CJ et al: Desmoid tumours. Eur J Surg Oncol 2001;27(8):7

Sorensen SA et al: Long-term follow-up of von Recklinghausen neu

Vikkula M et al: Molecular genetics of vascular malformations. Mat

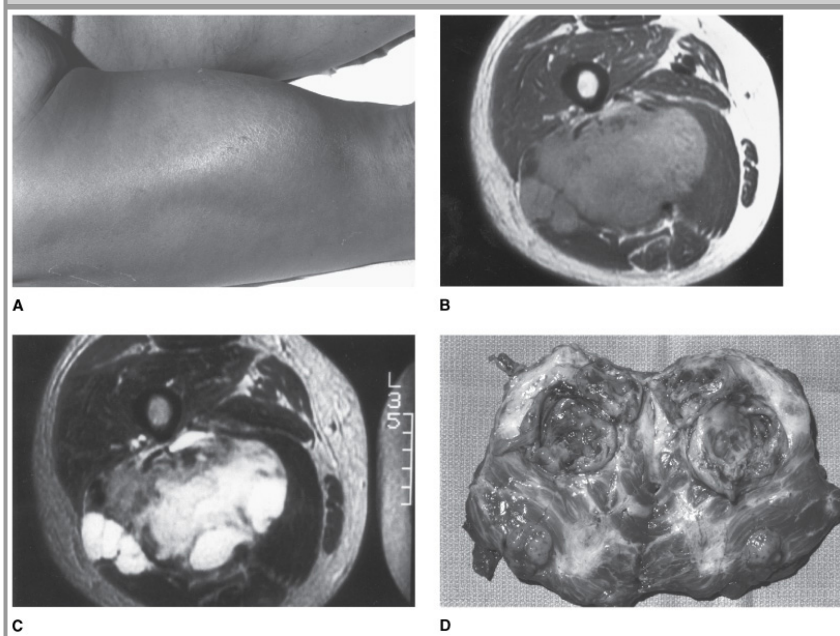
MALIGNANT SOFT-TISSUE TUMORS

Sarcomas are capable of invasive, locally destructive growth with a

FIBROHISTIOCYTIC TUMORS

Until recently, MFH was the most common soft-tissue sarcomas se

Figure 6–63.



Clinical appearance (**A**), T_1-weighted MRI (**B**), T_2-weighted MRI (**C**

Storiform Pleomorphic

Storiform pleomorphic is the most common subtype of MFH. It occ

On gross examination, the tumor appears multinodular and may d

The prognosis and treatment vary, depending on the size and loca

Although the treatment depends on the clinical situation, it genera

The use of adjuvant radiation therapy is important in reducing the

The use of adjuvant chemotherapy is more controversial. Because

Myxoid

The myxoid type is the second most common type of MFH and is s

Giant Cell

The giant cell type of MFH also affects older patients and is seen ir

Inflammatory

The inflammatory type of MFH affects the older age groups, is mo

DERMATOFIBROSARCOMA PROTUBERANS

Dermatofibrosarcoma protuberans, a low- to intermediate-grade fi

Figure 6–64.

Clinical appearance of dermatofibrosarcoma protuberans on the b

Characteristic cytogenetic abnormalities are described with charac

Surgical treatment, consisting of an aggressive resection, is associ

FIBROSARCOMA

Fifty years ago, fibrosarcoma was considered the most common of

On gross examination, fibrosarcoma appears as a firm and lobulat

The treatment and prognosis depend on the grade of tumor in a p

LIPOSARCOMAS

Liposarcoma is the second most common soft-tissue sarcoma after

Well-Differentiated Liposarcoma

This very low grade tumor affects individuals who are 40–60 years

On gross examination, this tumor has a fatty lobulated appearanc

Figure 6–65.

T_1-weighted MRI of a well-differentiated liposarcoma in the thigh (

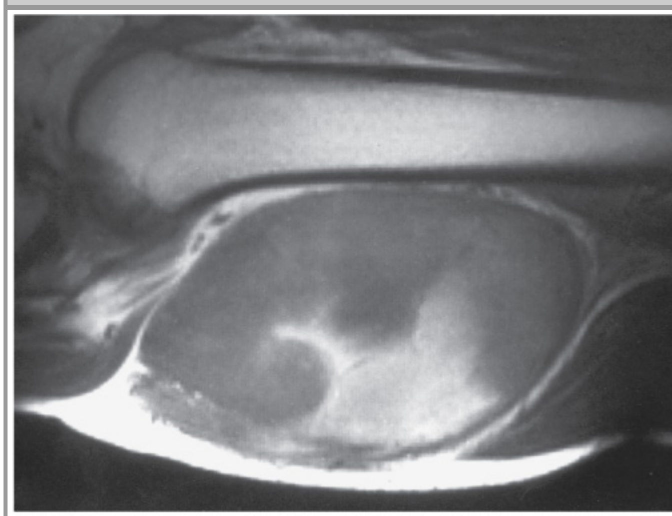
In cases of well-differentiated liposarcoma, a conservative wide re

Myxoid Liposarcoma

Myxoid liposarcoma is the most common fat sarcoma, accounting f

Gross examination of a myxoid liposarcoma reveals a lobulated pa

Figure 6–66.



Sagittal view T_1-weighted MRI of a myxoid liposarcoma in the thig

Characteristic translocations are also seen in myxoid liposarcoma.

Multifocal myxoid liposarcoma is also described. Consideration for

Although myxoid liposarcoma carries a very good prognosis, the tu

Round Cell and Pleomorphic Liposarcoma

These high-grade liposarcomas are seen in the same locations and

In cases of round cell or pleomorphic liposarcoma, the lesion does

In round cell and pleomorphic liposarcoma, there is an early and h

RHABDOMYOSARCOMAS

Rhabdomyosarcomas account for 20% of all soft-tissue sarcomas.

Embryonal Rhabdomyosarcoma

The embryonal type is seen in patients from birth to 15 years of a

Embryonal rhabdomyosarcoma is treated with local surgical resect

Alveolar Rhabdomyosarcoma

This type of rhabdomyosarcoma affects individuals between 10 an

Pleomorphic Rhabdomyosarcoma

In the 1940s, pleomorphic rhabdomyosarcoma was a popular histo

Pleomorphic rhabdomyosarcoma is a high-grade tumor that affects

LEIOMYOSARCOMA

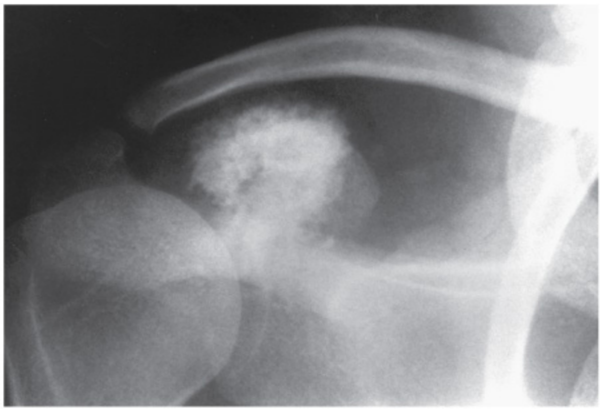
Leiomyosarcoma is a very rare soft-tissue tumor whose cell type o

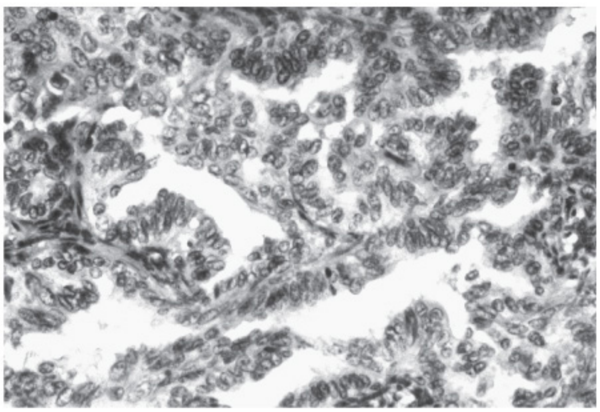
The prognosis and the treatment for leiomyosarcoma are similar to

SYNOVIAL SARCOMAS

Synovial sarcoma (Figure 6–67) is the fourth most common soft-ti

Figure 6–67.


A


B

Radiograph (**A**) and microscopic appearance (**B**) of a synovial sarc

Synovial sarcomas initially grow slowly and cause pain in approxim

Microscopic examination of the tumor shows a typical biphasic patt

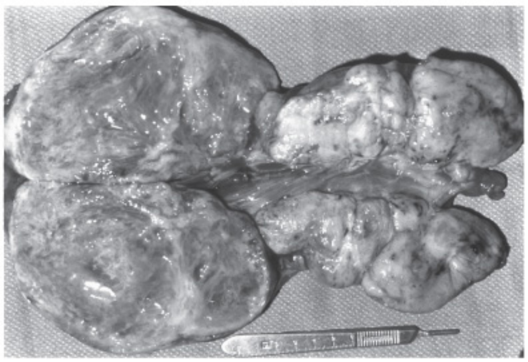
Molecular characterization of this tumor reveals a particular transl

Despite the slow growth of synovial sarcoma, the 5-year and 10-y

MALIGNANT PERIPHERAL NERVE SHEATH TUMOR

A malignant peripheral nerve sheath tumor can arise from a preex

Figure 6–68.



Clinical appearance of a café au lait defect in the skin overlying a

MALIGNANT VASCULAR TUMORS

Kaposi Sarcoma

Of the malignant vascular tumors, Kaposi sarcoma is the most con

Figure 6–69.

Clinical appearance of Kaposi sarcoma of the foot.

Angiosarcoma

Soft-tissue angiosarcoma is rare, accounting for less than 1% of a

Hemangiopericytoma

This rare perivascular tumor arises from pericytes. Pericytes are h

MISCELLANEOUS SOFT-TISSUE SARCOMAS

The remaining soft-tissue sarcomas are rare and only a brief descr

SOFT-TISSUE CHONDROSARCOMA

There are three types of soft-tissue chondrosarcomas.

Myxoid Chondrosarcoma

The myxoid chondrosarcoma is sometimes referred to as a chordo

Mesenchymal Chondrosarcoma

This tumor affects individuals between 15 and 40 years of age, is

Synovial Chondrosarcoma

The conversion of a synovial chondromatosis to a malignant synov

EWING SARCOMA

Extraskeletal Ewing sarcoma can be found in individuals between 1

ALVEOLAR SOFT PART SARCOMA

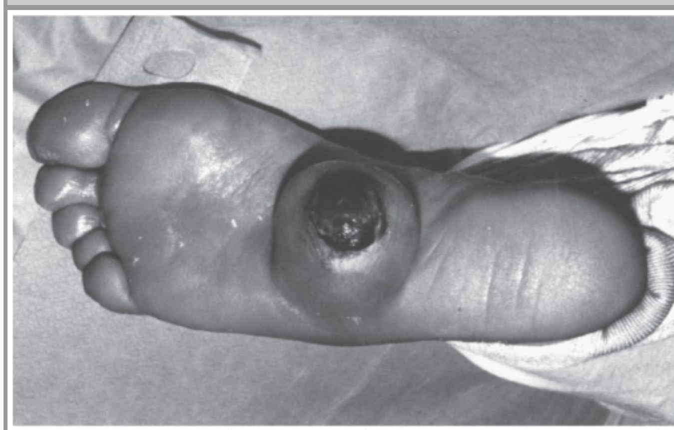
This round cell sarcoma affects more females than males, is usuall

EPITHELIOID SARCOMA

Although this superficial skin lesion is seen most commonly in the

Because epithelioid sarcoma has a whitish color that under the mic

Figure 6–70.



Clinical appearance of epithelioid sarcoma on the plantar aspect of

Epithelioid sarcoma spreads as a lumpy nodularity along tendon sh

CLEAR CELL SARCOMA

The clear cell sarcoma is thought to be a deep, noncutaneous vari
The prognosis is poor because of a high rate of pulmonary metast

Ahmad SA et al: Extraosseous osteosarcoma: Response to treatm

Anderson J et al: Detection of the PAX3-FKHR fusion gene in paed

Antonescu CR et al: Monoclonality of multifocal myxoid liposarcom

Bowne WB et al: Dermatofibrosarcoma protuberans: A clinicopath

Cormier JN et al: Concurrent ifosfamide-based chemotherapy and

Dei Tos AP: Liposarcoma: New entities and evolving concepts. Ann

dos Santos NR et al: Molecular mechanisms underlying human syn

Gibbs J et al: Malignant fibrous histiocytoma: An institutional revie

Hayes-Jordan AA et al: Nonrhabdomyosarcoma soft tissue sarcom

Ladanyi M: Fusions of the SYT and SSX genes in synovial sarcoma

Meis-Kindblom JM et al: Cytogenetic and molecular genetic analys

Nishio J et al: Supernumerary ring chromosomes in dermatofibros

Orvieto E et al: Myxoid and round cell liposarcoma: A spectrum of

Spillane AJ et al: Synovial sarcoma: A clinicopathologic, staging, a

MANAGEMENT OF CARCINOMA METASTAS

Incidence & Natural History of Metastases

COMMON METASTATIC CARCINOMAS AND AREAS OF SKELET

Metastatic involvement of the musculoskeletal system is one of th
The spine is the most frequent area of bone metastasis. Other co

CLINICAL COURSE OF METASTASES

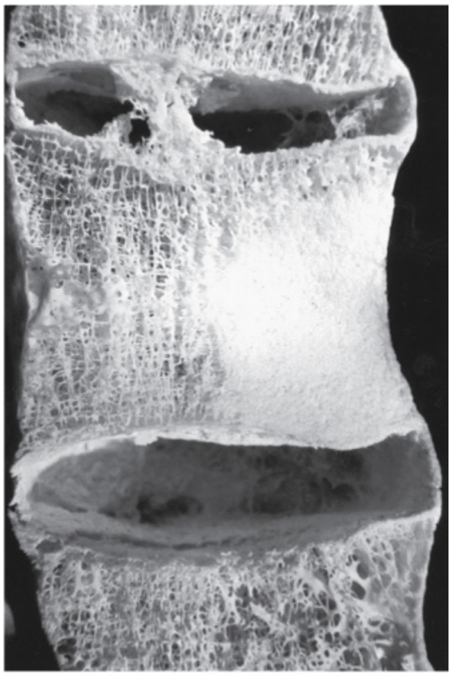
The mechanism of metastases is accounted for in a modified "seec

Patients with advanced metastatic disease frequently experience d
Blastic metastases are frequently painless and associated with a lc

Figure 6–71.

Radiograph of a blastic carcinoma that metastasized from the pros

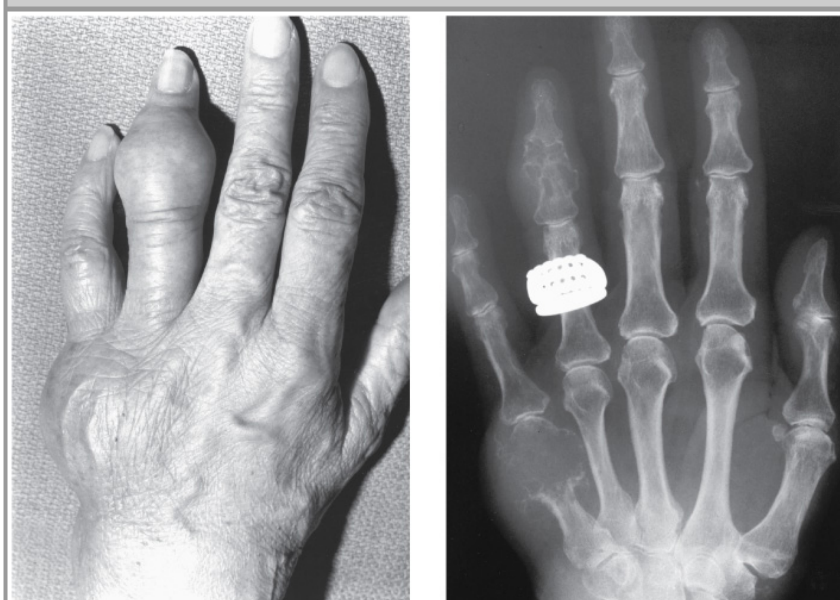
Figure 6–72.



Skeletal specimen of a blastic carcinoma that metastasized from t

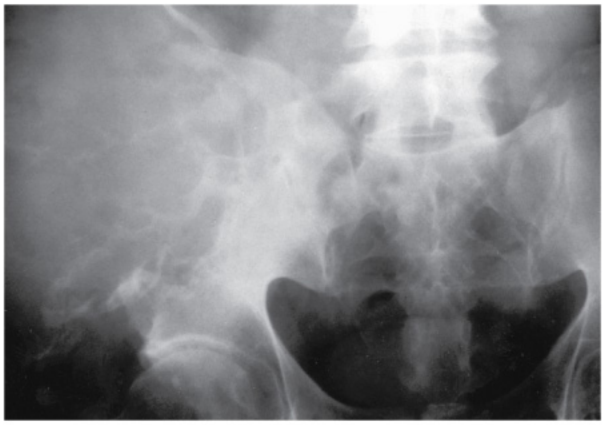
Most tumors that metastasize from the breast to the bone are bla
Bone destruction in lytic lesions is a response by native osteoclast

Figure 6–73.



Clinical appearance (**A**) and radiographic appearance (**B**) of aneur

Figure 6–74.



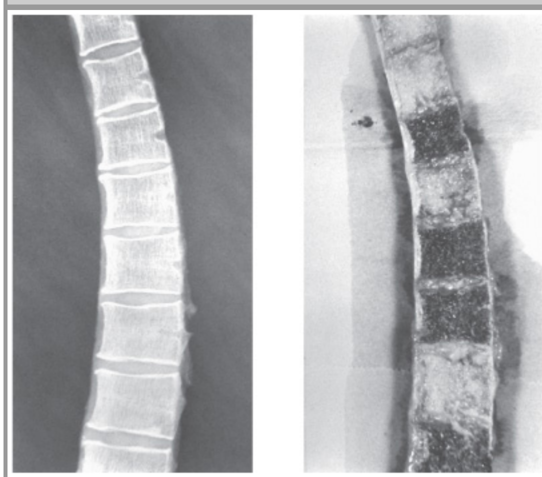
Radiograph of a metastatic hypernephroma in the ilium.

Diagnosis

GENERAL APPROACH

A methodical approach is mandatory in the workup of a patient wi
Radiographic examination should follow with a plain chest radiogra
These studies in conjunction with a well-planned biopsy detect the

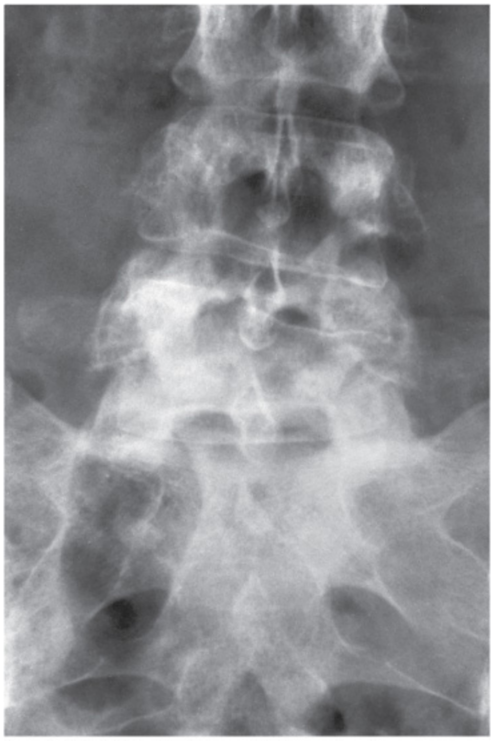
Figure 6–75.



A B

Radiograph (**A**) and gross appearance (**B**) of bone in a case of car

Figure 6–76.



Radiograph of the spine of a 45-year-old woman whose cancer ha

Treatment & Prognosis

NONSURGICAL TREATMENT

Nonsurgical management of metastatic carcinoma to bone includes

After sustaining a pathologic fracture secondary to metastatic carc

When a patient has sustained a true pathologic fixation (rather tha

Hormonal therapy has an important role in the management of me

For breast cancer, medical hormonal manipulation can be done by

For prostate cancer, reduction in testosterone levels via bilateral o

Cytotoxic chemotherapy is used in adenocarcinoma treatment quit

SURGICAL TREATMENT

The goals for surgical intervention in the patient with metastatic ca

Hip

Seventy-five percent of all surgery for cancer that has metastasize
lesions that might require a longer stem femoral component for th

Figure 6–77.

Radiograph of the pathologic fractures of both hips in a 55-year-o

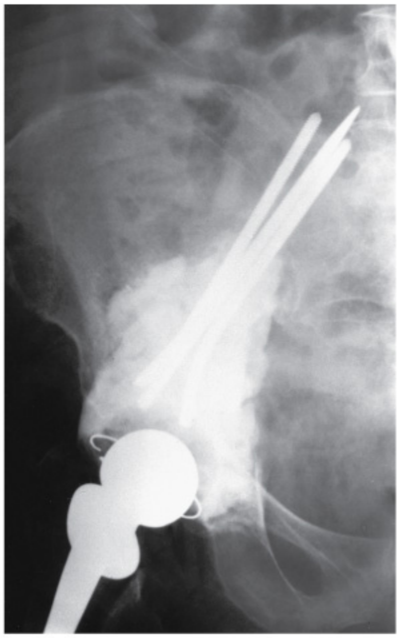
In many cases, the diagnosis of metastasis to the proximal femur

Supraacetabular Area

In the case of a small supraacetabular lesion with intact cortical bc

Figure 6–78.

A



B

Preoperative (**A**) and postoperative (**B**) radiographs of the pelvis c

Femoral Shaft

Diaphyseal lesions that affect the femur but spare the peritrochan

Figure 6–79.

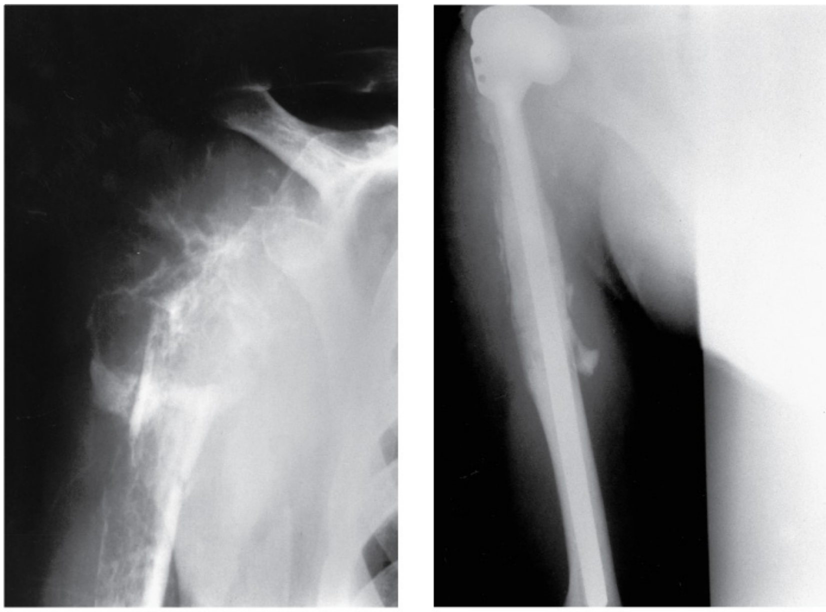
Preoperative (**A**) and postoperative (**B**) radiographs of the midsha

Humerus

The principle for the management of metastatic disease to the hur

In the case of the proximal humerus involving a large amount of tl

Figure 6–80.



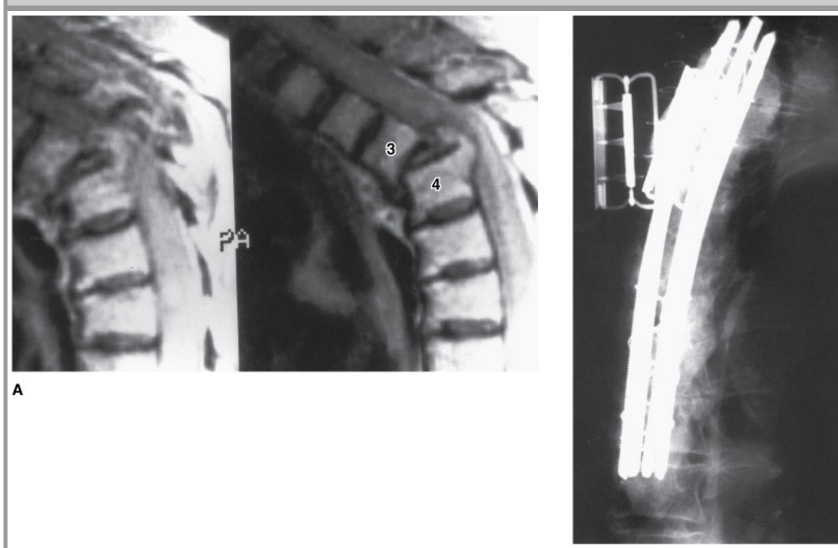
Preoperative (**A**) and postoperative (**B**) radiographs of the proxim

Spine

In most cases of metastasis to the spine, the patient's pain can be

The midthoracic spine is the most common area for paraplegia sec

Figure 6–81.



Preoperative T_1-weighted MRI (**A**) and postoperative radiograph (

The second most common site for cord compression is the thoraco

The cervical spine is the least likely area for surgical treatment, m
Radiation therapy is required postoperatively with all of these reco

Beauchamp CP: Errors and pitfalls in the diagnosis and treatment

Hipp JA et al: Predicting pathologic fracture risk in the manageme

Hortobagyi GN et al: Efficacy of pamidronate in reducing skeletal c

Mirels H: Metastatic disease in long bones. A proposed scoring sys

Mundy GR: Mechanisms of bone metastasis. Cancer 1997;80S:15

Rougraff BT et al: Skeletal metastases of unknown origin: A prosp

Wedin R: Surgical treatment for pathologic fracture. Acta Orthop S

Wedin R et al: Surgical treatment for skeletal breast cancer metas

DIFFERENTIAL DIAGNOSIS OF PSEUDOTU

In addition to benign, malignant, and metastatic neoplasms, a gro

Stress-Reactive Lesions

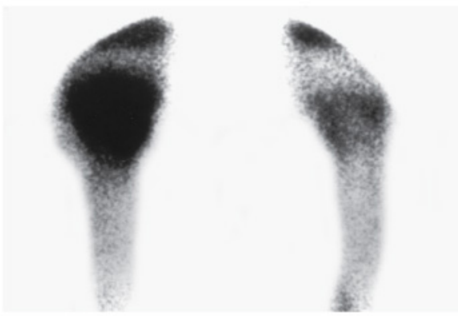
The most common pseudotumors are those related to either bone

STRESS FRACTURE OF BONE

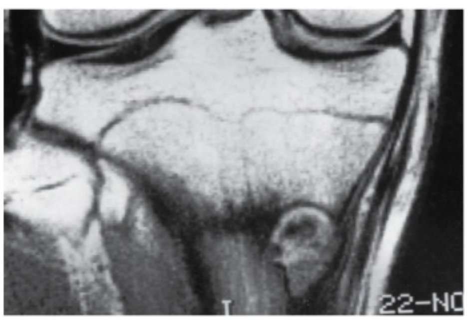
Stress fractures are common in young (less than 30 years) athleti
Stress fractures are commonly located in the metaphyseal-diaphys
At times, the clinical picture of a stress fracture is confused by the

Figure 6–82.

A



B

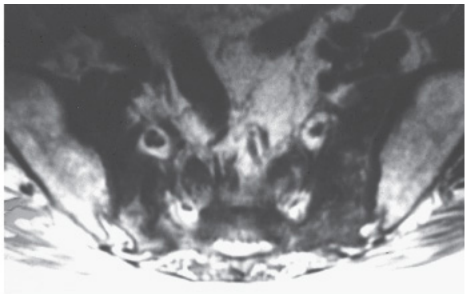


C

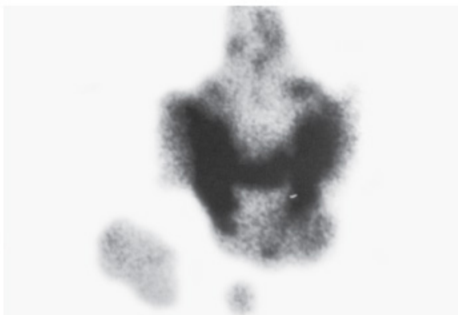
Radiograph (**A**), isotope bone scan (**B**), and T_1-weighted MRI (**C**)

In older patients, especially in postmenopausal women, stress frac

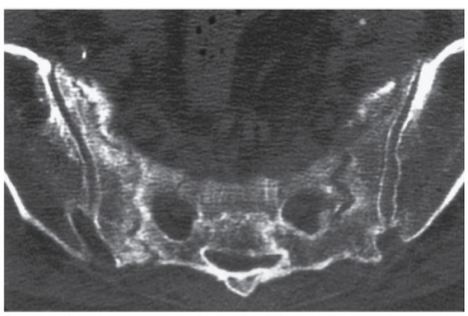
Figure 6–83.



A



B



C

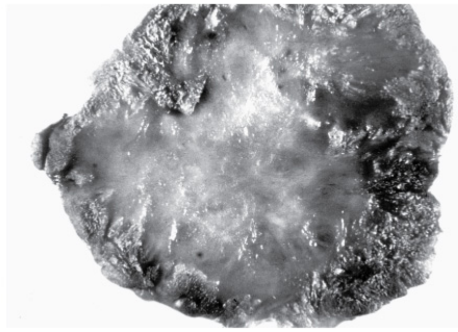
T_1-weighted MRI (**A**), isotope bone scan (**B**), and CT scan (**C**) of t

MYOSITIS OSSIFICANS

Another common stress-reactive pseudotumor seen in the extremi
Early radiographs may not reveal soft-tissue calcification. With ma

Figure 6–84.

A



B

Radiograph (**A**) and gross appearance of a resected specimen (**B**)

Infectious Diseases

Bacterial, viral, tuberculous, or fungal infections of the bone or sof

BACTERIAL INFECTION

Bacterial infections of bone can take on the appearance of a round

Figure 6–85.

Radiograph of acute osteomyelitis caused by *Staphylococcus aure*

TUBERCULOUS OR FUNGAL INFECTION

A tuberculous or fungal infection of the spine or extremity can pre

Figure 6–86.

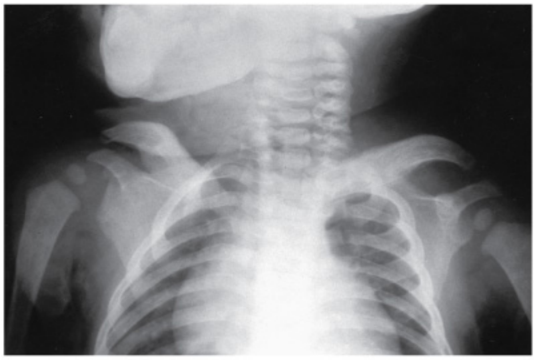
Radiograph of tuberculous osteomyelitis in the proximal tibia of a

CAFFEY DISEASE

Caffey disease can mimic a neoplastic process. It is an idiopathic f

Figure 6–87.

A



B

Preoperative (**A**) and postoperative (**B**) radiographs of Caffey dise

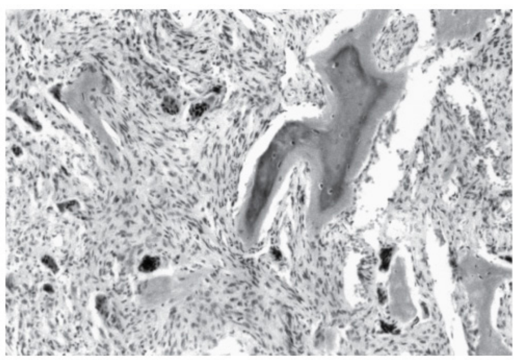
Metabolic Disorders

BROWN TUMOR OF PRIMARY HYPERPARATHYROIDISM

Brown tumor is the most common metabolic disorder that mimics

The radiographic features of the brown tumor in bone include a ro

Figure 6–88.



B

A

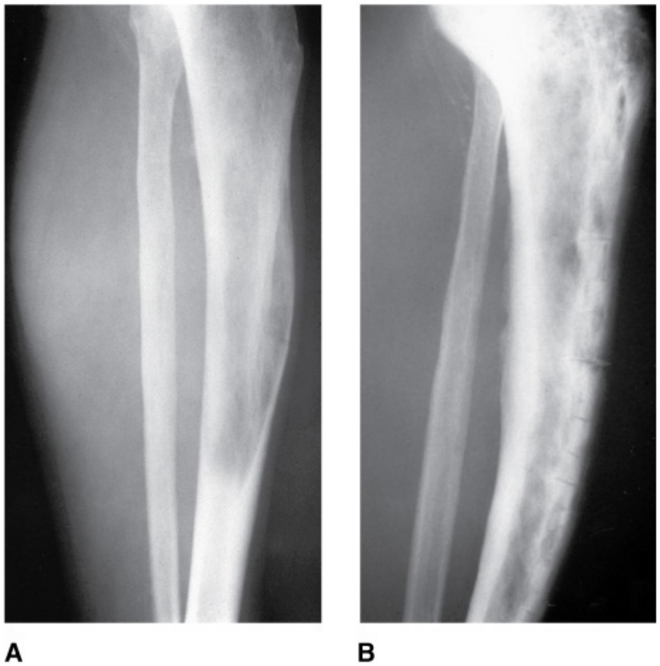
Radiograph (**A**) and photomicrograph (**B**) of a brown tumor of hyp

In patients with brown tumors, the treatment consists of removing

PAGET DISEASE

Paget disease is frequently included in discussions of metabolic bo

Figure 6–89.



Early and late radiographs of Paget disease of the tibia, taken whe

GAUCHER DISEASE

Gaucher disease is a rare familial disorder in which accumulation o

Figure 6–90.

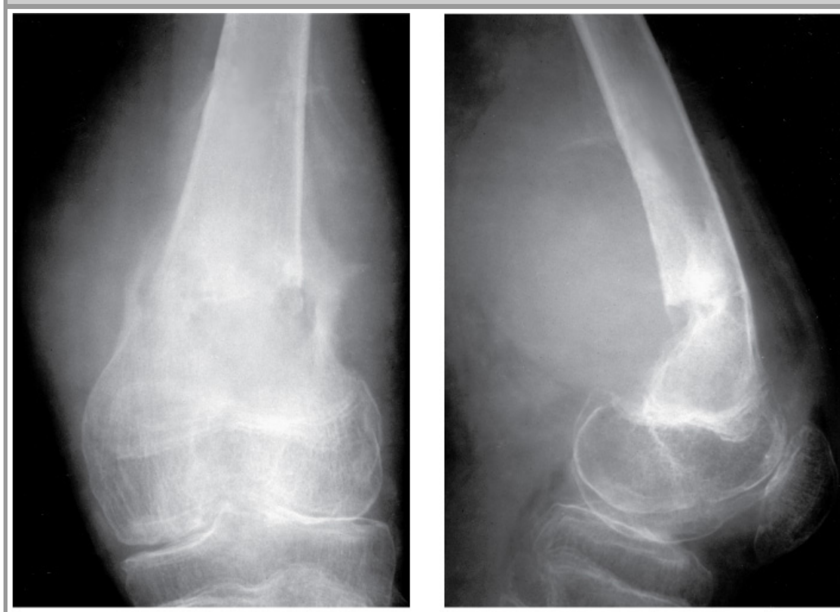
Radiograph of a pathologic fracture secondary to Gaucher disease

Hemorrhagic Conditions

PSEUDOTUMOR OF HEMOPHILIA

A hematoma in the soft tissue or bone under the periosteum may

Figure 6–91.



A

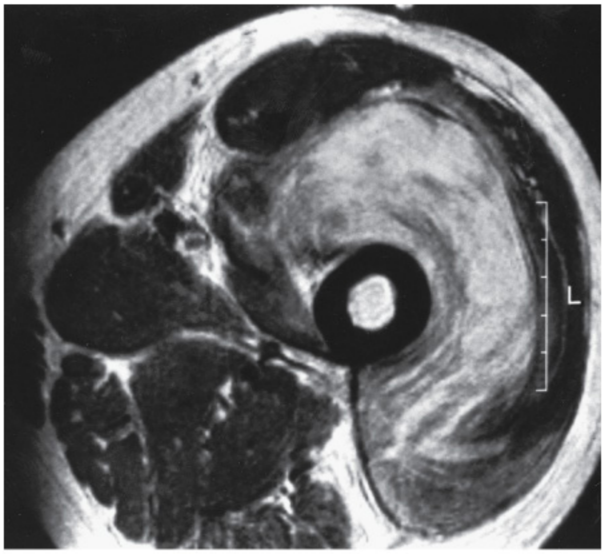
B

Anteroposterior (**A**) and lateral (**B**) radiographs of a pseudotumor

INTRAMUSCULAR HEMATOMA

Another hemorrhagic disorder that can produce a pseudotumor of

Figure 6–92.



Axial view T_2-weighted MRI of a hematoma in the quadriceps mus

Ectopic Calcification

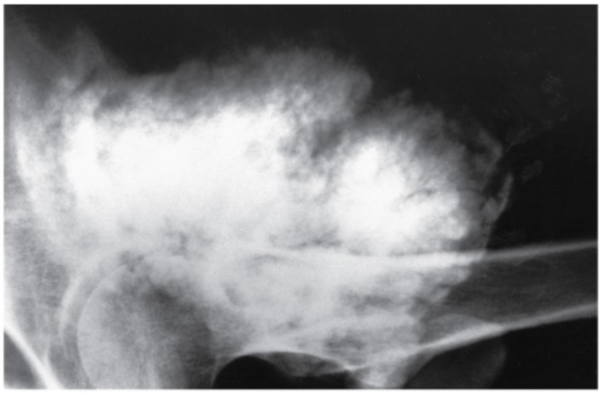
Ectopic calcification in soft tissue has many causes, most of which

TUMORAL CALCINOSIS

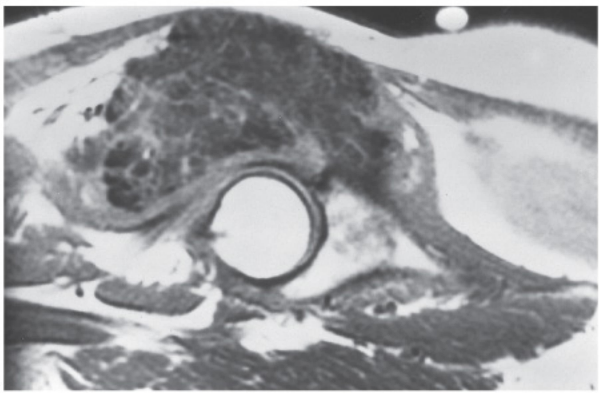
Tumoral calcinosis, seen about the hip, shoulder, and elbow, is cha

In cases of tumoral calcinosis, the extensive central fluffy calcificat

Figure 6–93.



A



B

Radiograph (**A**) and T_1-weighted MRI (**B**) of tumoral calcinosis in t

A similar condition is seen in patients with renal osteodystrophy wi

COMPARTMENT SYNDROME

The ischemic calcification and even ossification that occur in traum

Figure 6–94.

Radiograph of an old compartment syndrome in the flexor hallucis

Figure 6–95.

Radiograph of calcification in synovial sarcoma of the leg.

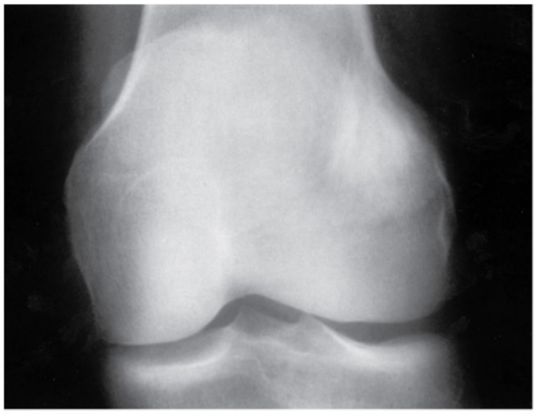
Dysplastic Disorders

Many developmental or dysplastic conditions can create bony abnc

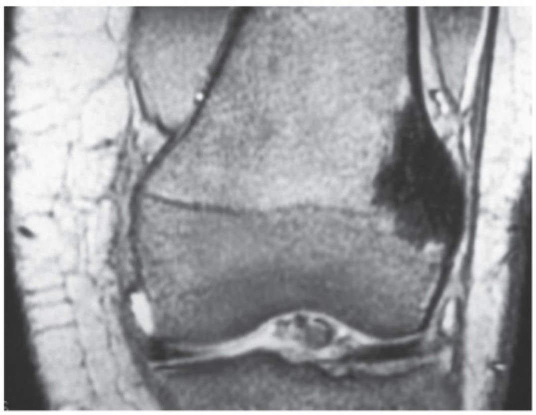
OSTEOMA

Osteoma commonly occurs in the skull or maxilla and is composed

Figure 6–96.



A



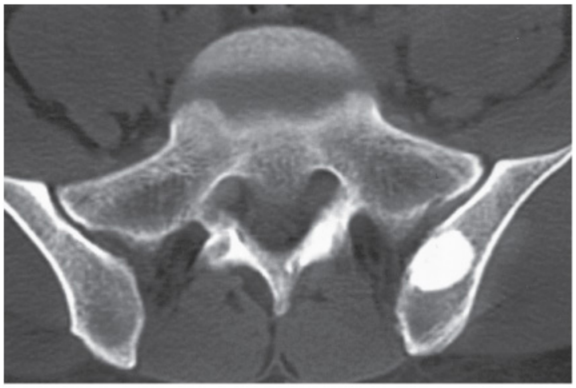
B

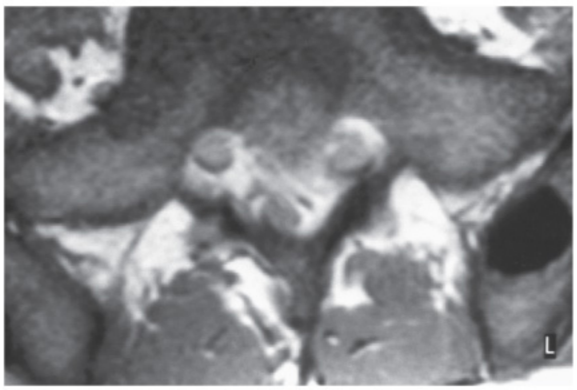
Radiograph (**A**) and T_2-weighted MRI (**B**) of a dysplastic process i

BONE ISLAND

The bone island is an even more sharply marginated dysplastic pro

Figure 6–97.





CT scan (**A**) and T_2-weighted MRI (**B**) of a bone island through the

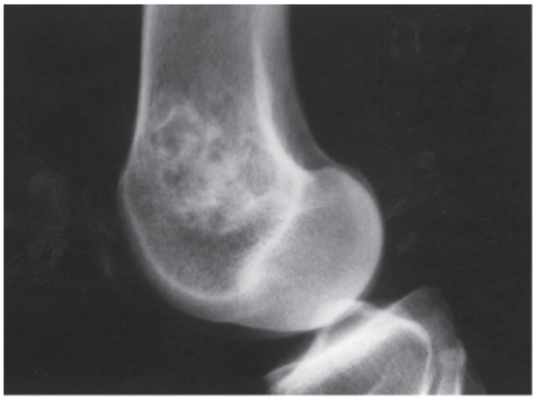
Bone Infarcts

The two types of bone infarcts that can mimic bone tumors are the

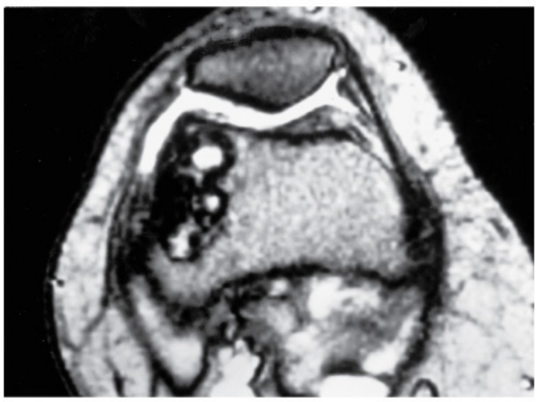
METAPHYSEAL BONE INFARCT

The most common bone infarct is in the metaphyseal region, which

Figure 6–98.



A



B

Radiograph (**A**) and T_1-weighted MRI (**B**) of a metaphyseal infarct

Figure 6–99.

Radiograph of a large enchondroma in the distal femur.

EPIPHYSEAL BONE INFARCT

Although epiphyseal bone infarcts have the same etiology as those

Figure 6–100.

Radiograph of an epiphyseal infarct in the femoral condyle of a 45

Histiocytic Disorders

LANGERHANS CELL HISTIOCYTOSIS

Sometimes inappropriately called histiocytosis X, Langerhans cell h
in the order of frequency. Besides affecting flat bones, it can arise

Eosinophilic granuloma can be extremely permeative and destructi

Figure 6–101.

Radiograph of an eosinophilic granuloma of the humerus in a 12-y

Figure 6–102.

Radiograph of an eosinophilic granuloma in the body of the C3 ver

Eosinophilic granulomas tend to involute spontaneously without tre

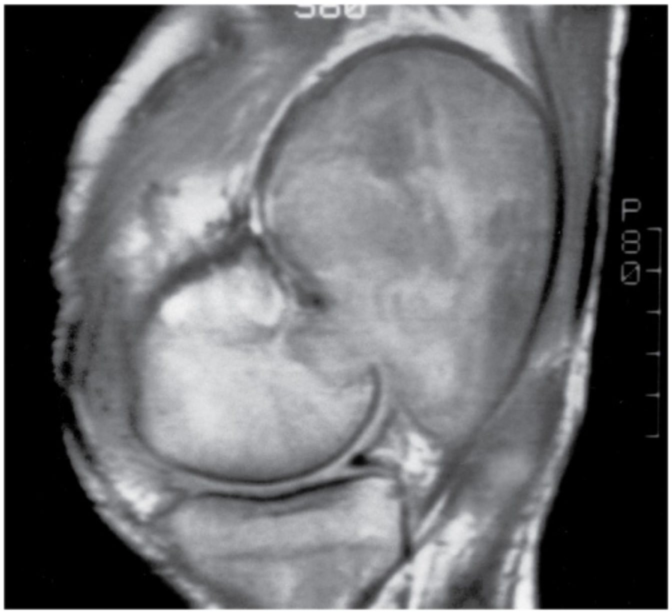
PIGMENTED VILLONODULAR SYNOVITIS

Although this form of synovitis can mimic a histiocytic tumor, it is t

The histopathology of pigmented villonodular synovitis is similar to

In fewer than 10% of cases, pigmented villonodular synovitis is mo

Figure 6–103.



T_1-weighted MRI of pigmented villonodular synovitis in the poplite

Figure 6–104.

Laminagram of pigmented villonodular synovitis in the proximal til

Mankin HJ et al: Gaucher disease. New approaches to an ancient c

Roodman GD: Studies in Paget's disease and their relevance to on

Shidham V et al: Evaluation of crystals in formalin-fixed, paraffin-e

Zelger B: Langerhans cell histiocytosis: A reactive or neoplastic dis

Note: Large images and tables on this page may necessitate printing in landscape mode.

ADULT RECONSTRUCTIVE SURGERY: INTR

Adult reconstructive surgery in orthopedics has rapidly evolved ov
active lifestyles. Millions of Americans are now benefiting from the

Statistics from American Academy of Orthopedic Surgeons: *Arthro*

ARTHRITIS & RELATED CONDITIONS

Evaluation of Arthritis

To treat arthritic conditions of the joints appropriately, an understa

Table 7–1. Causes of Arthritic Conditions.

Traumatic causes	Traumatic arthritis, osteonecrosis (posttraumatic

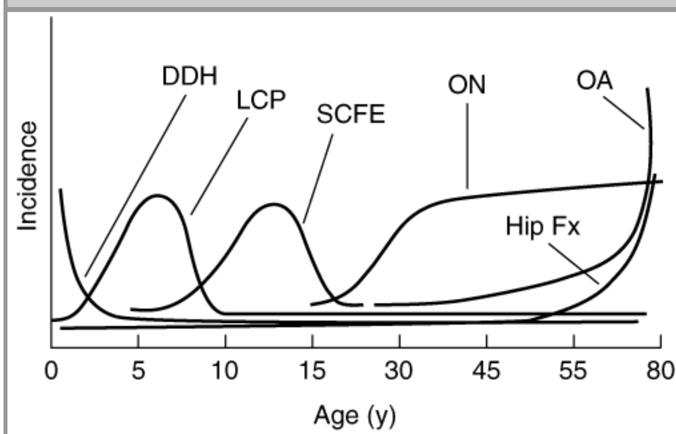
HISTORY

Clearly the history is important in defining the disease process. Th

The presence and extent of pain are valuable pieces of informatior

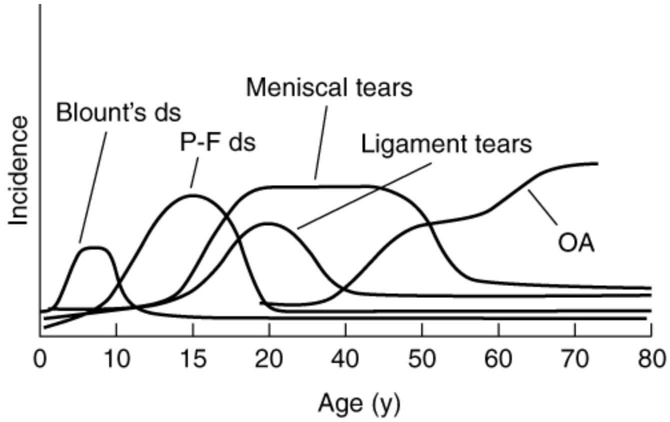
Knowledge of the age distribution of the various arthritic disorders

Figure 7–1.



The age distribution of hip disorders is given in a schematic repre

Figure 7–2.



The age distribution of knee disorders is given schematically as a

Hip pain is felt typically in the groin or in the lateral aspect of the

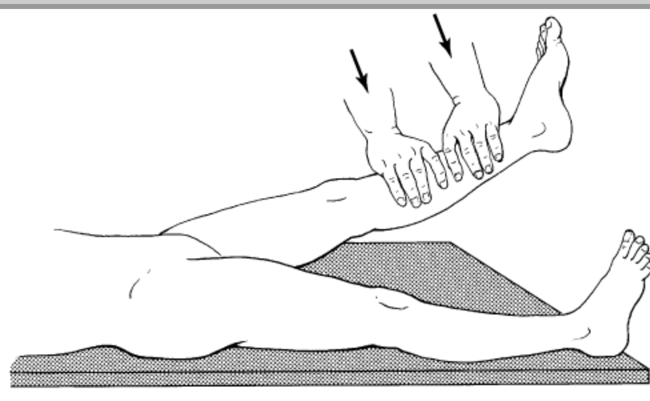
Knee pain is frequently anterior (patellofemoral), medial (medial c

PHYSICAL EXAMINATION

Hip

The physical examination of the hip is important to verify that the achieved by applying resistance to abduction. In the young (under

Figure 7–3.



Resisted straight leg–raising test. The examiner asks the patient t

The ROM in flexion, extension (flexion contracture), ABD, ADD, an

Knee

The physical examination of the knee localizes the pain to the knee advanced OA, whereas the lag is generally a quadriceps muscle or

Shoulder

After the cervical spine is ruled out as the source of pain, examina
area (eg, T6 or T7). When internal rotation is limited, the thumb n

Elbow

Inspection of the elbow includes measurement of the "carrying an

IMAGING STUDIES

Radiologic data, synovial fluid analysis, and blood testing may be b
flexion) (Table 7–2). Views of the shoulder should include AP, axilla

Table 7–2. Radiographic Findings in Arthritis.

Disease State	Findings in Hip or Knee
Osteoarthritis	Joint space narrowing, subchondral sclerosis, osteo

LABORATORY FINDINGS

Basic blood testing should include a complete blood count and sed

Synovial fluid analysis is indicated at any time to rule out infection

The combined history, physical examination, and appropriate labor

Sharma L et al: The role of knee alignment in disease progression

Solomon DH et al: Does this patient have a torn meniscus or ligam

Noninflammatory Arthritis

The term **osteoarthritis** is a misnomer, because inflammation is n

Categorization of primary and secondary forms of OA, although sti

The joints most commonly involved include the hip; knee; distal in

Primary Osteoarthritis

EPIDEMIOLOGIC FEATURES

OA is a widespread joint disorder in the United States, significantly

When all ages are considered, men and women are equally affecte

The incidence of hip OA is higher in European and American white

Evidence indicates that some distinct forms of OA may be inherite

PATHOLOGIC FEATURES

Early features of OA include focal swelling and softening of the car

Later features of OA include progressive loss of proteoglycans mar

New bone formation occurs in a subchondral location as well as at

LABORATORY FINDINGS

Specific diagnostic tests for OA are currently not available. Routine

IMAGING STUDIES

Typical radiographic features indicate late pathologic changes in O

Heberden nodes are commonly seen in primary OA, represented

Secondary Osteoarthritis

The term **secondary osteoarthritis** is applied when an underlyin

Bjell A: Cartilage matrix in hereditary pyrophosphate arthropathy.

Hoaglund FT, Steinbach LS: Primary osteoarthritis of the hip: Etiol

Kellgren JH et al: Genetic factors in generalized osteoarthrosis. An

Knowlton RG et al: Genetic linkage analysis of hereditary arthro-o

Lawrence RC et al: Estimates of the prevalence of arthritis and sel

Lowman EW: Osteoarthritis. JAMA 1955;157:487.

Marcos JC et al: Idiopathic familial chondrocalcinosis due to apatit

Mukhopadhaya B, Barooah B: Osteoarthritis of hip in Indians. Indi

Palotie A et al: Predisposition to familial osteoarthrosis linked to ty

Reginato AJ: Articular chondrocalcinosis in the Chiloé islanders. Ar

Solomon L et al: Rheumatic disorders in the southern African Neg

Spranger J: The epiphyseal dysplasias. Clin Orthop 1975;114:46.

Stickler GB et al: Hereditary progressive arthro-ophthalmopathy.

Inflammatory Arthritis

Rheumatoid Arthritis

A chronic systemic inflammatory disorder, rheumatoid arthritis (R

Joint involvement is typically symmetric, affecting the wrist, meta

EPIDEMIOLOGIC FEATURES

RA occurs two to four times more often in women than men. The c

Evidence for a genetic basis is provided by the association of RA w

PATHOLOGIC FEATURES

Early rheumatoid synovitis consists of a local inflammatory respons

Rheumatoid factors are antibodies specific to antigens on the Fc

LABORATORY FINDINGS

No specific laboratory test exists for RA, but a series of test result

IMAGING STUDIES

Early radiographic changes in RA include swelling of the small perip

Lipsky PE et al: The role of cytokines in the pathogeneis of rheuma

Saulsbury FT: Prevalence of IgM, IgA, and IgG rheumatoid factors

Sutton B et al: The structure and origin of rheumatoid factors. Im

Winchester RG: Genetic aspects of rheumatoid arthritis. Springer S

Zvaifler NJ: Etiology and pathogenesis of rheumatoid arthritis. In I

Ankylosing Spondylitis

A seronegative (negative rheumatoid factor) inflammatory arthritis

Joint involvement is primarily axial, including all portions of the spi

EPIDEMIOLOGIC FEATURES

The association of HLA-B27 and ankylosing spondylitis is strong, w

LABORATORY FINDINGS

During the active phase of the disease, the ESR is increased. Testi

IMAGING STUDIES

Early in the course of ankylosing spondylitis, the sacroiliac joints m

Ebringer RW et al: Sequential studies in ankylosing spondylitis: As

Geczy AF et al: A factor in *Klebsiella* filtrates specifically modifies a

Luong AA, Salonen DC: Imaging of the seronegative spondyloarthr

Moll JMH, Wright V: New York clinical criteria for ankylosing spondy

Van der Linden S et al: The risk of developing ankylosing spondyli

Psoriatic Arthritis

A seronegative inflammatory arthritis associated with psoriasis, ps

Although psoriatic arthritis is characterized by a relatively benign c

In addition to the dry erythematous papular skin lesions, nail chan

EPIDEMIOLOGIC FEATURES

A third of patients with psoriasis have arthritis, with joint sympton

LABORATORY FINDINGS

There are no specific laboratory tests for psoriatic arthritis. Nonsp

IMAGING STUDIES

Coexistence of erosive changes and bone formation is seen in peri

Gladman DD et al: HLA antigens in psoriatic arthritis. J Rheum 19

Hohler T, Marker-Hermann E: Psoriatic arthritis: Clinical aspects, g

Mader R, Gladman D: Psoriatic arthritis: Making the diagnosis and

Juvenile Rheumatoid Arthritis

Juvenile rheumatoid arthritis (JRA) is an inflammatory arthritic syr
suspected, to prevent blindness.

EPIDEMIOLOGIC FEATURES

The two peak ages of onset are between 1 and 3 years and betwe

LABORATORY FINDINGS

Leukocytosis up to 30,000/mL is seen with systemic-onset JRA, wi

Rheumatoid factor is typically negative in JRA. As many as 50% of

IMAGING STUDIES

Soft-tissue swelling and premature closure of physes may be seen

Falcini F, Cimaz R: Juvenile rheumatoid arthritis. Curr Opin Rheum

Schaller JG: The association of antinuclear antibodies with the chr

Systemic Lupus Erythematosus

Systemic lupus erythematosus (SLE) is a chronic inflammatory dis

EPIDEMIOLOGIC FEATURES

Females are affected eight times as often as males. An increased r

LABORATORY FINDINGS

Antinuclear antibody determination is the most helpful screening t

If antinuclear antibody levels are positive, more specific tests may

Anemia, leukopenia, and thrombocytopenia are seen, as well as ele

IMAGING STUDIES

The radiographic features of arthritis in SLE are similar to those of

Agnello V: Association of systemic lupus erythematosus and syster

Block SR et al: Immunologic observations on 9 sets of twins either

Kaine JL, Kahl LE: Which laboratory tests are useful in diagnosing

Serdula MK, Rhoads GG: Frequency of systemic lupus erythemato

Tan EM et al: Revised criteria for classification of systemic lupus er

Arthritis Associated with Inflammatory Bowel Disease

Peripheral arthritis and spondylitis are associated with ulcerative c

EPIDEMIOLOGIC FEATURES

Up to 25% of patients with inflammatory bowel disease develop ar

LABORATORY FINDINGS

There is no specific diagnostic test. Synovial fluid analysis reveals

IMAGING STUDIES

Peripheral arthritis is nonerosive, with juxtaarticular osteopenia an

Enlow RW et al: The spondylitis of inflammatory bowel disease. Ar

Morris RI et al: HLA-B27, a useful discriminator in the arthropathy

Wollheim FA: Enteropathic arthritis: How do the joints talk with the

Reiter Syndrome

The classic triad of conjunctivitis, urethritis, and peripheral arthriti

EPIDEMIOLOGIC FEATURES

Nongonococcal urethritis caused by *Chlamydia* accounts for the pr

LABORATORY FINDINGS

There are no specific diagnostic tests for Reiter syndrome. Anemia
IMAGING STUDIES
The radiographic features of Reiter syndrome are similar to those

Bradshaw CS et al: Etiologies of nongonococcal urethritis, bacteria

Caelin A, Fries JF: An "experimental" epidemic of Reiter's syndrom

Ford DK: Reiter's syndrome: Reactive arthritis. In McCarty DJ, ed:

Grayston JT, Wan SP: New knowledge of chlamydiae and the disea

Metabolic Arthropathy

Gout

Deposition of monosodium urate crystals in the joints produces go
The first attack involves sudden onset of painful arthritis, most oft
EPIDEMIOLOGIC FEATURES
Primary gout has hereditary features, with a familial incidence of 6
LABORATORY FINDINGS
The key diagnostic test is detection of monosodium urate crystals
Hyperuricemia is usually seen, but up to a fourth of gout patients
IMAGING STUDIES
Tophi may be seen when they are calcified. Soft-tissue swelling is

Abubaker MY et al: The management of gout. N Engl J Med 1996;

Agudelo CA, Wise CM: Gout: Diagnosis, pathogenesis, and clinical

Emmerson BT: Coexistence of acute gout and septic arthritis. Arth

Kelley WN et al: Gout and related disorders of purine metabolism.

Levinson DJ: Clinical gout and the pathogenesis of hyperuricemia.

Calcium Pyrophosphate Crystal Deposition Disease

Calcium pyrophosphate crystal deposition disease, a goutlike synd
Aging and trauma are associated with this disorder, as well as con
EPIDEMIOLOGIC FEATURES

Hereditary forms of calcium pyrophosphate dihydrate deposition d

PATHOLOGIC FEATURES

Calcification of multiple joint structures occurs, including hyaline ca

IMAGING STUDIES

Calcification of menisci and hyaline cartilage is seen as punctate or

Kohn NN et al: The significance of calcium phosphate crystals in th

McCarty DJ et al: The significance of calcium phosphate crystals in

Resnick D: Rheumatoid arthritis and pseudorheumatoid arthritis in

Rosenthal AK: Calcium crystal-associated arthritides. Curr Opin Rh

Ochronosis

A hereditary deficiency in the enzyme homogentisic acid oxidase is

The diagnosis is made when the triad of dark urine, degenerative a

EPIDEMIOLOGIC FEATURES

Transmission of alkaptonuria is by a recessive autosomal gene.

IMAGING STUDIES

Spondylosis is seen, with calcification of intervertebral disks with fo

Schumacher HR, Holdsworth DE: Ochronotic arthropathy: Clinicopa

Osteochondroses

Osteonecrosis of the Femoral Head

A variety of conditions and diseases are associated with femoral he

Other associated conditions include hemoglobinopathies, Gaucher d

PATHOLOGIC FEATURES

Regardless of underlying causes, the early lesions in femoral head

Leukocytes and mononuclear cells collect around necrotic and fibro

IMAGING STUDIES

Ficat created a classification based on the plain radiographic appea

A newer classification system, devised by Steinberg, is popular and

Cui Q et al: The Otto Aufranc Award: Lovastatin prevents steroid-i

Ficat RP: Idiopathic bone necrosis of the femoral head: Early diagr

Lavernia CJ et al: Osteonecrosis of the femoral head. J Am Acad O

Steinberg ME et al: A quantitative system for staging avascular ne

Other Disorders Associated with Arthritis

Hemophilia

Hemophilia A is a heritable bleeding disorder produced by deficien

PATHOLOGIC FEATURES

Recurrent hemarthrosis produces deposits of hemosiderin and syn

IMAGING STUDIES

Soft-tissue swelling, seen early, is associated with hemarthroses. L

Luck JV, Kasper CK: Surgical management of advanced hemophilic

Gaucher Disease

A rare familial disorder, Gaucher disease is an inborn error of meta

The femur is the most commonly affected bone, but the vertebrae

EPIDEMIOLOGIC FEATURES

Inherited in an autosomal recessive manner, Gaucher disease is th

PATHOLOGIC FEATURES

Histologic examination of involved reticuloendothelial tissues demo

IMAGING STUDIES

Early stages of skeletal involvement in Gaucher disease include dif

Amstutz HC, Carey EJ: Skeletal manifestations and treatment of G

Goldblatt J et al: The orthopaedic aspects of Gaucher's disease. Cl

Hip Labral Tears

The hip has a cartilaginous extension of the bony acetabulum calle

PATHOLOGIC FEATURES

The normal labrum is triangular in shape and variable in size from

IMAGING STUDIES

MRI arthrography is the test of choice for suspected labral tears. C

Plotz GM et al: Magnetic resonance arthrography of the acetabula

MEDICAL MANAGEMENT

Nonsteroidal Antiinflammatory Drugs

The use of nonsteroidal antiinflammatory drugs (NSAIDs) in the m

The therapeutic effect of NSAIDs can be dramatic in the osteoarth

Patients treated with NSAIDs have a three times greater relative r
life, on whether the NSAID inhibits thromboxane A, and on whethe

Table 7–3 compares the toxicities of currently available NSAIDs. Be

Table 7–3. Toxicity Profiles of Currently Available NSA

Generic Name	Proprietary Name	Gastrointestinal Toxicity	Renal Toxicity	Platelet Effects (d)[a]	Other Toxici
Diclofenac	Voltaren	Moderate	Moderate	1	Hepati

[a]Average time to normal platelet function after discontinuation of

[b]Other NSAIDs may have similar toxicity, but the effects are more

[c]Simultaneous efficacy comparisons in inflammatory disease not a

[d]No prostaglandin inhibition.

[e]Weak prostaglandin inhibitor.

NA = data not available.

The chemical families of these drugs are noted in Table 7–4 with th

Table 7–4. Dosage Data of Currently Available NSAIDs

Generic Name	Proprietary Name	Largest Unit Dose (mg)	Half-Life (h)	
Diclofenac	Voltaren	75	2	

[a]Dosage required for treatment of inflammation.

bid = twice a day; qd = each day; q4h = every 4 hours; qid = fou

Much anticipated is the development of COX-2-selective NSAIDs, w

Although COX-2-selective NSAIDs are purportedly safe, they are n

The choice of an appropriate NSAID should be based on the follow minimize the accumulation of the drug in the body because of lack

The advent of the COX-2-specific NSAIDs adds to their safety as a

Surgical intervention is generally indicated for patients who have f

Batchlor EE, Paulus HE: Principles of drug therapy. In Moskowitz R

Berger RG: Nonsteroidal anti-inflammatory drugs: Making the righ

Bombardier C et al: Comparison of upper gastrointestinal toxicity

Bradley JD et al: Comparison of an anti-inflammatory dose of ibup

Gabriel SE et al: Risk for serious gastrointestinal complications rel

Hochberg MC et al: Guidelines for the medical management of ost

Hochberg MC et al: Guidelines for the medical management of ost

Hosie J et al: Meloxicam in osteoarthritis: A 6-month, double-blind

Silverstein FE et al: Gastrointestinal toxicity with celecoxib vs nons

Simon LS et al: Preliminary study of the safety and efficacy of SC-

Disease-Modifying Agents in Rheumatoid Arthritis

Three new disease-modifying antirheumatic drugs (DMARDs) are r surgery, similar to methotrexate.

Kremer JM: Rational use of new and existing disease-modifying ag

OTHER THERAPIES

Nutritional Supplements

The nutritional supplements glucosamine sulfate and chondroitin s

Chondroitin sulfate is another glycosaminoglycan present in articul

Brief AA et al: Use of glucosamine and chondroitin sulfate in the m

Houpt JB et al: Effect of glucosamine hydrochloride (GHCl) in the t

Hughes RA, Carr AJ: A randomized double-blind placebo-controlled

Leffter CT et al: Glucosamine, chondroitin, and manganese ascorb

Mazieres B et al: Chondroitin sulfate in the treatment of gonarthro

McAlindon TE et al: Glucosamine and chondroitin for treatment of

Muller-Fabender H et al: Glucosamine sulfate compared to ibuprofe

Reginster JY et al: Long term effects of glucosamine sulphate on c

Rindone JP et al: Randomized, controlled trial of glucosamine for t

Injections

One of the mainstays of the treatment of osteoarthrosis and RA is
fusion. Intraarticular administration of hyaluronic acid is now availa

Hyaluronic acid is a long-chain polysaccharide responsible for the v

Adams ME et al: The role of viscosupplementation with hylan G-F

Altman RD, Moskowitz R: Intraarticular sodium hyaluronate (Hyalg

Marshall KW et al: Amelioration of disease severity by intraarticula

Watterson JR, Esdaile JM: Viscosupplementation: Therapeutic mec

Orthotic Treatment

The use of orthotics can ameliorate the symptoms of osteoarthrosi

Draper ERC et al: Improvement of function after valgus bracing of

Pollo FE: Bracing and heel wedging for unicompartmental osteoart

PROCEDURES FOR JOINT PRESERVATION

A joint can potentially deteriorate for the following reasons: (1) tra

Rotator Cuff Repair

Chronic rotator cuff tears of the shoulder can lead to a degenerati

Synovectomy

Synovectomy is a treatment that may prolong the life of the hyalir

INDICATIONS AND CONTRAINDICATIONS

The most common indication for synovectomy is RA, but the proce

More specific indications for synovectomy include the following con

1. synovitis with disease limited to the synovial membrane with little or no involvem
2. recurrent hemarthroses in conditions such as pigmented villonodular synovitis or
3. imminent destruction of the joint by lysosomal enzymes derived from white blood
4. failure of an adequate trial of conservative management.

Contraindications include reduced ROM, significant degenerative ar

TECHNIQUE

Synovectomy is most commonly performed on the knee and also c

Open Synovectomy

Open synovectomy is becoming less common because of pain that

Synovectomy with Use of Arthroscope

Synovectomy with use of the arthroscope may be tedious, especia

A study of pigmented villonodular synovitis of the knee treated by

Radiation Synovectomy

Radiation synovectomy is a technique that is becoming much more

A similar technique is used in the knee joint in hemophiliacs. Phosp

Cartilage Transplant Techniques

Defects of hyaline cartilage were long considered permanent injuri

Because cartilaginous tissues are avascular, prior surgical treatmen

Much enthusiasm followed the procedure described by Brittberg ar

Another method of dealing with focal defects of cartilage includes t

In contrast, OA is a more prevalent affliction of cartilage, affecting

Brittberg M et al: Treatment of deep cartilage defects in the knee

Hangody L et al: Mosaicplasty for the treatment of articular defect

Rodrigo JJ et al: Improvement of full-thickness chondral defect he

Core Decompression with or without Structural Bone (

INDICATIONS AND CONTRAINDICATIONS

Core decompression with or without bone grafting is a surgical tre

The treatment of osteonecrosis is controversial because the outcor

TECHNIQUE

The goal of core decompression is to alleviate hypertension in the

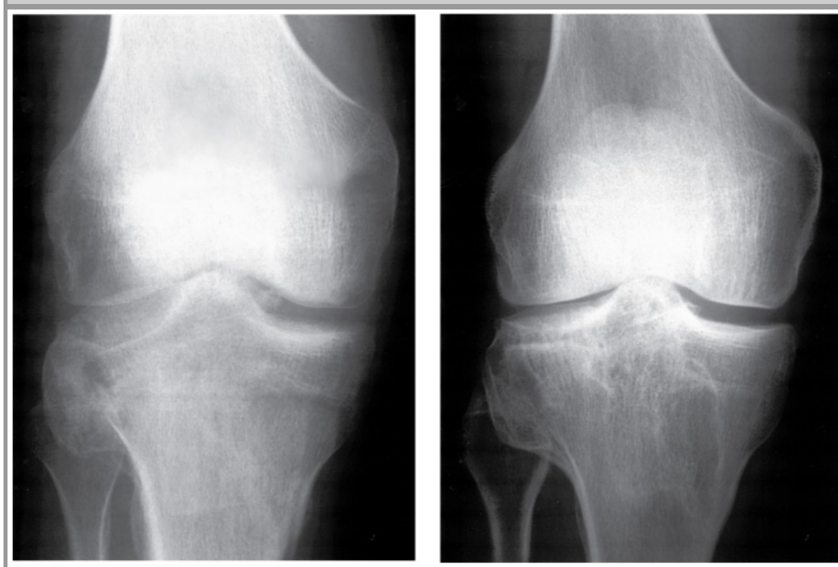
Core decompression is usually performed on the hip but may also

The results of core decompression are mixed, possible as a result

Osteotomy

Osteotomy should be considered part of the armamentarium of th
performed for residual deformity for fracture. These are tailored to

Figure 7–4.



A B

An intraarticular osteotomy can be of benefit in tibial plateau fract

HIGH TIBIAL OSTEOTOMY

Alleviation of abnormal stress through high tibial osteotomy preve
technetium bone scan. A cold scan of the uninvolved compartment

Proximal tibial osteotomy is performed through a lateral hockey-st
staples, and other commercial fixation devices are available. Care

Figure 7–5.

High tibial osteotomy, showing staples holding the osteotomy in pl

The results of high tibial osteotomy are not as predictable as unicc

Lateral gonarthrosis from genu valgum is a relatively frequent resu

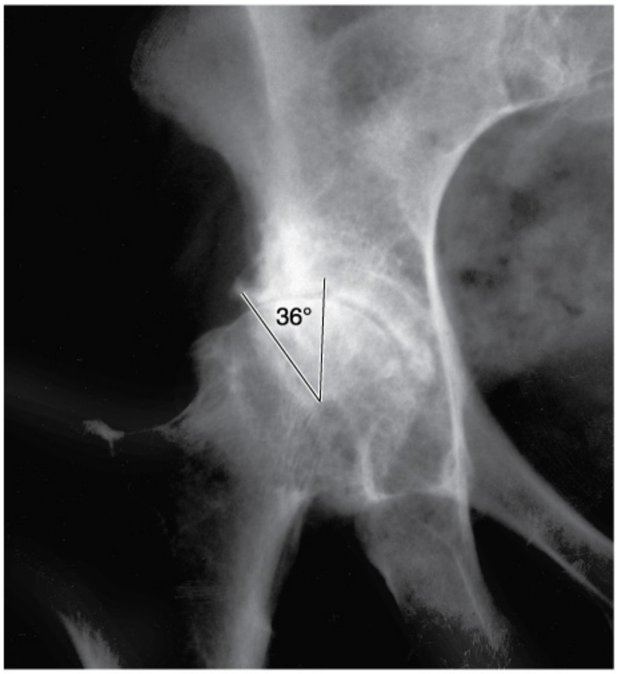
OSTEOTOMY OF THE HIP

Certain unusual conditions of the hip can be treated with osteotom
Significantly lengthening or shortening a muscle reduces the force

Treatment for Acetabular Dysplasia

Acetabular dysplasia may be defined by the center edge angle. Th

Figure 7–6.



Anteroposterior pelvis film demonstrating the center edge angle.

To improve coverage and hip biomechanics significantly, an acetab

Treatment of Femoral Disorders

Osteotomy of the femur can safely and reliably be performed in th
limited in the United States.

Bonfiglio M, Voke EM: Aseptic necrosis of the femoral head and no

Buckley PD et al: Structural bone-grafting for early atraumatic ava

Coventry MB: Osteotomy about the knee for degenerative and rhe

Crockarell JR et al: The anterior center-edge angle: A cadaver stu

Edgerton BC et al: Distal femoral varus osteotomy for painful genu

Fairbank AC et al: Long-term results of core decompression for isc

Haddad FS et al: CT evaluation of periacetabular osteotomies. J Bo

Mont MA et al: Core decompression versus nonoperative managem

Morita S et al: Long-term results of valgus-extension femoral oste

Ogilvie-Harris DJ et al: Pigmented villonodular synovitis of the kne

Ohashi H et al: Factors influencing the outcome of Chiari pelvic ost

Shoji H, Insall J: High tibial osteotomy for osteoarthritis of the kne

Sledge CB et al: Synovectomy of the rheumatoid knee using intra-

Urbaniak JR, Harvey EJ: Revascularization of the femoral head in c

JOINT SALVAGE PROCEDURES

Arthrodesis

Arthrodesis is the creation of a bony union across a joint. The crea
technique used in any of the joints follows the same general patte

Table 7–5. Optimal Position of Joints after Arthrodesi

Joint	Angle	Length	Other Consideration
Ankle	0° dorsiflexion	Slight shortening	Talus displaced posteriorl
Knee		15° flexion	Slight shortening
Shoulder			20–30° flexion
Hip			

Ankle Arthrodesis

The orthopedic community generally considers arthrodesis of the t

The indications for ankle arthrodesis are as follows:

1. degenerative arthrosis;
2. rheumatoid arthritis;
3. posttraumatic arthritis;
4. avascular necrosis of the talus;
5. neurologic disease resulting in an unstable ankle; and
6. neuropathic ankle joint.

The relative contraindications include degenerative joint disease in

The ankle arthrodesis can be performed through an anterior, later

Kitaoka HB, Patzer GL: Arthrodesis for the treatment of arthrosis c

Scranton PE: An overview of ankle arthrodesis. Clin Orthop 1991;2

Knee Arthrodesis

Knee arthrodesis is seldom done for primary problems and genera
knee arthroplasty, usually because of infection. In a patient who w

The technique of arthrodesis varies with the problem being treatec
and at the normal valgus alignment of 5–8 degrees, if possible.

Donley BG et al: Arthrodesis of the knee with an intramedullary na

Nichols SJ et al: Arthrodesis with dual plates after failed total knee

Papilion JD et al: Arthroscopic assisted arthrodesis of the knee. Ar

Elbow Arthrodesis

Elbow arthrodesis is an uncommon procedure. Loss of elbow motic

Several techniques are described, but the relative rarity of the ope

Irvine GB, Gregg PJ: A method of elbow arthrodesis: Brief report.

Morrey BF et al: A biomechanical study of normal elbow motion. J

Shoulder Arthrodesis

Paralysis of the deltoid muscle and sepsis after an arthroplasty are

The AO technique (Arbeitsgemeinschaft für Osteosynthesefragen t
Additional fixation may be obtained by placing another plate poste

A modification of the AO technique that uses an external fixator to

Johnson CA et al: External fixation shoulder arthrodesis. Clin Orth

Muller ME et al: *Manual of Internal Fixation.* Berlin: Springer-Verla

Richards RR et al: Shoulder arthrodesis using a pelvic-reconstructi

Riggins RS: Shoulder fusion without external fixation: A preliminar

Hip Arthrodesis

Arthrodesis of the hip, as of other joints, produces a relatively pai

The most obvious indication for arthrodesis of the hip is tuberculos
relatively uncommon operation.

Multiple techniques are described for performing hip arthrodesis. T
to the foot. Too much flexion makes both walking and lying in bed

Blasier RB, Holmes JR: Intraoperative positioning for arthrodesis o

Callaghan JJ et al: Hip arthrodesis: A long-term follow-up. J Bone .

Resection Arthroplasty

Resection arthroplasty, or excisional arthroplasty, is a procedure th

Hip Arthroplasty

Resection arthroplasty of the hip produces a relatively pain-free jo
procedure can be very helpful in reambulating wheelchair-bound p

For infection compromising total hip replacement, resection arthro

Knee Arthroplasty

Resection arthroplasty of the knee has a much less satisfactory fu

Elbow Arthroplasty

Resection arthroplasty or fascial arthroplasty of the elbow is one m
performed.

Milgram JW, Rana NA: Resection arthroplasty for septic arthritis of

Thornhill TS et al: Alternatives to arthrodesis for failed total knee a

JOINT REPLACEMENT PROCEDURES

Hemiarthroplasty

Hemiarthroplasty is the replacement of only one side of a diarthro
may, however, take many years, and the patient may have a servi

The choice of prosthesis depends on factors such as life expectanc
a total hip arthroplasty, should this become necessary.

The operative technique is quite similar to that of total joint replac

Total Joint Arthroplasty

Joint replacement surgery became a viable treatment for arthritic
application of technology to these joints is not at the level applied

The design of the prosthesis is an evolutionary process that depen

Total Hip Arthroplasty

The original Charnley total hip arthroplasty was a stainless steel fe
cement fixation prostheses.

Figure 7–7.

Radiograph of a Charnley arthroplasty.

INDICATIONS

The indications for hip arthroplasty are incapacitating arthritis of tl

Table 7–6. Harris Hip Evaluation (Modified).

I. Pain (44 possible)	A. None or ignores it	44	B. Slight, occasional, no compromise in activities	40	C. Mild pain, no ef average activities, r moderate pain; witl activity may take as

Physical examination typically demonstrates a limited ROM, pain at
Radiographs demonstrate loss of joint space and other findings co
After consideration of the lifestyle requirements of the patient, the
A choice must be made between cemented and uncemented arthr
porous-coated prosthesis.

SURGICAL TECHNIQUE

Certain aspects of hip replacement surgery apply to all arthroplast

Posterolateral Approach

The most common approach for total hip arthroplasty is the poster

Alternatively, with the hip in the extended position, the incision is
preserved and protected, and a capsulectomy is performed. Altern
if appropriate when medial osteophytes are present. Anterior oste

If a cemented cup is used, multiple holes with a diameter of 1/4–3

If an uncemented cup is used, reaming progresses to a diameter 1

The hip is internally rotated, flexed to approximately 80 degrees, a
into the femoral canal with a cement gun. The cement is pressuriz
the hip extended) is similar to prior to surgery. A further check on

After the cement hardens, a trial femoral head is used to put the h

The design and insertion technique of the uncemented femoral co

Abbreviated mini incisions for the posterolateral approach to the h

Lateral Approach

The lateral approach to the hip is performed with a trochanteric os
the trochanter when the procedure is completed, so reliable union

Anterolateral Approach (Watson-Jones Approach)

The interval between the gluteus medius muscle and the tensor fa
hip joint can then be dislocated. Osteotomy of the femoral neck pr

Other Approaches

Other approaches are used for hip replacement, some of which ar

IMPLANTS

The two basic types of total hip replacement are cemented and un
recommend a polished surface. Adequate offset is necessary to re

The choice of material for the femoral head is a trade-off between
provide adequate thickness of the polyethylene bearing surface. A

New bearing surfaces for the articulation of the hip joint are becor

No evidence justifies use of a metal backing on the cemented acet

Uncemented acetabular components have a spherical outer surfac

Table 7–7. Preferred Materials for Total Hip Replacem		
Component	Material	Alternative Mater
Uncemented femoral component	Titanium alloy	Cobalt chromiumall

Design considerations for the uncemented femoral component are
reduce the torsional and bending stiffness also seems to be effecti

COMPLICATIONS

Any major surgery is associated with a certain incidence of complic

Deep Venous Thrombosis

Although some morbidity results from DVT, the real risk is pulmon

Pharmacologic and mechanical measures are used to reduce the ri
approved by the Food and Drug Administration (FDA) for prophyla
may be more convenient for outpatient use.

Because DVT can lead to a catastrophic outcome, preventative me

Nerve Palsies

Three degrees of nerve injury are recognized. In order of increasir

Nerve palsies after total hip arthroplasty are relatively infrequent,
cement extrusion, are also suggested as causes.

Nerve injury may be prevented by identifying high-risk cases, prot

Management of nerve palsy is generally conservative, with observa

Vascular Complications

Significant vascular complications are reported to occur in approxi

Fracture or Perforation

The typical fracture associated with total hip arthroplasty involves
arthroplasties, depending on the size of the perforation. An altern

After total hip arthroplasty, the stress state of the bone is definite
grafting techniques may be necessary with poor bone stock. Open

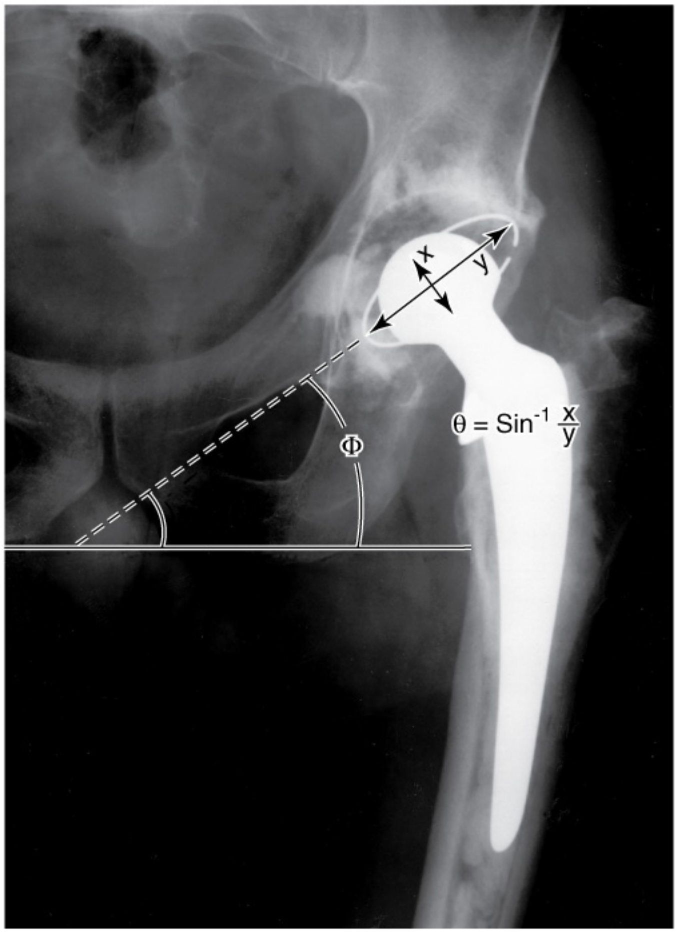
Dislocation Following Total Hip Arthroplasty

The incidence of dislocation following total hip arthroplasty varies s

Factors important in preventing dislocation are proper placement c

The risk of dislocation after total hip arthroplasty diminishes as tim
femoral head (Figure 7–8). Examination under fluoroscopy may re

Figure 7–8.



Approximate determination of the abduction-adduction angle and

After careful evaluation of the cause(s) of dislocation, surgical corr
seek surgical correction. The recurrence rate in such patients is as

Leg-Length Discrepancy

During hip replacement surgery, an attempt is made to maintain t

Trochanteric Nonunion

The rate of trochanteric nonunion after a primary total hip arthrop

The rate of nonunion after revision surgery is much higher, as muc

Pain after trochanteric nonunion may be the result of a painful pse

Heterotopic Ossification

The incidence of significant heterotopic ossification after total hip a

Heterotopic bone is classified by either the Brooker or the Mayo cl
retarded. Irradiation may cause problems if ingrowth components

Table 7–8. Heterotopic Bone Classification Systems.

Stage	Mayo Classification	Brooker Classificat

Reprinted, with permission, from Brooker AF et al: Ectopic ossifica

If heterotopic ossification causes symptoms (pain, decreased ROM

Infection

Prevention of infection after total hip arthroplasty is important bec

An innovation in the treatment of infected total hips and knees is t

Prevention is much more desirable than subsequent treatment of i
infection, including pain, elevated white blood cell count, fever, and

Amoxicillin, 3 g taken 1 hour before and 1.5 g taken 6 hours after

Barrack RL, Harris WH: The value of aspiration of the hip joint bef

Callaghan JJ et al: Charnley total hip arthroplasty with cement: Mi

Coventry MB: Late dislocations in patients with Charnley total hip

Daly P, Morrey BF: Operative correction of an unstable total hip ar

DeHart MM and Riley LH: Nerve injuries in total hip arthroplasty. J

Dorr LD et al: Total hip arthroplasty with use of the Metasul metal

Harris WH: Traumatic arthritis of the hip after dislocation and acet

Harris WH, Barrack RL: Contemporary algorithms for evaluation of

Huddleston HD: An accurate method for measuring leg length and

Khan MAA et al: Dislocation following total hip arthroplasty. J Bone

Lester DK, Helm M: Mini-incision posterior approach for hip arthro

Lewinnek GE et al: Dislocations after total hip replacement arthrop

Markolf KL et al: Mechanical stability of the greater trochanter foll

McDonald DJ, Fitzgerald RH Jr: Two-stage reconstruction of a tota

Mont MA et al: Total hip replacement without cement for noninflan

Ritter MA: A treatment plan for the dislocated total hip arthroplast

Schmalzried TP et al: Update on nerve palsy associated with total

Waldman BJ et al: Total knee arthroplasty infections associated wi

Revision Total Hip Arthroplasty

The clinical success of revision total hip arthroplasty (THA) procedu
Improved techniques of cementing femoral stems led to improved

Estok DMD II, Harris WH: Long-term results of cemented femoral

Katz RP et al: Cemented revision total hip arthroplasty using conte

Kavanagh BF et al: Revision total hip arthroplasty. J Bone Joint Su

Pellicci PM et al: Revision total hip arthroplasty. Clin Orthop 1982;

Rubash HE, Harris WH: Revision of nonseptic, loose, cemented fer

Cementless reconstructions of failed femoral components were dev

Gustilo RB, Pasternak HS: Revision total hip arthroplasty with titar

Harris WH et al: Results of cementless revisions of total hip arthro

Hedley AK et al: Revision of failed total hip arthroplasties with unc

Lawrence JM et al: Revision total hip arthroplasty: Long term resu

McCarthy JC et al: Revision of the deficient femur with a modular

Paprosky WG et al: Cementless femoral revision in the presence o

In the situation where inadequate femoral bone stock exists, the u

Gie GA et al: Impacted cancellous allografts and cement for revisio

Gross AE et al: Proximal femoral allografts for reconstruction of bo

Similar to early experience with cemented revisions of the femoral
Kavanagh BF et al: Charnley total hip arthroplasty with cement: F

Snorrason F, Karrholm J: Early loosening of revision hip arthroplas

The introduction of cementless porous-coated acetabular implants
Engh CA et al: Results of cementless revision for failed cemented

Harris WH et al: Results of cementless revision of total hip arthrop

Hedley AK et al: Revision of failed total hip arthroplasties with unc

Padgett DE et al: Revision of the acetabular component without ce

Where inadequate bone stock of the acetabulum precludes reconst
Berry DJ, Muller M: Revision arthroplasty using an antiprotrusio ca

Garbuz D et al: Revision of the acetabular component of a total hi

Peters CL, Curtain M, Samuelson KM: Acetabular revision with the

Sutherland CJ: Early experience with eccentric acetabular compon

Total Knee Arthroplasty

INDICATIONS

As with other joints, the primary indication for total knee arthropla
When both hips and knees are involved with painful arthritis, the j

IMPLANTS

Early designs of total knee arthroplasty were developed in Europe
Contemporary total knee replacements represent a convergence o
The Duocondylar knee replacement was the forerunner of the duo
Retention of the posterior cruciate ligament permitted increased fl
To overcome limitations in flexion and stair-climbing function, the
The differences in ROM and stair-climbing function achieved with c

Problems with high-contact, stress-inducing fatigue wear of the po
address the biomechanical aspects of the knee, but results are ear

SURGICAL TECHNIQUE

Total knee replacement surgery is greatly facilitated by use of a th

Instrumentation systems guide the surgeon to create bone cuts w
flexion and facilitates tracking of the patellar component.

Retention or sacrifice of the posterior cruciate ligament depends o

When the patellar surface is replaced, a saw is used to create a fla
implant slightly medially on the patellar bone surface also improve

After appropriate trials are used to confirm accurate sizes of the c

CLINICAL RESULTS

Long-term results of contemporary cemented total knee arthroplas

COMPLICATIONS

Complications are infrequent with total knee arthroplasty but inclu

Deep Vein Thrombosis

DVT is common following knee arthroplasty, occurring in more tha

Wound Problems

Wound problems can arise from incision-related issues and from pa

Treatment of wound problems depends on the type of problem. Dr

Prevention of wound problems through careful planning, gentle ha

Nerve Palsy

Nerve palsies are a rare complication of total knee arthroplasty. Th

Femoral Fracture

Notching of the anterior femoral cortex may predispose to distal fe
placement of a Steinmann pin in the tubercle to prevent excessive

Patellar complications include maltracking, loosening of the patella
during lateral release, can predispose to fractures. When using a p

In some studies, patellar complications are the cause for as many

Extensor Mechanism Complications

Many extensor mechanism problems can be prevented by careful s

Intraoperative rupture of the patellar or quadriceps tendon at the

Knee Stiffness

Knee stiffness is a common problem in the early postoperative per

Prevention of significant flexion contracture at the time of surgery

Ayers DC et al: Common complications of total knee arthroplasty.

Barrack RL, Wolfe MW: Patellar resurfacing in total knee arthropla

Callaghan JJ et al: Cemented rotating-platform total knee replace

Callaghan JJ et al: Mobile-bearing knee replacement: Concepts an

Figgi HF et al: The influence of tibial-patellofemoral location on fu

Hahn SB et al: A modified Thompson quadricepsplasty for stiff kn

Rinonapoli E et al: Long-term results and survivorship analysis of

Scuderi GR et al: Survivorship of cemented knee replacements. J

Ververeli PA et al: Continuous passive motion after total knee arth

Total Shoulder Arthroplasty

INDICATIONS

The primary indication for shoulder arthroplasty is severe pain tha
only if the rotator cuff is intact or reparable at the time of surgery
hemiarthroplasty may be the only viable option because the gleno

SURGICAL TECHNIQUE

A deltopectoral surgical approach is performed, with careful retrac
extension and external rotation of the arm. The humeral head is c
glenoid component. Long-term follow-up studies show that both b

IMPLANTS

Early total shoulder arthroplasties were designed with constrained

CLINICAL RESULTS

Shoulder arthroplasty has made significant progress, similar to the

Functional results are variable, however, depending largely on the

The major complication associated with total shoulder arthroplasty

Radiolucent lines were observed around the glenoid component in
advantage of the deltoid. Alternatively, the so-called reverse or inv

Baumgarten KM et al: Glenoid resurfacing in shoulder arthroplasty

Gupta R, Lee TQ: Positional-dependent changes in glenohumeral j

Harman M et al: Initial glenoid component fixation in "reverse" tot

Jain N et al: The relationship between surgeon and hospital volum

Levy O et al: Copeland surface replacement arthroplasty of the sh

Lyman S et al: The association between hospital volume and total

Sperling J et al: Minimum fifteen-year follow-up of Neer hemiarthr

Total Elbow Arthroplasty

INDICATIONS

Although total elbow arthroplasty (TEA) may be an appropriate me

1. rheumatoid arthritis (RA);
2. posttraumatic arthritis;
3. juvenile rheumatoid arthritis (JRA);
4. distal humeral nonunions and severe comminuted distal humeral fractures, espe
5. primary OA.

The severity of the disease and the choice of prosthesis in all of th failure rates approximately 10 years after implantation, alternative

SURGICAL TECHNIQUE

Attention to the soft tissue, including the triceps insertion, collater

Because maintenance of the collateral ligaments is of vital importa

The Bryan posteromedial approach is routinely used for implantati

IMPLANTS

Early TEA designs included constrained devices, which predictably there is increased risk of loosening. Excision of the radial head is a

CLINICAL RESULTS

Ten-year follow-up studies for TEA are currently only available for intermediate follow-up results, seem to suggest that the better se

Although previous radial head resection and synovectomy does no

Common complications encountered following TEA include aseptic proximal ulna may be an option. These remain extremely challeng

Blaine TA et al: Total elbow arthroplasty after interposition arthrop

Chafik D, Lee TQ, Gupta R: Total elbow arthroplasty: Current indic

Kelly EW et al: Five- to thirteen-year follow-up of the GSB III tota

Loebenberg MI et al: Impaction grafting in revision total elbow art

Malone AA et al: Successful outcome of the Souter-Strathclyde elb

Sarris I et al: Ulnohumeral arthroplasty: Results in primary degen

Wada T et al: Debridement arthroplasty for primary osteoarthritis

Whaley A et al: Total elbow arthroplasty after previous resection o

Total Ankle Arthroplasty

The total ankle arthroplasty was under development for many yea
motion.

Encouraging early reports with newer designs of total ankle arthro

Kitaoka HB, Patzer GL: Clinical results of the Mayo total ankle arth

Pyevich MT et al: Total ankle arthroplasty: A unique design. Two t

Evaluation of Painful Total Joint Arthroplasty

A certain degree of adaptation and accommodation is possible in t
fatigue fractures. All of these problems may result in a painful arth

HISTORY

Referred pain from other sources must be ruled out, particularly w

PHYSICAL EXAMINATION

The same tests are performed as for an arthritic joint to evaluate

WORKUP

Laboratory Findings

Laboratory data may be helpful. The ESR (more than 35–40 mm/h

Arthrographic Evaluation

Arthrographic evaluation may be helpful by showing dye penetrati

Bone scans have little value immediately after surgery. Significant

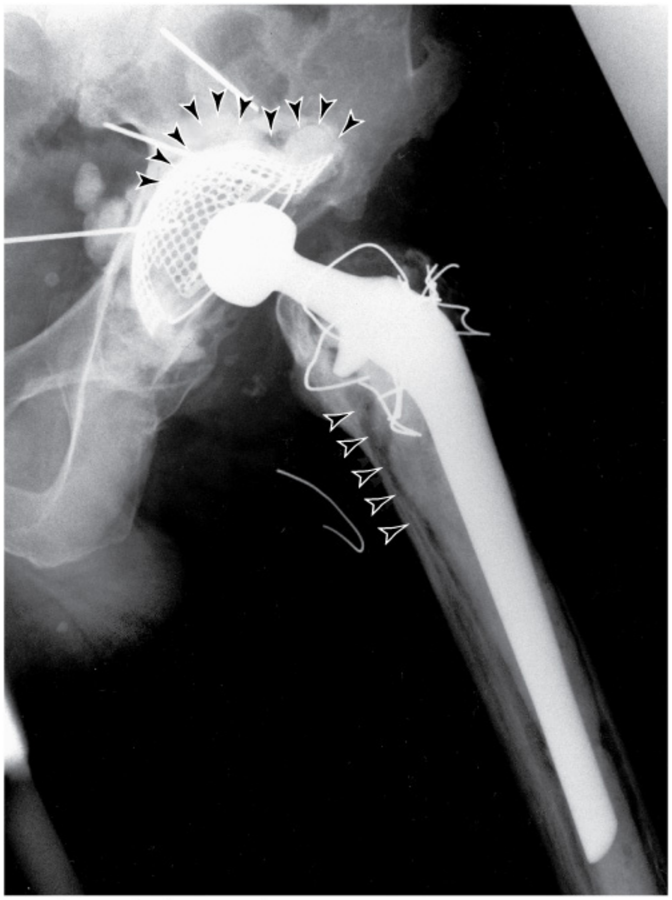
Indium-Labeled White Blood Cell Scan

This nuclear medicine study uses the patient's polymorphonuclear

Plain Radiographs

Roentgenographic examination is the single most useful test in the

Figure 7–9.



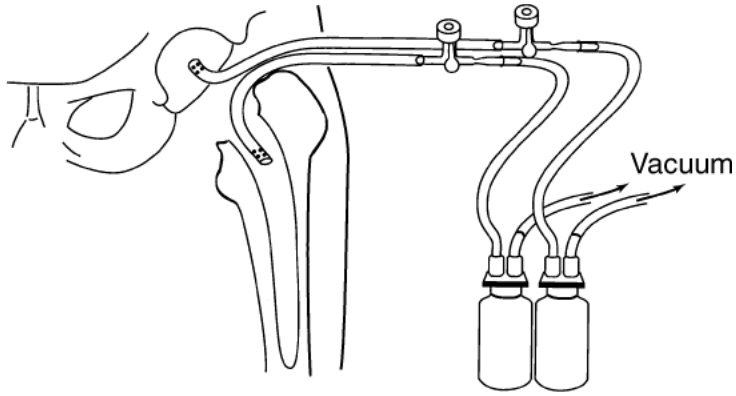
Radiograph of radiolucent lines around an acetabular component.

Treatment of Infected Total Joint Arthroplasty

Definitive evidence of a septic total joint arthroplasty forecasts a p

There is general concurrence that thorough debridement of the joi antibiotic solution are instilled into the joint twice a day, the joint i

Figure 7–10.



Schematic diagram of the Jergesen system of instillation of antibic

In cases of loose prostheses, little alternative is available except tc
is used to obtain specimens for culture. If these are negative, reim

OVERVIEW

Introduction

Musculoskeletal infections are common; they can affect all parts o
optimally. This chapter summarizes the pathogenesis, diagnosis, a

Because this subject is so important, other chapters in this book i
outlines the care of patients with prosthetic joint infections. Chapt

Pathogenesis

GENERAL

All clinical infections must be thought of in terms of the attacking
technique.

In acute osteomyelitis in children, the metaphysis is commonly inv
necrosis that may lead to abscess formation. As pus accumulates

The physis and joint capsule act as barriers to the flow of pus. Ho

In hematogenous septic arthritis, the synovial membrane lacks a b
produced by the leukocytes and synovial tissue recruit a further in

ORGANISMS

Although the musculoskeletal system may be infected by any infe
Klebsiella, Enterobacter, Serratia, Proteus, and *Salmonella.* Uncom
increase in the immunocompromised population because of iatrog

Table 8–1 lists common conditions associated with specific bacteri

Table 8–1. Bacterial Species Associated with Commo

Organism	Common Occurrence
Staphylococcus aureus	Most common organism in osteomyelitis, acute infected metal implants.

Ahmed S, Ayoub EM: Poststreptococcal reactive arthritis. Pediatr I

Bezwada HP et al: Haemophilus influenza infection complicating a

Brook I: Joint and bone infections due to anaerobic bacteria in chil

Dubost JJ et al: No changes in the distribution of organisms respo

Franz JK, Krause A: Lyme disease (Lyme borreliosis). Best Pract R

Geyik MF et al: Musculoskeletal involvement of brucellosis in differ

Gonzalez TB et al: Acute bacterial arthritis caused by group C stre

McCarthy JJ et al: Musculoskeletal infections in children: Basic trea

McLemore MM, Stapleton FB: Atypical septic arthritis due to *Neiss*

Press J et al: Leukocyte count in the synovial fluid of children with

Shirtliff ME, Mader JT: Acute septic arthritis. Clin Microbiol Rev 20

Tachi M et al: Pathophysiology and treatment of streptococcal toxi

Weinstein MA, Eismont FJ: Infections of the spine in patients with

HOST FACTORS

Any host with compromised immunity and wound healing or with a autoimmune connective tissue diseases; and usage of immunosup

Patients with chronic renal and liver disease, diabetes, cancer, AID

Nutritional depletion with negative nitrogen balance, weight loss, a with a major fracture has a 20–25% increase in energy expenditu who have normal nutritional status. Table 8–2 outlines methods to

Table 8–2. Tests to Measure Nutritional Depletion.

Serology		Albumin	< 3.5 g/dL	Prealbumin	< 10 mg/dL	Total ly

FOREIGN MATERIAL

Experimental studies indicate that all biomaterials commonly used

Adherence of bacteria to the surface of implants is promoted by a

Mixing antibiotics such as vancomycin and gentamicin to methacry

Implantation of small amounts of allograft bone and connective tis
implants were used in the United States, with a rate of infection w

Synthetic suture materials such as nylon and polyglycolic acid are

Archibald LK et al: Update: Allograft-associated bacterial infection

Kainer MA et al: Clostridium infections associated with musculoske

Mankin HJ, Hornicek FJ, Raskin KA: Infection in massive bone allo

Menovsky T et al: Skin closure in carpal tunnel surgery: A prospec

Prophylaxis

GENERAL

Transmission of bacterial and viral infections can easily occur in the
mandatory. Blades and needles (which should not be recapped) m

ANTIBIOTICS

The administration of prophylactic antibiotics immediately before s
administered approximately a half hour prior to skin incision, this

OPERATING ROOM STERILITY

Sterile technique in the operating room is extremely important. Th
rooms or rooms with ultraviolet lights as additional techniques tha

EXPOSURE TO BLOOD-BORNE PATHOGENS

Health care workers may be accidentally exposed to infection whe
infection. If exposure with a potentially infected source occurs, the

The threat of health care workers acquiring hepatitis B is now dra
hepatitis B vaccinations.

Currently there is no vaccination against HCV and no recommende

Workers with any viral exposures should be subsequently monitore

Table 8–3. Testing and Treatment of Exposed Persons

Virus	Seroconversion (percutaneous exposure)[a]
Hepatitis B	6–30%

[a]Larger inoculations from increased exposure confer higher risk of

[b]Patient may benefit from early treatment if symptoms develop.

[c]0.09% risk of seroconversion from mucosal exposure.

[d]Three drugs recommended if large exposure or source has AIDS.

Adapted, with permission, from Updated U.S. Public Health Servic

Clarke MT et al: Contamination of primary total hip replacements i

Gillespie WJ, Walenkamp G: Antibiotic prophylaxis for surgery for

Owers KL, James E, Bannister GC: Source of bacterial shedding in

Tai CC et al: Antibiotic prophylaxis in surgery of the intervertebral

Diagnosis

RADIOLOGIC WORKUP

Plain Films

Plain radiographs are useful in establishing a diagnosis of osteomy of a reactive rim of bone called the involucrum, which envelops a s

Plain radiographs are usually normal in early septic arthritis. Only

Soft-tissue infections are virtually invisible on plain radiographs ex

Figure 8–1.

Plain radiograph of the knee, showing air in the soft tissues of the

Ultrasound

Ultrasound is useful at identifying a joint effusion and particularly

Radionuclide Imaging

Radionuclide imaging is not routinely necessary to diagnose acute
process before an invasive procedure is performed.

The most common imaging agents are technetium-99m and indiun
bone.

Imaging with indium-111 requires collection of 80–90 mL of venou

Imaging with technetium-99m methylene diphosphonate is a highl

Although radionuclide imaging can be sensitive for chronic musculo

Computed Tomography

Computed tomography (CT) with sagittal and coronal reformatting
of a joint capsule and any evidence of bony destruction but is not

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) with T_2 and inversion recovery
bones, joint spaces, and soft tissues that may represent abscesses

Acute inflammation in bone and soft tissues is nonspecific. Acute ir
decreased signal uptake on T_2 images that represent areas of hem

As infection progresses in a joint, eroded cartilage and subchondra

Keat A: Reactive arthritis or post-infective arthritis? Best Pract Re

Palestro CJ et al: Osteomyelitis: diagnosis with (99m) Tc-labeled a

Roddy E, Jones AC: Reactive arthritis associated with genital tract

Sigal LH: Update on reactive arthritis. Bull Rheum Dis 2001;50:1.

IDENTIFICATION OF PATHOGENS

Whenever possible, antibiotic therapy must be delayed until deep

Deep cultures must be obtained percutaneously or intraoperatively and an infection can be distinguished from an unsuspected neopla

Superficial swabs of skin ulcers and draining sinus tracts usually id infected foot ulcers who have a high risk for mixed aerobic/anaero

A Gram stain of the culture samples is not diagnostic by itself but

Joint aspiration is usually necessary to identify the organisms resp average of 18,900/mL and 92% neutrophils compared to 300/mL a

Table 8–4. Analysis of Synovial Fluid.

Analysis	Normal Results	Noninflammatory Effusion	Inflammatory Effusion	Septic Effusion	
Gross Exam					Vc

Normal synovial fluid is clear and viscous. Inflammation causes syı percentage of polymorphonuclear leukocytes exceeding 75%. Man

HISTOLOGY

Pathologic examination of a tissue sample can help determine the

During revision arthroplasty, samples of periprosthetic tissue may

Histologic study can distinguish between acute inflammatory respo

Occasionally, the inciting organisms can be identified as well. For e a tumor that radiographically may mimic an infection such as eosi

Lu TS et al: Concurrent acute gouty and gonococcal arthritis. Lanc

Trampuz A et al: Synovial fluid leukocyte count and differential for

Treatment

ANTIBIOTICS

Selection and Use

Whenever possible, antibiotics should be chosen based on the anti
disease experts are often more closely attuned to the latest clinica
is emerging in some gram-negative bacilli, and penicillin resistance

Antibiotic therapy is usually continued for 6 weeks for patients wit

Erythrocyte sedimentation rates (ESRs) and C-reactive protein (CF
debridement of necrotic tissue, the immunocompromised status of

Occasionally, antibiotics must be given for palliation rather than cu

For example, an 80-year-old woman with a history of a revision to
that tracked down to the cut end of the femur. The antibiotic bead
febrile illness. Her infection was suppressed using culture-specific

Figure 8–2.

Anteroposterior pelvic radiograph depicting the Girdlestone arthro

Intravenous Route of Administration

Use of a peripheral intravenous central catheter (PICC) line is now
A subclavian central line such as a Hickman catheter is used as a b

Most home health agencies are expert in managing PICC lines and

Methicillin-Resistant *Staphylococcus Aureus/Epidermidis*

Methicillin-resistant *Staphylococcus aureus* (MRSA) is the most cor
current standard treatment for MRSA. However, this drug has rela

adjusted in patients with renal insufficiency based on creatinine cle
orally.

SURGERY

Septic Arthritis

Complete surgical evacuation of a purulent effusion offers the best
the patient. Whenever technically possible arthroscopy is preferrec

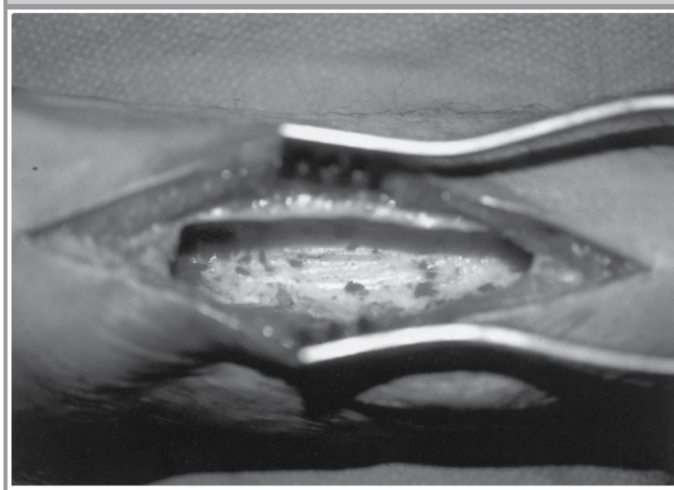
In chronic septic arthritis, a pannus of hypertrophic synovium forn

Osteomyelitis

Successful treatment of bone and soft-tissue infections requires th
exploration of the bullet wounds is necessary to remove any embe

Skin, subcutaneous fat, and muscle should be sharply debrided un
simplest and most popular method of determining the viability of c

Figure 8–3.



Intraoperative photograph of the so-called paprika sign, represent

Infections occasionally are so severe or are located in such unforgi
free flap coverage after peripheral arterial bypass would have bee

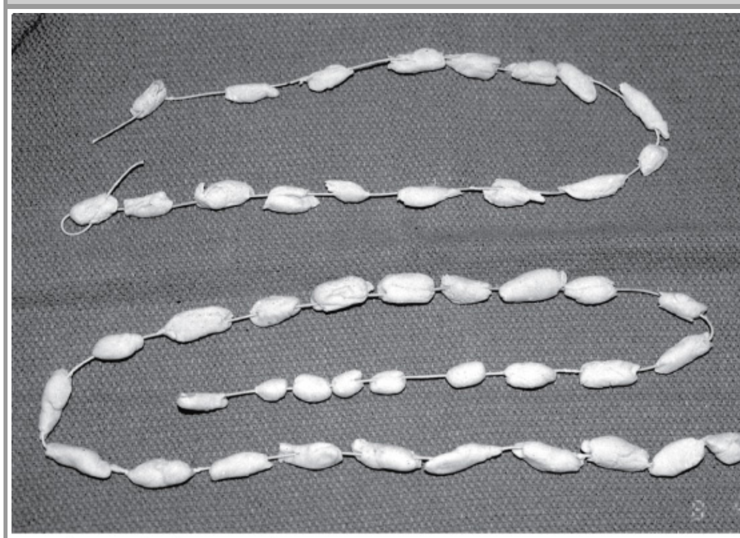
Figure 8–4.

Calcaneus ulcer with exposed bone and blackened eschar.

Implantable Antibiotics

An excellent method to supplement the IV administration of syster
monomer. The antibiotic dough can be fashioned into a string of be
commercially available. Palacos cement has superior antibiotic elut
the antibiotic cement implant, enhances the elution of the antibioti
as a foreign body and precipitate a new infection.

Figure 8–5.



Two strings of antibiotic beads were molded onto a number 5 brai

Soft-Tissue and Bone Reconstruction—

Assuming musculoskeletal infections were treated comprehensivel

Expeditious soft-tissue coverage is the first reconstructive priority achieved with orthotics, skeletal traction, or external fixation.

An acute infection occasionally develops after orthopedic fixation o hardware with the placement of an external fixator can provide sta

ADJUNCTIVE THERAPIES

Local Wound Care

Newer alginate dressing materials are more absorbant and may be these caustic agents inhibits fibrogenesis. Instead, petroleum gel o

Treatment of open wounds is now transformed using a new metho contraction of the walls of the wound. All drainage fluids are sucke

Figure 8–6.

Portable wound suction pump (also known as a wound *vacuum-as*

Hyperbaric Oxygen

Hyperbaric oxygen (HBO) therapy is used to treat a variety of ortl anaerobic bacteria. It does not cause oxygen to be absorbed from

Acute problems that can be helped by HBO include severe crush ir 48-hour delay in initiating HBO can render it ineffective.

Chronic wounds that can be helped by HBO are primarily related t
bone transport for bone defect restoration, have empowered the s

Nutritional Support

Patients with severe infections and large wounds have increased n

Antony SJ, Diaz-Vasquez E, Stratton C: Clinical experience with lin

Centers for Disease Control and Prevention: Vancomycin-resistant

Connolly LP et al: Acute hematogenous osteomyelitis of children: A

Gristina AG et al: The glycocalyx, biofilm, microbes, and resistant

Hanssen AD, Spangehl MJ: Practical applications of antibiotic-loade

Herscovici D Jr et al: Vacuum-assisted wound closure (VAC therap

Hiramatsu K: Vancomycin-resistant *Staphylococcus aureus*: A new

Jenson JE et al: Nutrition in orthopaedic surgery. J Bone Joint Surg

Jones S et al: Cephalosporins for prophylaxis in operative repair of

Kartsonis N et al: Efficacy of caspofungin in the treatment of esop

Ledermann HP et al: Pedal abscesses in patients suspected of hav

Mazza A: Ceftriaxone as short-term antibiotic prophylaxis in ortho

Mohanty SS, Kay PR: Infection in total joint replacements: Why do

Neut D et al: Biomaterial-associated infection of gentamicin-loaded

Perea S, Patterson TF: Antifungal resistance in pathogenic fungi. C

Petty W et al: The influence of skeletal implants on the incidence o

Roeckl-Wiedmann I, Bennett M, Kranke P: Systematic review of hy

Schmidt AH, Swiontkowski MF: Pathophysiology of infections after

Segreti J: Efficacy of current agents used in the treatment of Grar

Shirtliff ME, Mader JT: Acute septic arthritis. Clin Microbiol Rev 20(

Stewart PS, Costerton JW: Antibiotic resistance of bacteria in biofil

Stott NS: Review article: Paediatric bone and joint infection. J Orth

Stratton RJ et al: Malnutrition in hospital outpatients and inpatient

Stumpe KD et al: FDG positron emission tomography for differenti

Tarkowski A et al: Current status of pathogenetic mechanisms in s

Tomas MB et al: The diabetic foot. Br J Radiol 2000;73:443. [PMID

Turpin S, Lambert R: Role of scintigraphy in musculoskeletal and s

van de Belt H: Infection of orthopedic implants and the use of ant

Vandecasteele SJ et al: New insights in the pathogenesis of foreigr

Webb LX: New techniques in wound management: Vacuum-assiste

Zhuang H et al: Exclusion of chronic osteomyelitis with F-18 fluoro

Zhuang H et al: Persistent non-specific FDG uptake on PET imagin

CLASSIFICATION SYSTEMS

Several classification systems are used to describe osteomyelitis. T
subacute osteomyelitis is between several weeks and several mont

Table 8–5. Classification Systems for Osteomyelitis.

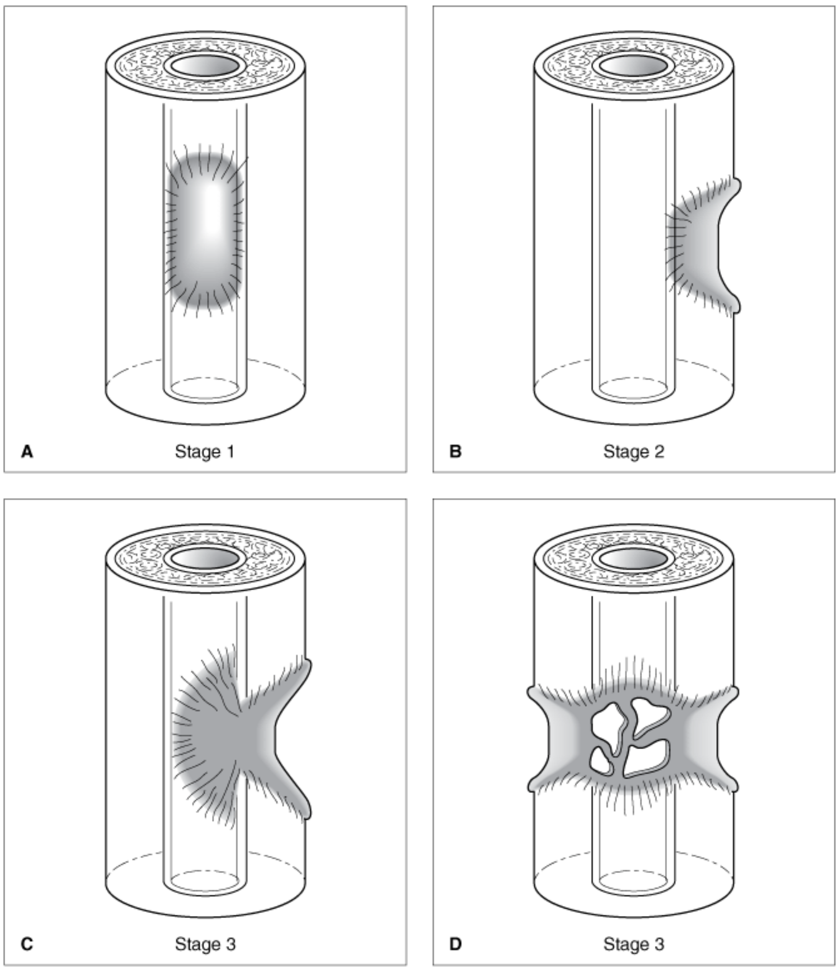
Traditional system	**Type**	**Time of onset**	Acute	≤ 2 weeks	Subacute	Weeks t months

Another system, developed by Waldvogel, categorizes bone infecti
Therefore, Waldvogel created this subcategory to acknowledge the

Cierny and Mader developed a staging system for osteomyelitis th
1). The latter two categories are best distinguished by the presenc

Box 8-1. The Cierney and Mader Staging System.

The Cierney and Mader Staging System.



The Cierny and Mader staging system for osteomyelitis is classifie

Host factors that mitigate healing are subcategorized into three gr
debridement that would risk destabilizing the bone, worsening a n

Systemic factors that compromise the host include diabetes mellitu
use.

Belzunegui J et al: Musculoskeletal infections in intravenous drug a

Casado E et al: Musculoskeletal manifestations in patients positive

Gilad J et al: Polymicrobial polyarticular septic arthritis: A rare clin

Lazzarini L, Mader JT, and Calhoun JH: Osteomyelitis of long bones

ACUTE OSTEOMYELITIS

Acute Hematogenous Osteomyelitis

Acute hematogenous osteomyelitis (AHO) is most frequently encou demonstrate guarding of an infected arm, refusing to use it and h

Serology characteristically shows dramatic elevations in the CRP a

Plain radiographs taken early in the course of disease are usually periosteum and adjacent soft tissues as the infection progresses. I

The clinical and radiologic appearance of AHO may be similar to in

Standard evaluation of a patient with suspected AHO includes a ne infections, 2 weeks of parenteral antibiotics may be followed by 4

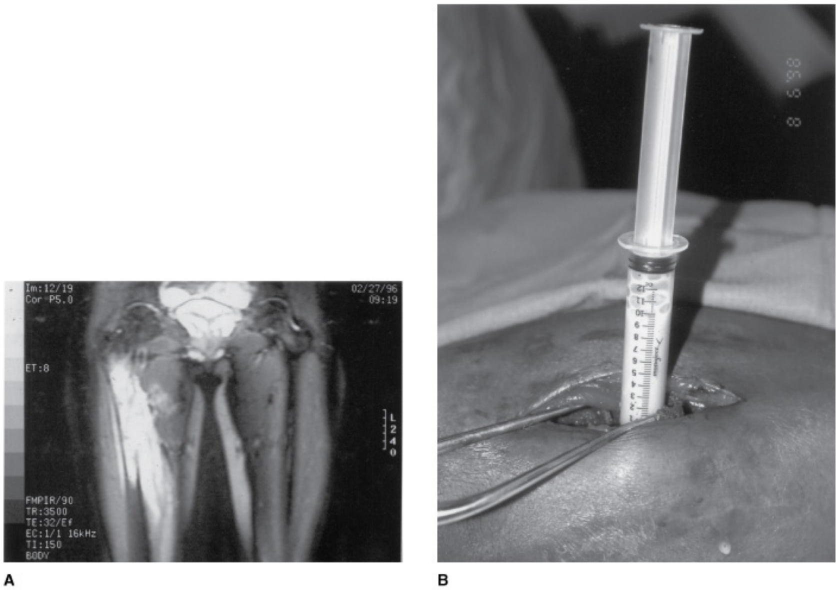
If the patient does not improve, temporary discontinuation of anti culture yield. This further highlights the potential problems of beg

In patients with stable prosthetic joints who acquire an acute hem

Clinical Example

A 13-year-old girl complained of acute knee pain beginning 7 days normal. An MRI of the thigh showed significant inflammation of th

Figure 8–7.



A: T_2-weighted MRI of the thigh, showing marrow edema in the fe

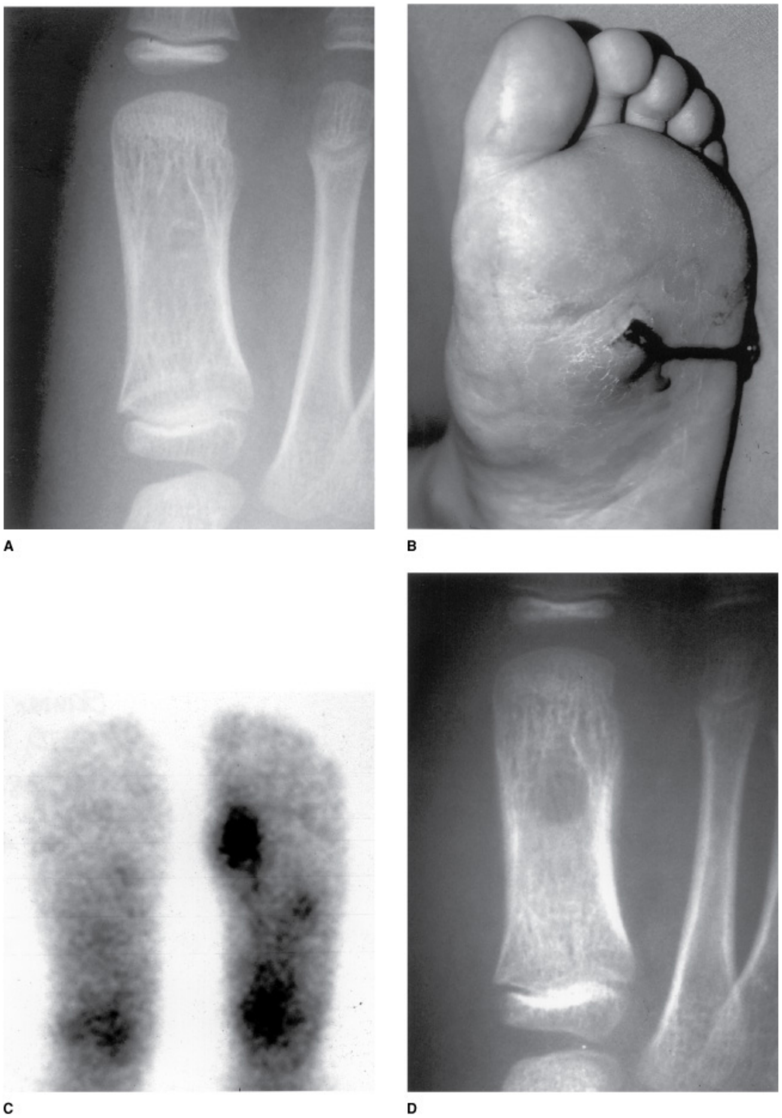
Acute Osteomyelitis Caused by Puncture Wound

Acute osteomyelitis must be considered in the evaluation of a pati

Clinical Example

An 11-year-old boy punctured his foot when he stepped on a shar 8B). He was admitted to the hospital and placed empirically on tri

Figure 8–8.



A: Initial plain radiograph of the first metatarsal. **B:** Preoperative

A technetium bone scan identified a significant uptake of radiotrac
mycobacteria other than tuberculosis (MOTT). He clinically improve

This case illustrates the need to obtain accurate wound cultures in

Agrawal A et al: Cryptococcal arthritis in an immunocompetent ho

Babhulkar SS, Pande SK: Unusual manifestations of osteoarticular

Blumberg HM, Leonard MK Jr, Jasmer RM: Update on the treatme

Caspofungin: New preparation. A last resort for invasive aspergillo

Centers for Disease Control and Prevention: Trends in Tuberculosis

Dhillon MS et al: Tuberculosis of the sternoclavicular joints. Acta O

Hansen BL, Andersen K: Fungal arthritis. A review. Scan J Rheuma

Nolan CM, Goldberg SV: Treatment of isoniazid-resistant tuberculo

Silber JS et al: Insidious destruction of the hip by *Mycobacterium*

SUBACUTE OSTEOMYELITIS

Subacute infections are often associated with pediatric patients. Th
circumferential zone of reactive sclerotic bone may be visualized. W

Clinical Example

A 14-year-old boy presented with a 2-month history of left ankle p

Anteroposterior (AP) and lateral radiographs of the tibia show mixe
far proximally as the midtibia (Figure 8–9D). During open surgical

Figure 8–9.

A: Anteroposterior radiograph of the distal tibia. **B:** Lateral radiog

Lazzarini L, Lipsky BA, Mader JT: Antibiotic treatment of osteomye

Mader JT et al: Antibiotic therapy for musculoskeletal infections. In

Vinod MB et al: Duration of antibiotics in children with osteomyelit

CHRONIC OSTEOMYELITIS

Chronic osteomyelitis is the result of untreated acute or subacute
antibiotics. Therefore, removal of the metal and dead bone are ne

Surgical debridement of necrotic bone for infection control is akin t

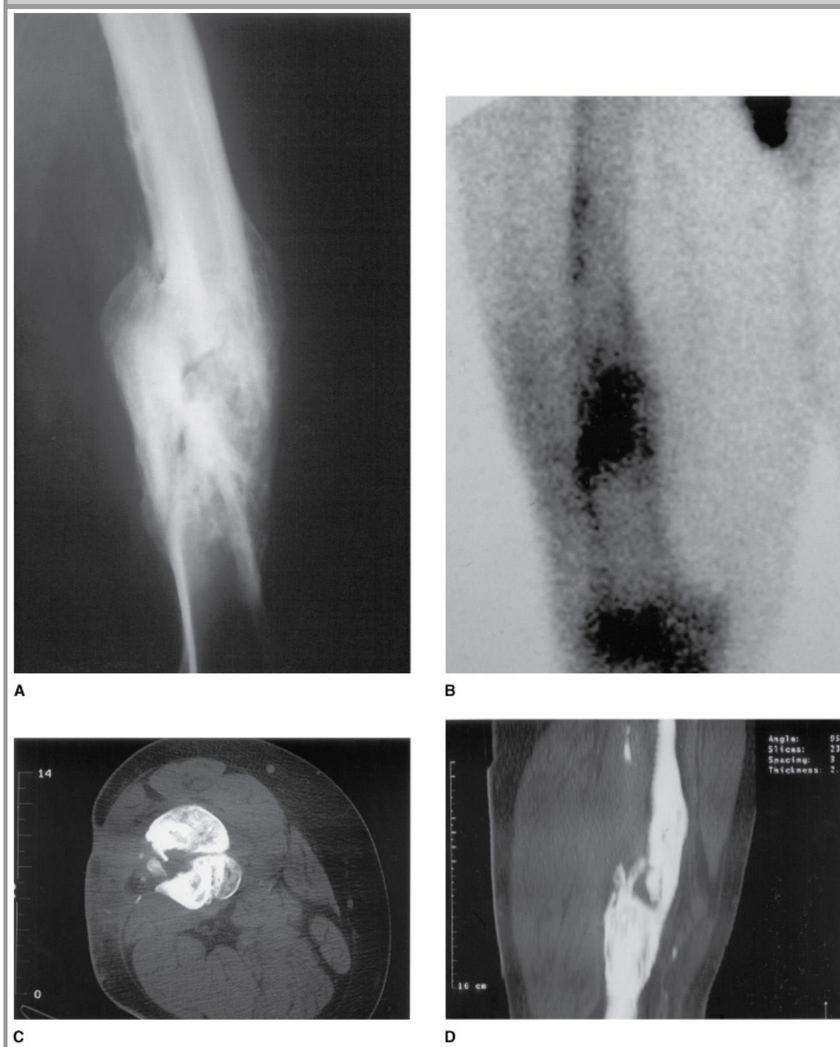
Clinical Example

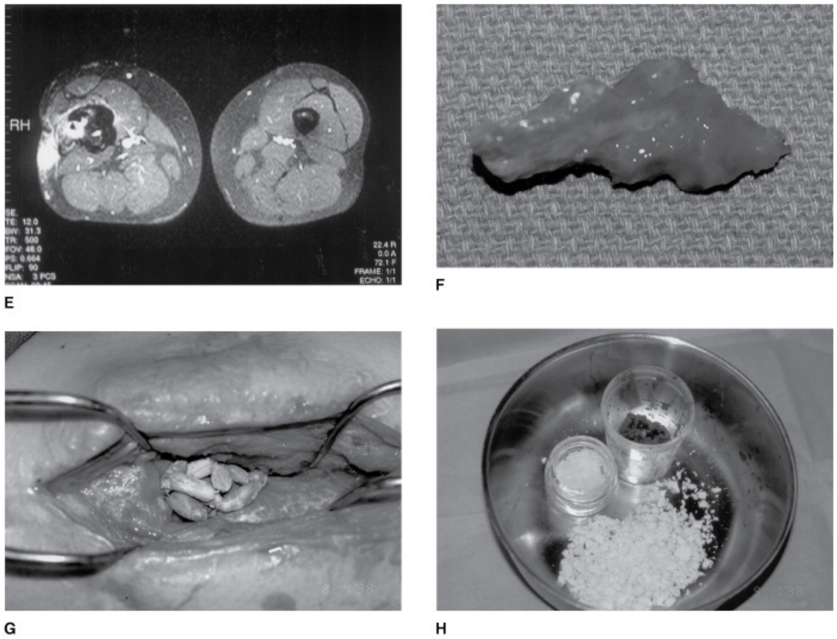
A 62-year-old man sustained a closed femur fracture when he fell
between successive debridements. For the last 4 years he had an

At the time of presentation he had had a fever of 38.5ºC (101.3ºF
7.9 (5–10 k is normal). A sensitive *S. aureus* was cultured.

Radiographs depict an irregularly expanded callus of sclerotic bone
area outlining the relatively small area of focal inflammation (Figur

Figure 8–10.





A: Lateral radiograph of the femur. **B:** Indium-labeled white blood

Curettage of the femur produced a 3.5-cm sequestrum (Figure 8–
later (Figure 8–10G). The adjacent soft tissues were curetted to re

Three weeks later, the beads were removed and a mixture of post

OSTEOMYELITIS CAUSED BY OPEN FRACTURES

Osteomyelitis caused by trauma may present acutely or chronically
including road dirt, clothing, and bullet shell wadding, must be cor
of large soft-tissue defects, early flap coverage is ideal to prevent
wound. This system is easy to apply and only needs to be changec

Fractures can heal even in the presence of a soft-tissue or bone in
comprehensive debridement, the bone should be held to length wi

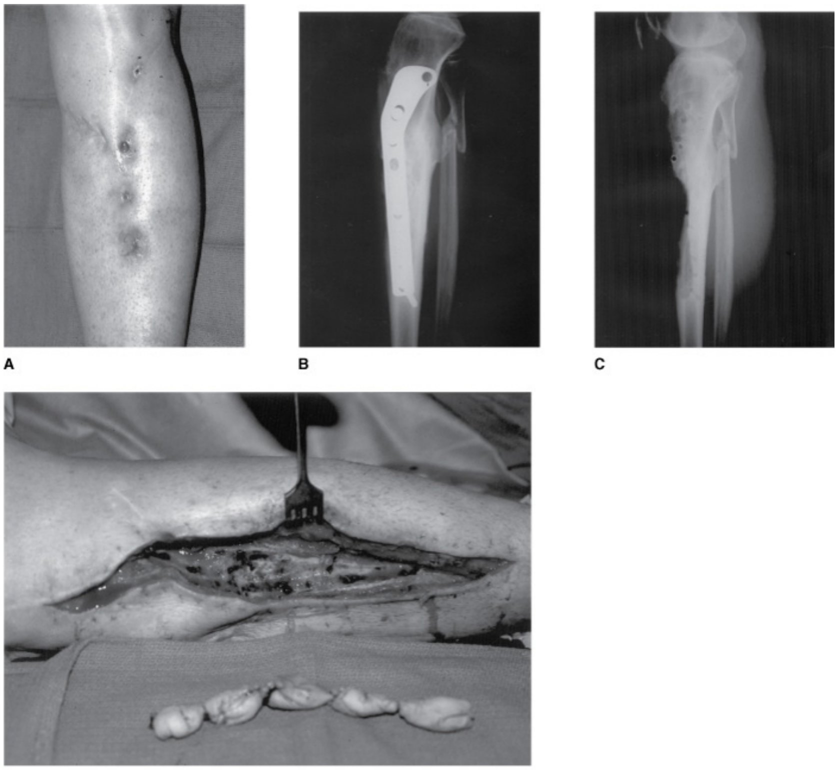
Chronic osteomyelitis caused by open trauma may often be associ
flap to reconstruct the soft tissue defect.

Antibiotic therapy for osteomyelitis remains controversial. Antibioti
takes on significant importance. Oral antibiotic therapy could be le

Clinical Example

A 42-year-old woman sustained an open fracture of the proximal t
primarily closed. Half way through the 6-week course of IV antibio

Figure 8–11.



A: Leg with draining sinus tracts. **B:** Preoperative radiograph show

SQUAMOUS CELL CARCINOMA ARISING FROM A CHRO

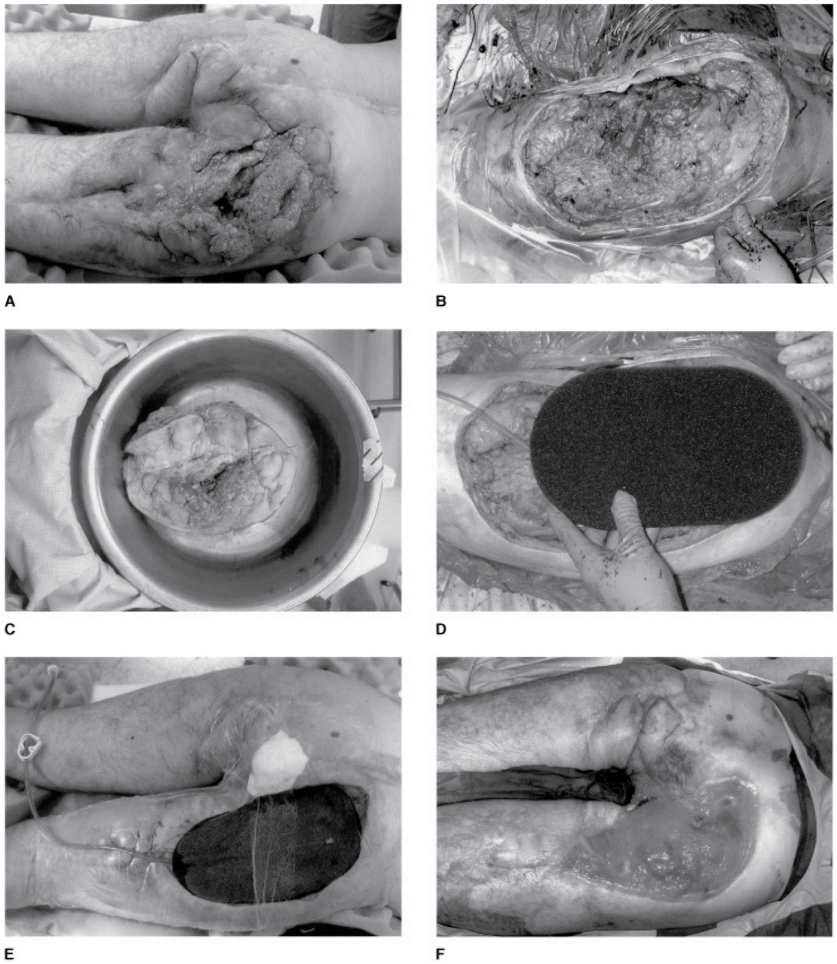
Squamous cell carcinoma may arise in the chronically infected gra tissue. The focus of carcinoma appears to be an exuberance of pro distinguish readily between squamous cell carcinoma and chronic g

Staging studies, including contrast CT scan of the chest, abdomen surgical excision in most cases.

Clinical Example

A 49-year-old man presented with a 30-year history of ischial decu friable spongelike neogranulation was identified adjacent to a scar dissection. All lymph nodes were negative. The tumor subsequentl

Figure 8–12.



A: Photograph of chronic ulcerative wound with neogranulation tis

Copcu E et al: Thirty-one cases of Marjolin's ulcer. Clin Exp Derma

Gonzalez MH, Weinzweig N: Muscle flaps in the treatment of osteo

Kuokkanen HO et al: Radical excision and reconstruction of chroni

Moroni A et al: State of the art review: Techniques to avoid pin loo

Strauss MB, Bryant B: Hyperbaric oxygen. Orthopedics 2002;25:3

Thio D et al: Malignant change after 18 months in a lower limb ulc

DIAGNOSIS

There is no formal classification system for septic arthritis. Most jc
require systemic medical treatment to control the joint symptoms.

Diagnosis of septic arthritis depends much more on arthrocentesis

ACUTE SEPTIC ARTHRITIS

Hematogenous septic arthritis commonly affects patients with com
increased risk for superimposed infections. Patients routinely comp

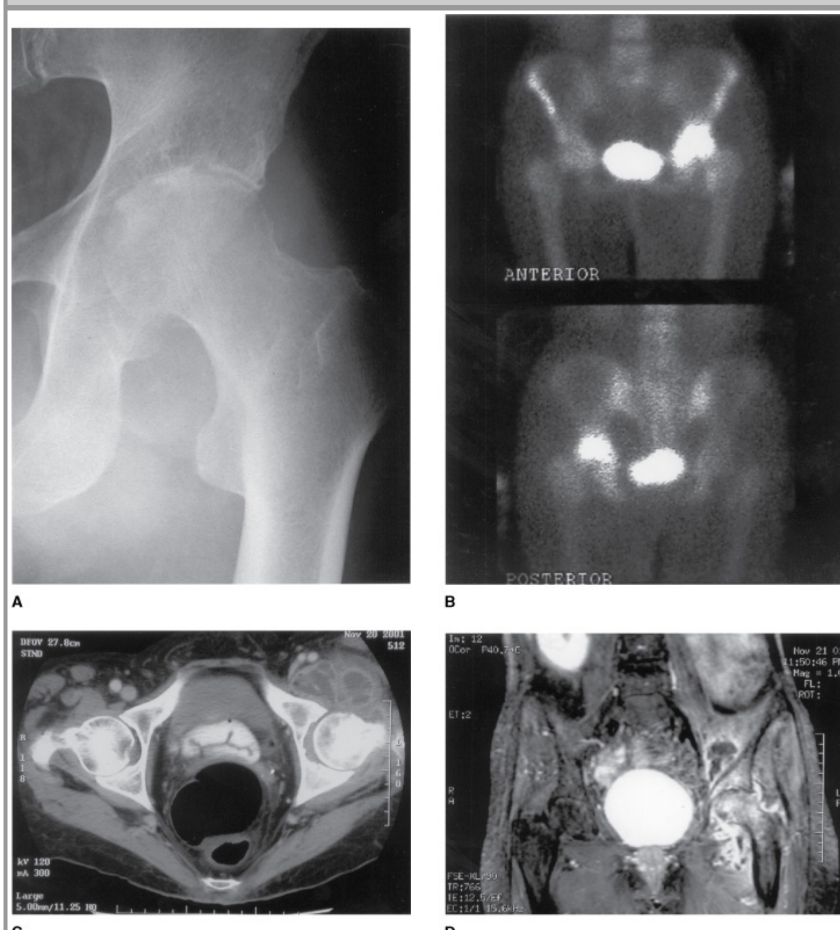
The most common joint affected by hematogenous septic arthritis

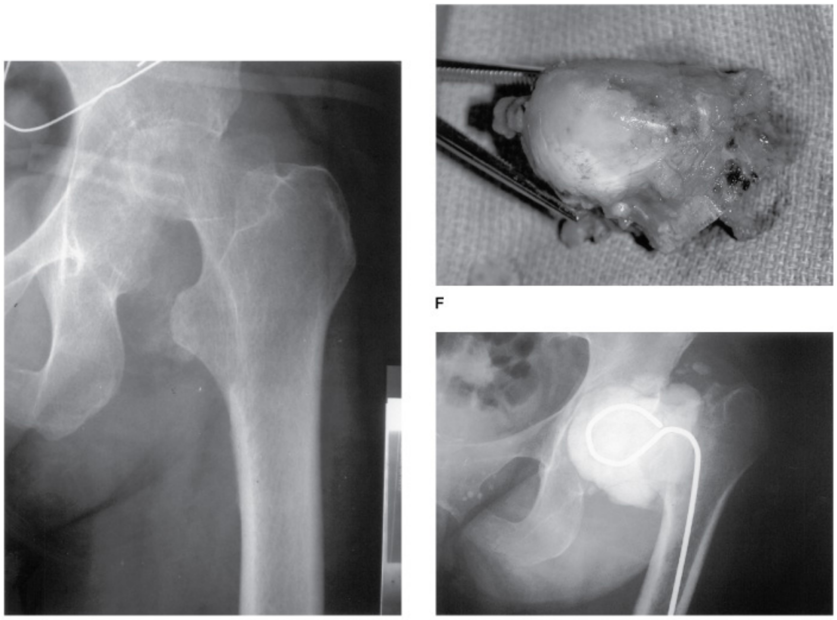
Although infections often spread from joints to affect adjacent met

Clinical Example

A 53-year-old woman with RA and a painful left hip presented with
region of the hip (Figure 8–13B). A CT of the pelvis outlines a locu
radiograph at that time showed a dramatic collapse of the femoral
frozen section analysis. At that time a total hip prosthesis was suc

Figure 8–13.





E

G

F

A: Initial anteroposterior radiograph of hip joint with narrowed ca
muscle by a dark central area of signal void surrounded by a halo

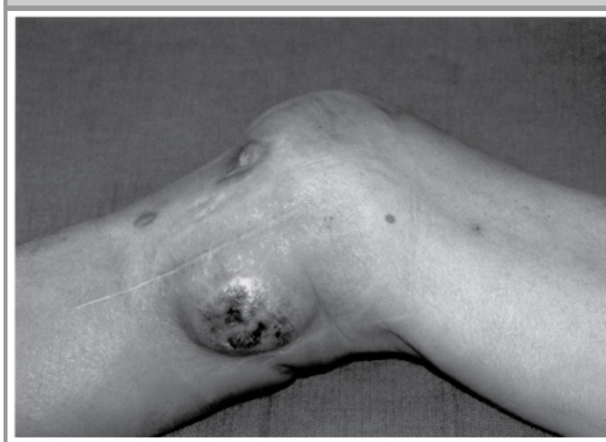
CHRONIC SEPTIC ARTHRITIS

Unlike acute septic arthritis, which is intensely painful, chronic sep
effusion, resulting in a delay in diagnosis.

Clinical Example

A 52-year-old man with AIDS on retroviral therapy presented with
During arthrotomy, the medial swelling was found to communicate

Figure 8–14.



A

B

A: A large focal erythematous soft-tissue swelling and a longitudir

Even though this patient's symptoms appeared acute, he actually
immunosuppression is known, a comprehensive diagnostic survey

Aubry A et al: Sixty cases of *Mycobacterium marinum* infection: Cl

Biviji AA et al: Musculoskeletal manifestations of human immunode

Le Dantec C et al: Occurrence of mycobacteria in water treatment

Laine M, Luukkainen R, Toivanen A: Sindbis viruses and other alph

Mylonas AD et al: Natural history of Ross River virus-induced epid

Stahl HD et al: Detection of multiple viral DNA species in synovial

SEPTIC ARTHRITIS CAUSED BY ADJACENT INFECTION

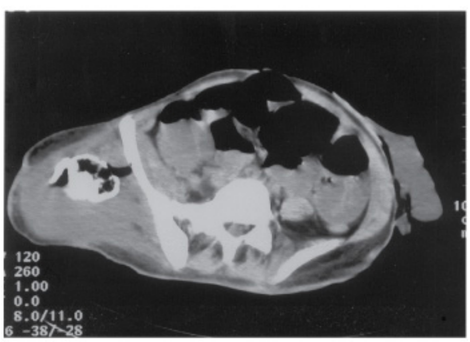
Contiguous spread of infection to a joint most commonly occurs in

Clinical Example

A 28-year-old man with paraplegia and a long-standing history of
Plain films revealed a chronically dislocated hip with cephalad migr
the lateral ulcer. A wound VAC was placed on both ulcers, and cult

Figure 8–15.

A



C

B

D

A: Large sacral and right ischial ulcer. **B:** Anteroposterior radiogra

Goergens ED et al: Acute osteomyelitis and septic arthritis in child

Li SF et al: Laboratory tests in adults with monoarticular arthritis:

Salter RB, Bell RS, Keeley FW: The protective effect of continuous

Shirtliff ME, Mader JT: Acute septic arthritis. Clin Microbiol Rev 20(

Swan A, Amer H, Dieppe P: The value of synovial fluid analysis in

Yu KH et al: Concomitant septic and gouty arthritis—An analysis o

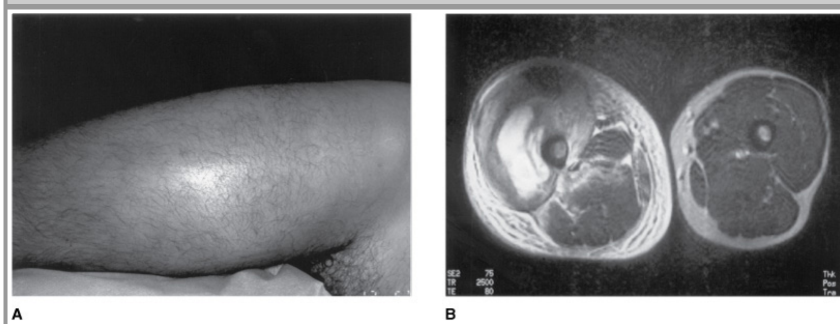
CELLULITIS

Skin infections are common, and it is important to distinguish cellu

Clinical Example

A 43-year-old man fell 3 weeks ago, injuring his leg. He presented
ultrasound ruled out a deep venous thrombosis but identified diffu
had become hematogenously seeded with *S. aureus.* The infection
circumstance a search for an underlying cause was necessary to u

Figure 8–16.



A: Cellulitis and diffuse thigh swelling. **B:** Axial T_2-weighted MRI o

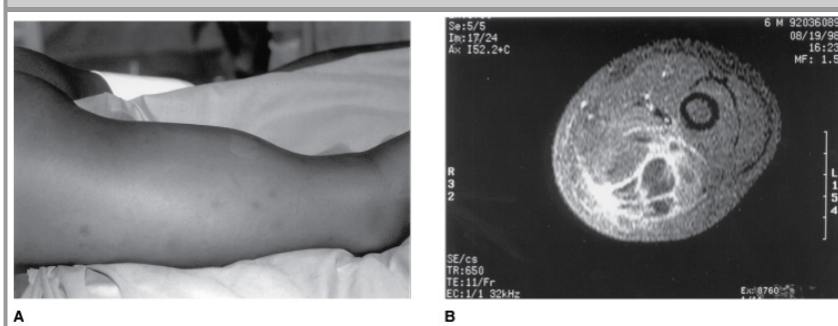
PYOMYOSITIS

Pyomyositis is usually caused by hematogenous spread of bacteria
for drainage can be done with ultrasound or CT guidance.

Clinical Example

A 6-year-old boy presented with a 2-week history of a posterior th
collection represents intense localized inflammation. The patient u
infection.

Figure 8–17.



A: Prone patient with focal swelling of the posterior region of the

BURSITIS

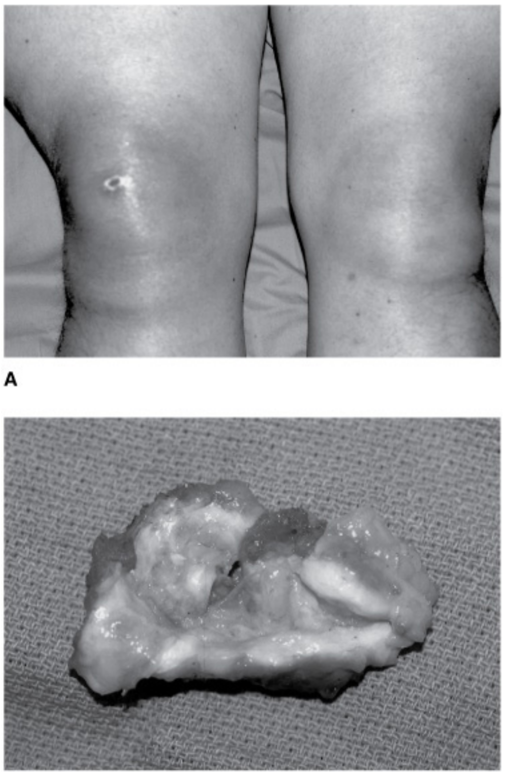
A bursa occasionally becomes infected by hematogenous spread o
olecranon tophus may yield fluid that is strikingly similar to pus. G

If infectious bursitis is identified within the first several days, an o

Clinical Example

An 18-year-old woman skinned her knee on the gym floor during a
inflammation worsened. A complete bursectomy was performed (F

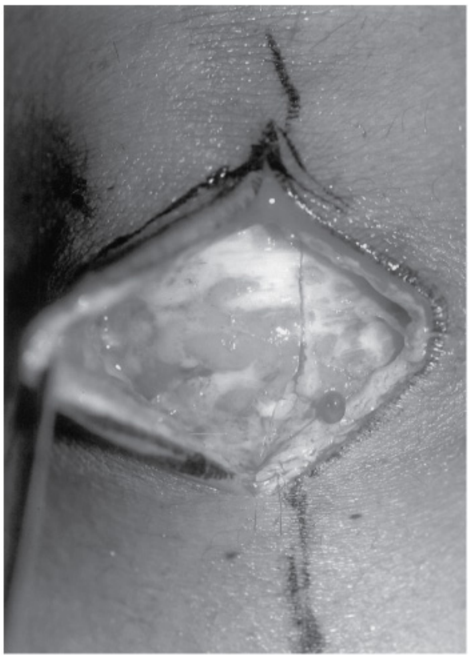
Figure 8–18.



A

C

B



D

A: Anterior view of acute prepatellar bursitis. Notice small dark es

NECROTIZING FASCIITIS

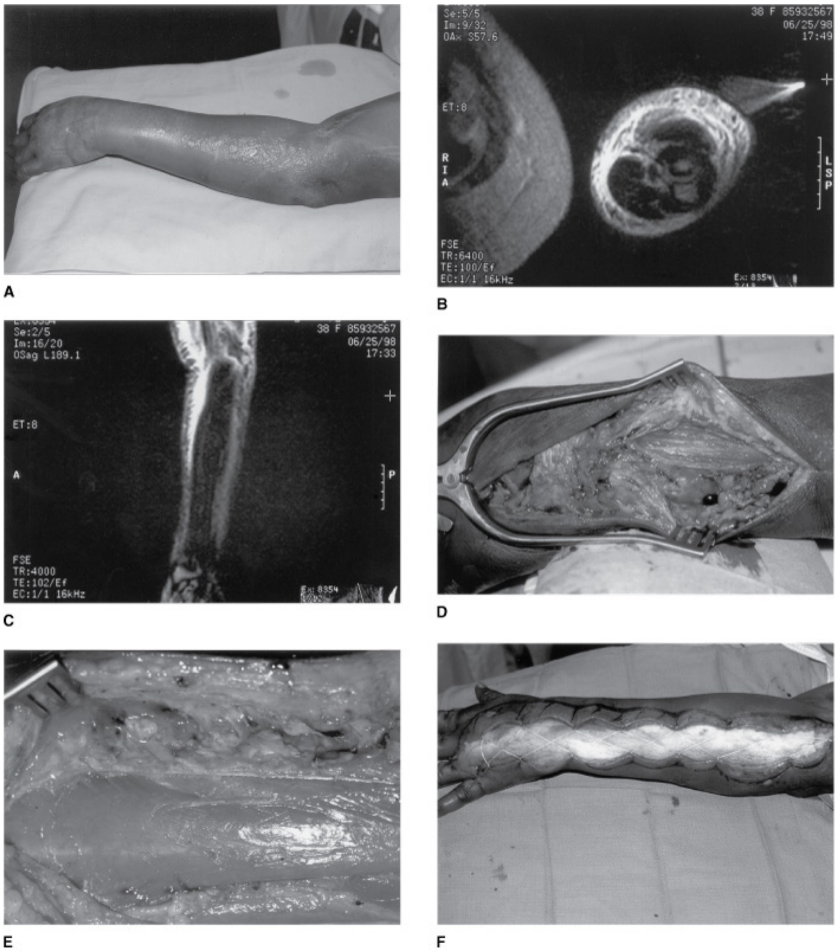
Necrotizing fasciitis is a rare but extremely aggressive, life-threate
usually be seen on plain radiographs in gas-producing clostridial in

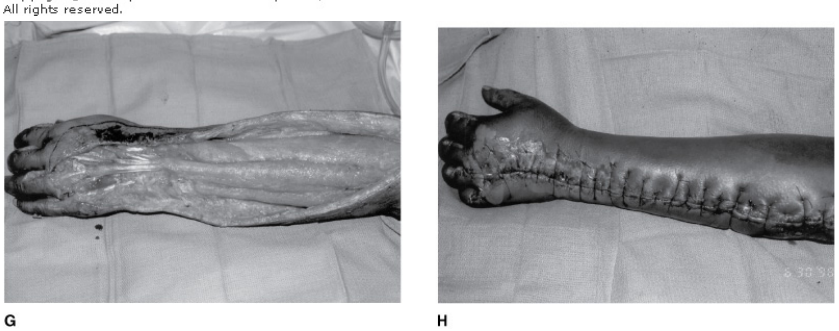
Clinical Example

A 38-year-old woman with a history of insulin-dependent diabetes
of 22,000 with a left shift, and normal plain radiographs of the for

The patient was admitted to the hospital and started empirically o
the skin and all of the muscle tissues were viable, necrosis of the s
secured with sterile rubber bands and staples in a shoelace fashio
primary closure with use of split-thickness skin grafts where neces

Figure 8–19.





A: A small draining puncture wound is noted at the middorsum of
of wound with saline-dampened gauze sponges secured with stapl

Tiu A et al: Necrotizing fasciitis: Analysis of 48 cases in South Aucl

BIOMECHANIC PRINCIPLES OF THE FOOT & ANKLE

The following is a limited discussion of the biomechanic principles o
normal biomechanic function is understood, anatomic and function

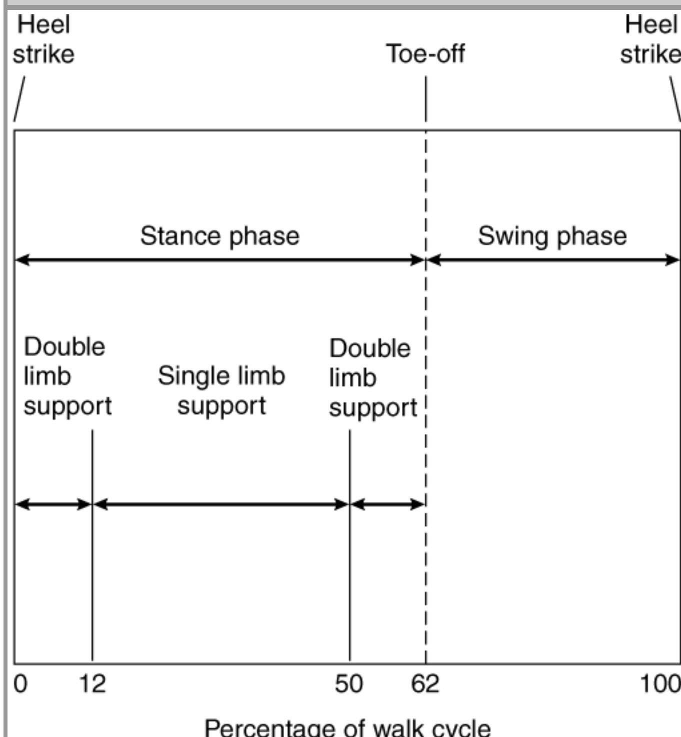
Gait

Gait is the orderly progression of the body through space while ex
body. To accommodate these forces, the foot is flexible at the time
on the foot increases significantly as the speed of gait increases. F
approximately 160%. The peak force against the foot during walki

The Walking Cycle

The walking cycle is discussed more extensively in Chapter 1, but

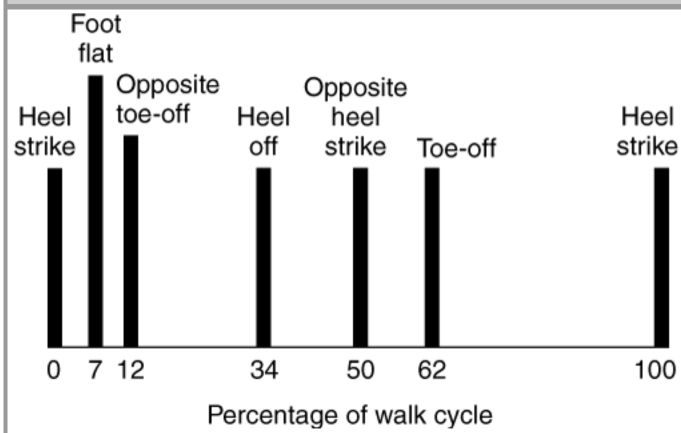
Figure 9–1.



Phases of the walking cycle. Stance phase constitutes approximate
(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Observation of the patient while walking may give the clinician insi
than the heel. At 7% of the gait cycle, the foot is usually flat on th
foot begins at 34% of the cycle as the swinging leg passes the sta
single-limb support; this may occur sooner if there is weakness of
observing gait, so pathologic conditions may be identified.

Figure 9–2.



Events of the walking cycle.

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

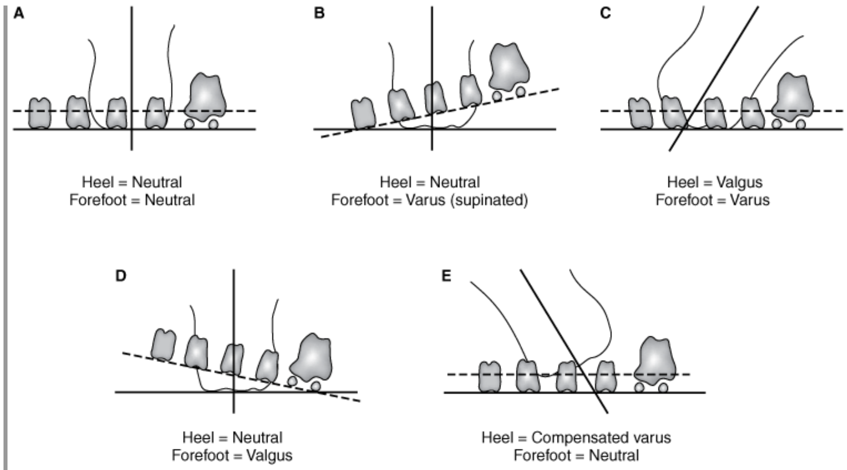
Motions of the Foot & Ankle

The names for various motions about the foot and ankle may be c
are inversion (varus) and eversion (valgus), respectively. The mot

Supination and *pronation* are terms for two different combinations
abduction of the transverse tarsal joint. *Supination* is the opposite

The nomenclature may also be confusing when such terms as *fore*
achieved when the calcaneus is aligned with the long axis of the ti
aspect. With a flexible deformity, the foot lies flat on the floor duri
position, and this may result in lateral impingement of the calcane
metatarsal head. To accommodate for this deformity, the calcaneu

Figure 9–3.



Biomechanics of foot posture. **A:** Normal alignment: forefoot perp
floor, the heel assumes a valgus position. **D:** Forefoot valgus (unc
(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Mechanisms of the Foot during Weight Bearing

As mentioned previously, the normal foot is flexible at the time of
unlocking of the transverse tarsal (talonavicular and calcaneocuboi
control the initial rapid plantar flexion following heel strike by an e
body passes over the foot, which lifts the heel up and forces the m
the foot from a flexible to a rigid structure are (1) the tightening o
the subtalar joint, and (3) the stabilization of the transverse tarsal

Joints About the Foot & Ankle

ANKLE JOINT

The ankle joint consists of the articulation of the talus with the tibi
degrees. The anterior compartment muscles of the leg, the tibialis
the ankle joint during swing phase. If this muscle group does not f
4.5 times body weight; this force is present at 40% of the walking

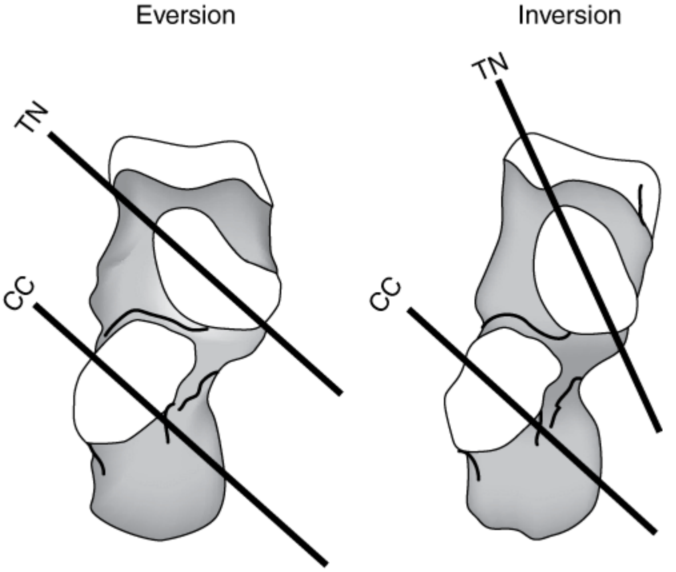
SUBTALAR JOINT

The subtalar joint is the articulation between the talus and the cal
approximately 10 degrees. The tibialis posterior causes inversion a
ligamentous support. Inversion occurs both actively and passively
of the lower extremity, and the oblique metatarsal break.

TALONAVICULAR JOINT AND CALCANEOCUBOID JOINT

The talonavicular and calcaneocuboid joints functionally act as a ur
firmly seated into the navicular at the time of toe-off, adding stabi
nonparallel, giving rise to increased stability of the hindfoot. When
implication is that when carrying out a subtalar arthrodesis, placer
position of 5–7 degrees of valgus, the flexibility of the transverse t

Figure 9–4.



The function of the transverse tarsal joint as described by Elftmar
position, the axes are incongruent, giving increased stability to th

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

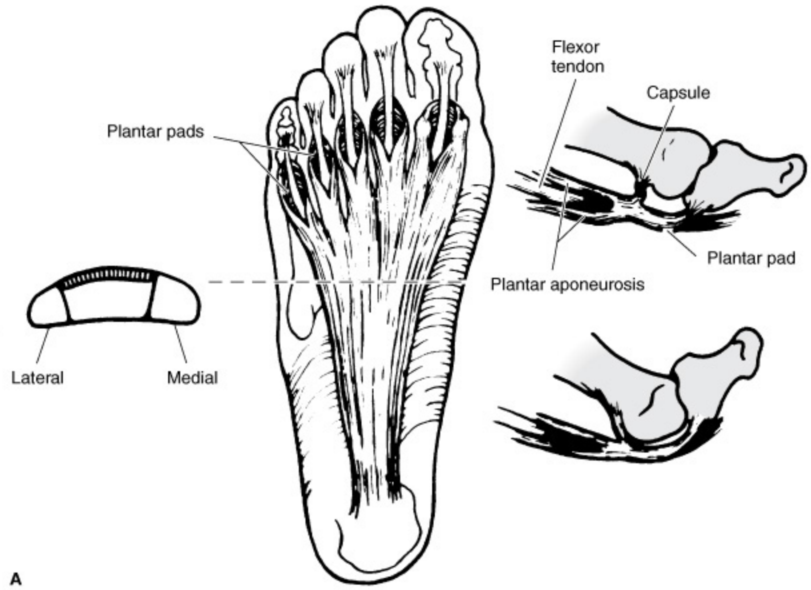
METATARSOPHALANGEAL JOINTS

The motion at the metatarsophalangeal joints is between 50 and 7
first toe.

THE PLANTAR APONEUROSIS

Although the plantar aponeurosis is not an articulation per se, it pr
proximal phalanx (Figure 9–5). As the metatarsophalangeal joints
This is known as a windlass mechanism. It also increases the effec
mechanism also helps bring about inversion of the subtalar joint.

Figure 9–5.



Windlass mechanism. **A:** The plantar aponeurosis, which arises frc
the metatarsal head, depressing the metatarsal heads and elevati
(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

GAIT ABNORMALITIES

The following is a brief description of the more common gait abnor

Dropfoot Gait

Patients with dropfoot gait lack ankle dorsiflexion, resulting in plan
clear the ground. If this compensatory mechanism does not occur,

Equinus Gait

In an equinus gait pattern, the ankle joint is fixed in plantar flexio
the posterior capsule. This gait pattern is characterized by forefoo
weak quadriceps muscle may accentuate this problem.

Cavus Deformity

A cavus deformity is an excessive elevation of the longitudinal arch
frequently observed in Charcot-Marie-Tooth disease but may also b
patients. Clawing of the toes may further reduce contact with the
underneath the first metatarsal head as the gait cycle progresses.

Pes Planus Deformity

Usually, the patient with a pes planus deformity demonstrates just
arch with an associated abduction of the forefoot. This results in a

Carlson RE, Fleming LL, Hutton WC: The biomechanical relationshi

Hunt AE, Smith RM, Torode M: Extrinsic muscle activity, foot motio

Mann RA: Biomechanics of the foot and ankle. In Mann RA, Cough

Nester CJ, Findlow AF, Bowder P et al: Transverse plane motion at

Saunders JB, Inman VT, Eberhart HD: The major determinants in

DEFORMITIES OF THE FIRST TOE

Biomechanic Principles

The first metatarsophalangeal joint functions mainly as a weight-b
plantar plate, which consists of the plantar aponeurosis and the jo
muscle inserts into the metatarsal head per se, and therefore it is

As previously discussed, the plantar aponeurosis forces the metata
especially the hallux (see Figure 9–5). If this windlass mechanism
especially beneath the lesser metatarsal heads. The second metata

Any type of surgical procedure that disrupts this mechanism may
replacement of the first metatarsal joint. Metatarsal osteotomy wit

Normal Anatomy

The first metatarsophalangeal joint consists of the articulating surf
dual tendons of the flexor hallucis brevis and lie on either side of t
along the lateral and medial sides of the joint. Further toward the
passes the flexor hallucis longus tendon. Dorsally, the extensor ha
the lateral aspect of the joint. Normal motion of the metatarsopha

Hallux Valgus

The most common deformity of the metatarsophalangeal joint is h
head. The medial eminence becomes prominent as the proximal ph
are firmly anchored by the adductor hallucis tendon and transvers

hallucis longus and flexor hallucis longus, which insert into the bas
intrinsic muscles lie lateral to the longitudinal axis of the first meta
dorsomedial aspect) allows the abductor hallucis tendon to slide be
metatarsocuneiform joint demonstrates a significant degree of inst

Etiology of Hallux Valgus Deformity

Hallux valgus deformity occurs in women approximately 10 times r
cause of hallux valgus deformity is wearing tight pointed-toed sho
spasticity, hypermobility of the first metatarsocuneiform joint, and

Clinical Findings

HISTORY

The clinical evaluation of hallux valgus deformity begins with a car
deformities of the lesser toes, or the inability to wear certain shoe

PHYSICAL EXAMINATION

The physical examination starts with the patient in a standing posi
contact or early heel rise, which would indicate possible tightness
assessed, noting venous stasis changes. Doppler studies are obtai
along the medial aspect of the great toe.

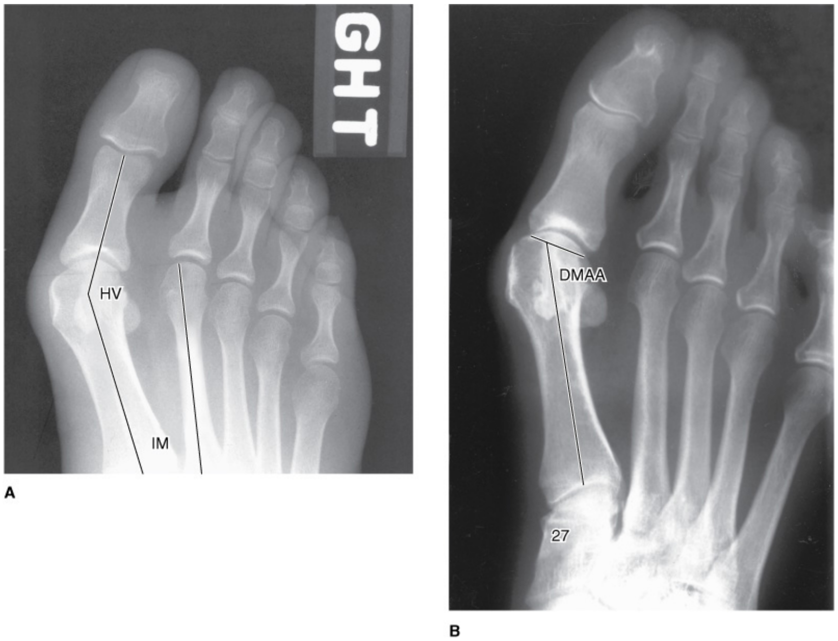
The motion of the first metatarsophalangeal joint is carefully obser
can be obtained at the joint without impairing motion of the joint.

IMAGING STUDIES

The radiographic evaluation consists of weight-bearing anteroposte

1. The hallux valgus angle is the angle created by the intersection of the lines that
2. The intermetatarsal angle is defined as the angle created by the intersection of t
3. The distal metatarsal articular angle measures the relationship of the distal articu
4. A determination is made as to whether or not the first metatarsophalangeal joint (Figure 9–7).
5. The shape of the metatarsocuneiform joint is observed, looking for evidence of e
6. The presence of arthrosis of the metatarsophalangeal joint is evaluated, as chara
7. The size of the medial eminence is measured by a line drawn down the medial as
8. The presence of a hallux valgus interphalangeus is characterized by lateral devia

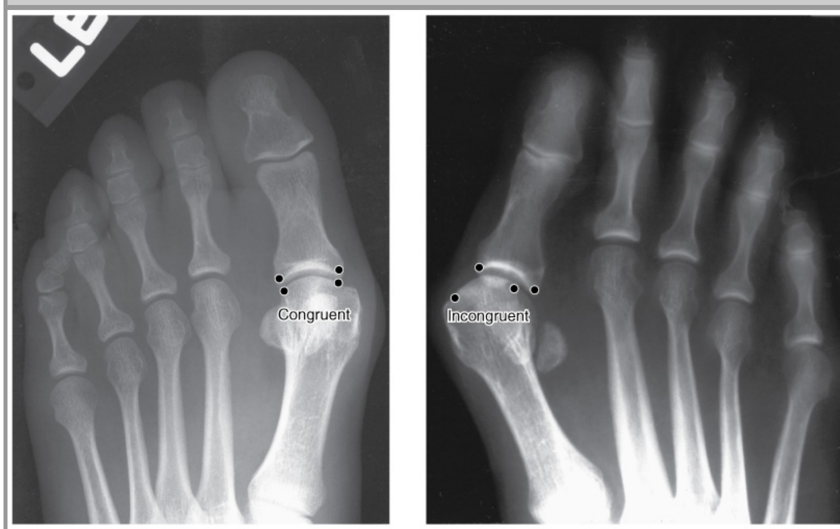
Figure 9–6.



Radiologic evaluation. **A:** Hallux valgus (HV) and intermetatarsal (

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Figure 9–7.



Left: Congruent joint. **Right:** Incongruent joint.

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Treatment

NONOPERATIVE TREATMENT

The patient should be encouraged to wear shoes of adequate size

A variety of pads are available to address symptoms that occur be
be placed underneath the metatarsal heads to take pressure off p

If after adequate conservative management the patient continues
symptomatic structural deformity.

Juvenile hallux valgus deformity presents a significant problem in
consideration in the juvenile population where cosmetic appearanc

Hallux valgus surgery is generally contraindicated in high-perform
special abilities.

SURGICAL TREATMENT

Algorithm for Surgical Treatment

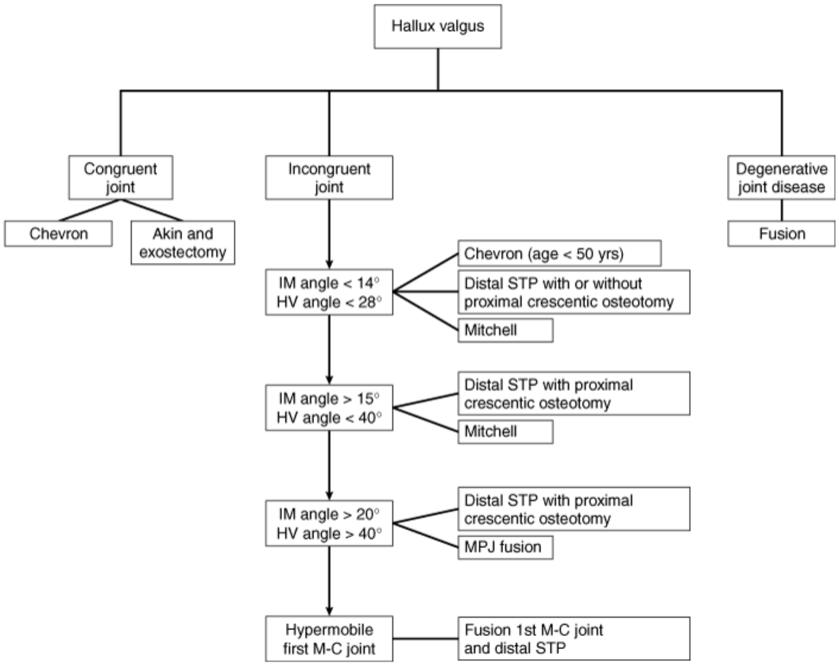
If surgery is being considered, the patient's chief complaint, the p
and careful preoperative planning is essential.

The following factors need to be considered in the decision-makin

1. patient's chief complaint;
2. physical findings;
3. degree of hallux valgus and intermetatarsal angle;
4. distal metatarsal articular angle;
5. congruency or incongruency of the metatarsophalangeal joint;
6. presence of arthrosis of the joint;
7. degree of pronation of the hallux;
8. age of the patient;
9. circulatory status; and
10. patient expectations for outcome of operation.

The algorithm in Figure 9–8 divides hallux valgus deformities into
best correct the deformity within each classification. Although no

Figure 9–8.



Algorithm for hallux valgus deformities. STP = soft-tissue procedu
Productions, 1991.)

In using this algorithm, the first question to ask is if the deformity
metatarsophalangeal is required. For the congruent joint, a chevro

If the deformity is incongruent to the degree that the proximal ph
of the deformity (see Figure 9–8).

If the first metatarsocuneiform joint is hypermobile, the distal soft
and degenerative joint disease, arthrodesis of the joint is indicatec
general rule, does not produce a satisfactory long-term result, par

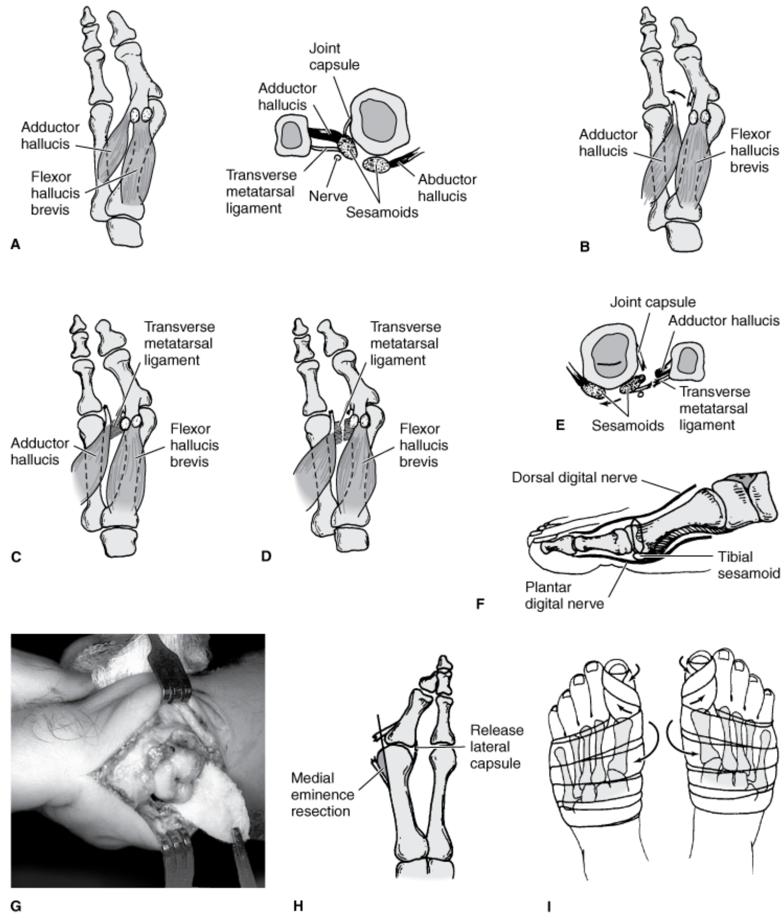
Surgical Procedures

DISTAL SOFT-TISSUE PROCEDURE

The distal soft-tissue procedure was previously referred to as the
usually with an intermetatarsal angle of less than 12–13 degrees a

The procedure requires releasing the soft-tissue contracture on the
metatarsophalangeal joint, the medial eminence is removed 2–3 m
Postoperatively, the patient is maintained in a firm compression dr

Figure 9–9.



Distal soft-tissue procedure. **A:** The adductor tendon inserts into t
base of the proximal phalanx. **C:** The transverse metatarsal ligam
metatarsophalangeal joint were released. **F:** The medial capsular i
that is based proximally and plantarward. **H:** The medial eminence
toe is rotated so as to keep the sesamoids realigned beneath the

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

The most common complication consists of recurrence of the defor
correction.

Hallux varus deformity is a medial deviation of the proximal phalar
sesamoidectomy, which causes joint instability. Occasionally, the m
joint is also hyperextended.

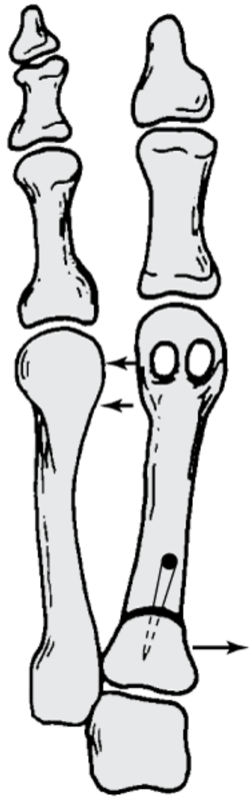
DISTAL SOFT-TISSUE PROCEDURE WITH PROXIMAL METATA

Addition of the proximal metatarsal osteotomy to the distal soft-tis
first and second metatarsal prevents adequate correction of alignn
combined procedure to be used for deformities with up to 50 degr

In carrying out this operative procedure, the distal soft-tissue proc
most commonly used osteotomy is a crescentic-shaped osteotomy

This usually results in approximately 2–3 mm of lateral displaceme
chevron-shaped, and closing-wedge osteotomies.

Figure 9–10.



The osteotomy site is reduced by pushing the proximal fragment r

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

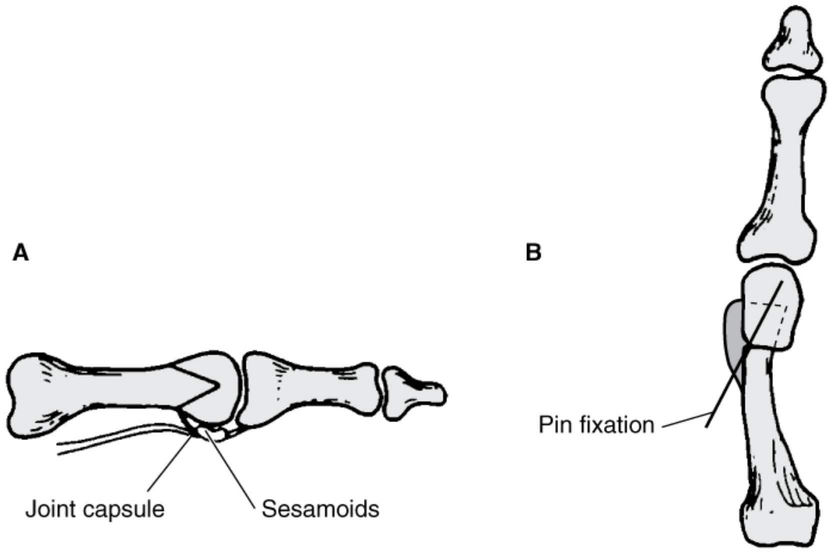
Postoperatively, the treatment is the same as for the distal soft-tis

The long-term postoperative results following the distal soft-tissue
uniformly low. Dorsiflexion of the osteotomy site may occur but is
more resistant to treatment than when osteotomy is not included.

CHEVRON OSTEOTOMY

The chevron osteotomy is usually indicated for hallux valgus defor
be obtained. The operative procedure is based on lateral translatic
A chevron-shaped cut with the apex based distally is carried out a
fixed with a pin or a screw (Figure 9–11).

Figure 9–11.



Chevron procedure. **A:** The apex of the chevron osteotomy starts
B: The osteotomy site is displaced laterally 20–30% of the width o

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Postoperatively, the foot is firmly bandaged for 6–8 weeks, and th

Uniformly good results, short and long term, are reported followin
patients had equally positive outcomes. If it is used to correct a de
result of extensive stripping of the soft tissue surrounding the hea
deformity. Occasionally, arthrofibrosis of the joint is noted, resultir

AKIN PROCEDURE

The Akin procedure consists of a medial closing-wedge osteotomy
congruent joint. The Akin procedure is indicated for a hallux valgus

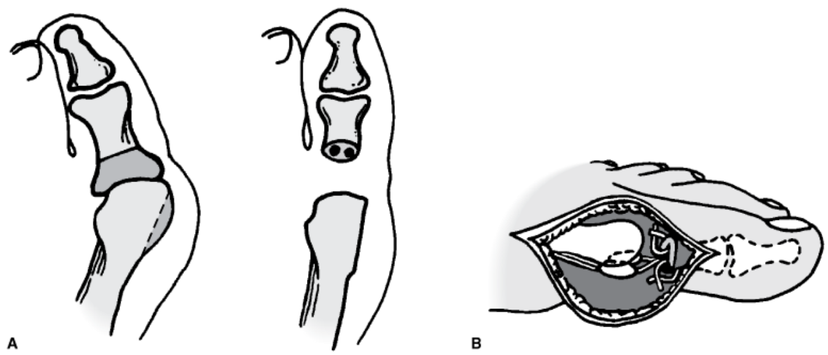
The operative procedure consists of a medial approach to the base
phalanx. The osteotomy is closed down and stabilized internally wi

KELLER PROCEDURE

The Keller procedure is reserved for the older, less active patient,

The procedure consists of removal of the base of the proximal pha
them into the remaining stump of bone (Figure 9–12). As a rule, a
approximately 6 weeks.

Figure 9–12.



Keller procedure. **A:** The medial eminence is removed in line with
remaining base of the proximal phalanx.

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

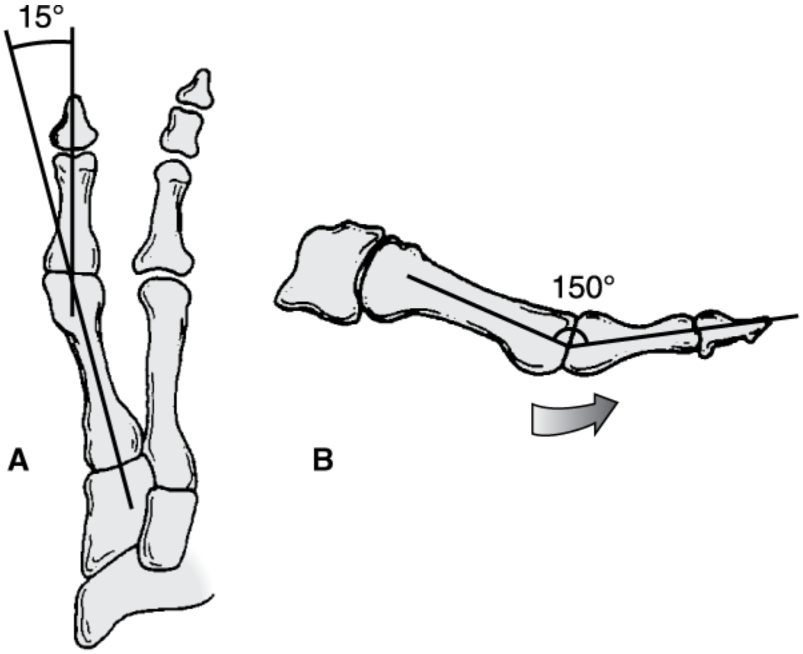
Results in the older (more than 65 years) patient with low functior
base of the proximal phalanx was removed. There is significant los
becomes cocked upward and into varus.

ARTHRODESIS OF THE FIRST METATARSOPHALANGEAL JOI

Arthrodesis of the first metatarsophalangeal joint is indicated in th
metatarsophalangeal joint. The procedure is also indicated in the p
50% of the metatarsal head or one with a significant degree of sti

The arthrodesis is carried out by creating two flat surfaces or a ba
critical. The joint should be placed in 15–20 degrees of valgus and
should be in approximately 30 degrees of dorsiflexion (Figure 9–1

Figure 9–13.



Arthrodesis of the first metatarsophalangeal joint. **A:** The joint is p
dorsiflexion in relation to the first metatarsal shaft.

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

The patient must wear a postoperative shoe until arthrodesis occu

The main complication associated with arthrodesis of the first meta
arthritic condition of the joint. The fusion rate is approximately 95
possible discomfort.

The patient's gait following arthrodesis of the first metatarsophala
activity that is difficult because the toe must be in full dorsiflexion

Hallux Rigidus

GENERAL CONSIDERATIONS

Hallux rigidus or first metatarsophalangeal joint arthritis is a relati
joint is seen in younger patients is unclear but may be associated
Hallux rigidus is not associated with elevatus, first ray hypermobili

CLINICAL FINDINGS

Patients present with complaints of joint stiffness and pain with do
uncomfortable. Radiographs show varying degrees of joint space r

CONSERVATIVE TREATMENT

Conservative treatment consists of nonsteroidal antiinflammatories
surgical treatment is usually indicated.

SURGICAL TREATMENT

Several surgical treatment methods are available for treating hallu
removed along with the bone spur, and a thorough synovectomy o
and increased physical abilities. This procedure is less likely to hav

A resection arthroplasty (Keller procedure) can be used on older, l
patients but has high rates of failure in younger, more active indiv

First metatarsophalangeal joint arthrodesis provides predictable pa
described previously.

Sesamoid Disorders

GENERAL CONSIDERATIONS

The two sesamoid bones on the plantar aspect of the first metatar
reason, a condition referred to as sesamoiditis.

CLINICAL FINDINGS

The patient with a painful sesamoid complains of discomfort on the
most commonly, the pain has an insidious onset.

PHYSICAL EXAMINATION

The painful sesamoid is determined by direct palpation. Postural al
with the plantar aspect of the metatarsal head, causing pain.

RADIOGRAPHIC FINDINGS

Radiographs of the foot are taken, including a skyline or sesamoid
seen in osteonecrosis, or joint space narrowing as seen in the case
helpful in the case of normal radiographs to diagnose osteonecrosi

TREATMENT

If an acute injury has occurred and radiographs are consistent wit
pressure off the involved area. Usually the majority of symptoms r
sesamoid can be removed, which relieves the pain.

Coughlin MJ, Shurnas PS: Hallux rigidus: Demographics, etiology,

Coughlin MJ, Shurnas PS: Hallux rigidus: Grading and long-term re

Machacek F, Easley ME, Gruber F et al: Salvage of the failed Keller

Schneider W, Aigner N, Pinggera O et al: Chevron osteotomy in ha

Veri JP, Pirani SP, Claridge R: Crescentic proximal metatarsal osteo

DEFORMITIES OF THE LESSER TOES

The most common problems involving the four lesser toes include
shape of the foot and at times make wearing shoes difficult. Furth

The most common cause of clawtoe, hammer toe, and mallet toe
abnormalities, or neuromuscular disorders. Additional predisposing

Anatomy & Pathophysiologic Findings

The metatarsophalangeal joint is stabilized on the plantar aspect b
affected by the intrinsic muscles, the interossei, and lumbricals, w
interphalangeal and distal interphalangeal joints, respectively. On
metatarsophalangeal joint and can cause extension of the distal in
extensor hood to extend the distal interphalangeal and proximal in
rule, a fixed deformity is significantly more bothersome to the pati

Mallet Toe Deformity

A mallet toe is a flexion deformity of the distal interphalangeal joi

Clinical Findings

SYMPTOMS AND SIGNS

A mallet toe tends to cause pain over the dorsal aspect of the dist
itself is deformed if the pressure was chronic.

The initial physical examination is carried out with the patient stan
deformity is fixed or flexible. If the distal interphalangeal joint is fl
deformity, ankle motion does not affect the deformity.

IMAGING STUDIES

Radiographic evaluation confirms the clinical findings of the flexion

Treatment

CONSERVATIVE MANAGEMENT

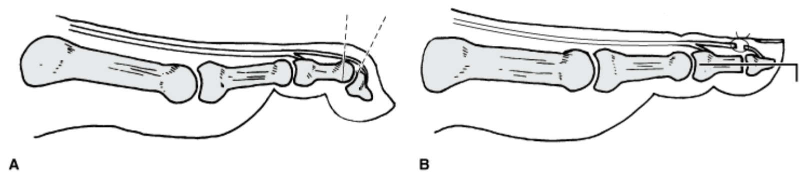
The patient should be encouraged to obtain a shoe with a wide en
be placed underneath the toe to keep it from striking the ground,

SURGICAL TREATMENT

Surgical treatment of a flexible mallet toe deformity requires relea
results in resolution of the problem.

A fixed mallet toe deformity requires a condylectomy, which is car
released, and the distal portion of the middle phalanx removed. Th

Figure 9–14.



Mallet toe repair. **A:** Resection of condyles of the middle phalanx.
(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Good results may be expected following this procedure. The most
phalanx to decompress the deformity adequately.

Hammer Toe Deformity

A hammer toe deformity is a plantar flexion deformity of the proxi
distal interphalangeal joint usually accompanies a hammer toe, bu

Clinical Findings

SYMPTOMS AND SIGNS

Clinical evaluation is similar to that of a mallet toe deformity, with
ulcer may be present over the extensor surface of the proximal int
may require treatment to make room for correction of the hamme

IMAGING STUDIES

Radiographs help in the evaluation of proximal interphalangeal flex
considered.

Treatment

CONSERVATIVE MANAGEMENT

The conservative management of hammer toe deformities is forem

Conservative management becomes more difficult if a significant f

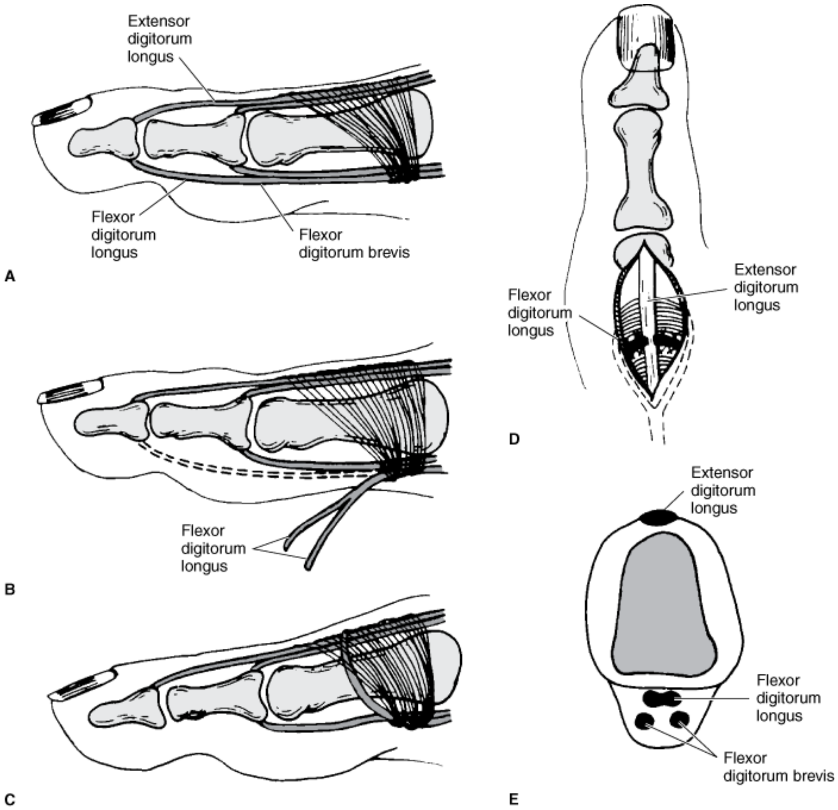
SURGICAL TREATMENT

Surgical decision making regarding the hammer toe hinges on whe
the hallux valgus deformity.

Flexible Hammer Toe Deformity

A flexible hammer toe deformity is corrected with the Girdlestone
the extensor hood with the toe held in approximately 5 degrees of
joint, thereby correcting the deformity. A soft dressing is applied a

Figure 9–15.

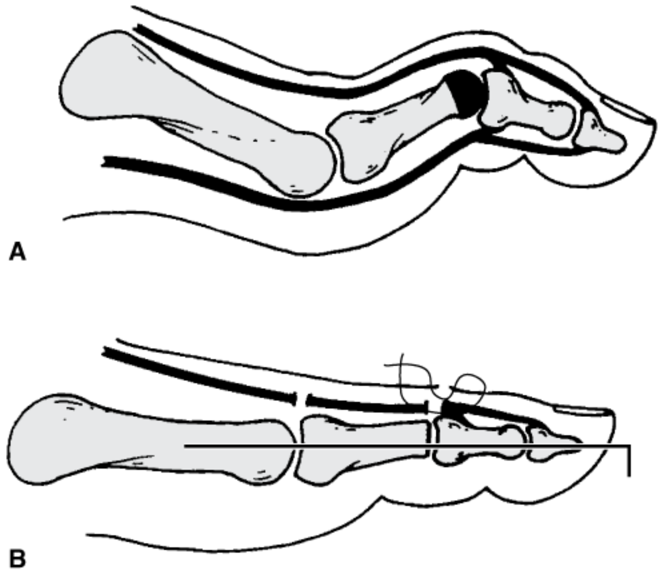


Flexor tendon transfer for flexible hammer toe deformity. **A:** Later
transferred dorsally on either side of the proximal phalanx and se
(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Fixed Hammer Toe Deformity

The DuVries proximal phalangeal condylectomy is used for the fixe
joint (Figure 9–16). Clinical results show a majority of patients we

Figure 9–16.



Fixed hammer toe repair. **A:** Resection of the head of the proxima
(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Complications

The main complication observed with either procedure is inadequa

Clawtoe Deformity

Clawtoe deformity involves both the metatarsophalangeal and inte
dorsiflexion of the metatarsophalangeal joint, which results in pain
hammer toe or mallet toe deformities, which usually involve a sing

Clinical Findings

SYMPTOMS AND SIGNS

The clinical evaluation is similar to that described for the previous
present on the extensor surface of the proximal interphalangeal jo

IMAGING STUDIES

Radiographs demonstrate the deformity, which is present at the m
dorsiflexion pitch of the calcaneus and increased plantar flexion of

Treatment

CONSERVATIVE MANAGEMENT

An extra-depth shoe reduces the pressure on the lesser toes, and
joints. These can have the effect of balancing the extensors and fl

SURGICAL TREATMENT

The type of operative intervention depends upon the nature of the
metatarsophalangeal joints to neutral plantar flexion.

A concomitant fixed contracture of the proximal interphalangeal jo
tendon is performed at the metatarsophalangeal joint. Postoperati

Following this surgical procedure no active motion of the toes occu
problems that can occur after surgery are (1) failure to correct a f
deformity.

Hard Corn & Soft Corn (Clavus Durum & Clavus Mollum

A corn is a keratotic lesion that forms over a bony prominence on
proximal phalanx. A soft corn represents a keratotic lesion in a we
occurs in the fourth web space between the base of the proximal p

Treatment

CONSERVATIVE MANAGEMENT

The main objective of conservative management is reducing press
younger patients without assistance but becomes increasingly diffi
placed around the toe to minimize pressure on the involved area,

SURGICAL TREATMENT

Surgical Treatment of the Hard Corn

The hard corn, over the fifth toe, is managed surgically by removi
the scar will not chafe against the shoe. The extensor tendon is sp
Following closure, a compression dressing is applied for several da
complication, which causes the small toe to become too floppy, cre

Surgical Treatment for the Soft Corn

Soft corns are treated surgically by making an incision over the les

Syndactyly

Because the soft corn is caused by pressure on the skin, removal o
eliminate the problem of a soft corn in the web space. Although th
cases, syndactyly is indicated. Occasionally, a floppy fifth toe from

Subluxation & Dislocation of the Metatarsophalangeal

Dorsal subluxation or dislocation of the metatarsophalangeal joint
hammer toe may occur in the toe itself. Pain usually occurs either

Etiologic Findings

The most common cause of a subluxed or dislocated joint is proba

A nonspecific synovitis, isolated to the metatarsophalangeal joint a
subsides over a period of 3–6 months, followed by progressive sub

Arthritic conditions such as rheumatoid or psoriatic arthritis can ca

A variant of this condition results from attenuation of collateral liga
subluxing in a dorsalward direction, deviates medially or occasiona
toe, the patient may have difficulty wearing shoes.

Clinical Findings

SYMPTOMS AND SIGNS

Patients complain of pain on the dorsal and plantar aspects of the standing and sitting position. The affected metatarsophalangeal jo

The dorsal-plantar stability of the joint is evaluated by holding the crossover of the second toe on the first toe, the hallux valgus requ

IMAGING STUDIES

The radiographs of the foot reveal the extent of the subluxation or

Treatment

CONSERVATIVE MANAGEMENT

Conservative management consists of using a shoe with a wide en causing impingement on the toe box area of the shoe and some di cannot be accommodated adequately with these modalities, surgic recurrence.

SURGICAL TREATMENT

The subluxed metatarsophalangeal joint with a flexible hammer to brings the toe into better alignment, although the patient loses so

The more severe complete dorsal dislocation of the metatarsophala metatarsophalangeal joint. The distal third of the metatarsal head

A longitudinal K-wire stabilizes the correction for 2 weeks. After pi

An osteotomy of the metatarsal neck is now used to treat dislocate shaft, creating a long osteotomy site. Once the osteotomy is comp and 6.0 mm. The osteotomy is fixed with a single 2.5-mm or smal stiffness as occurs with the previously described procedures. Com

Repair of the medially or laterally dislocated metatarsophalangeal the toe deviates, allowing realignment of the toe. Alternatively, a c previously described for treatment of dorsally subluxated metatars

Coughlin MJ: Lesser toe abnormalities. Instr Course Lect 2003;52:

Coughlin MJ, Kennedy MP: Operative repair of fourth and fifth toe

Dhukaram V, Hossain S, Sampath J et al: Correction of hammer to

Migues A, Slullitel G, Bilbao F et al: Floating-toe deformity as a co

Trnka HJ, Gebhard C, Muhlbauer M et al: The Weil osteotomy for t

REGIONAL ANESTHESIA FOR FOOT & ANKLE DISORDE

Regional anesthesia is becoming more commonly used because ma
nervous system depression. Pain develops gradually as the anesth

Digital Block

INDICATIONS

Digital block is suitable for procedures used in the toes, such as tr

TECHNIQUE

Short- and longer-term anesthesia is provided by digital block usir
between the skin and deeper fascia. The needle is then passed tov
allow approximately 15 minutes necessary for the block to take eff

Ankle Block

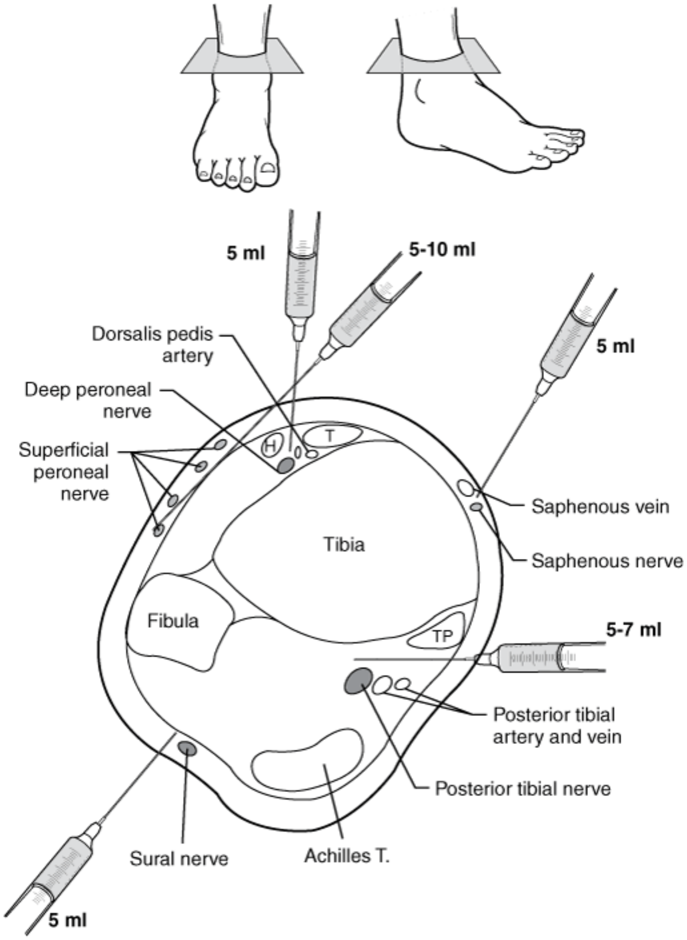
INDICATIONS

Ankle block anesthesia is commonly used for operations on the for
block is preferred to multiple digital blocks. Ankle block anesthesia

TECHNIQUE

The successful ankle block must anesthetize the posterior tibial ne
and approximately 7–10 mL of a 1:1 mixture of 1% lidocaine hydr
medial border of the Achilles tendon (Figure 9–17). The needle is i
mL of anesthetic agent is injected into this area after aspiration is

Figure 9–17.



Anesthetic technique for ankle block. H: extensor hallucis longus t
(Reproduced, with permission, from Delgado-Martinez AD, Marcha

To anesthetize the deep peroneal nerve, the site of the injection is gauge needle is inserted and advanced to bone and then withdraw

The saphenous nerve is identified one to two finger breadths proxi

The sural nerve is blocked approximately 1–1.5 cm distal to the ti

The superficial peroneal nerve branches are blocked starting two f block. Approximately 5 mL of anesthetic agent is used. The anesth

Popliteal Block

INDICATIONS

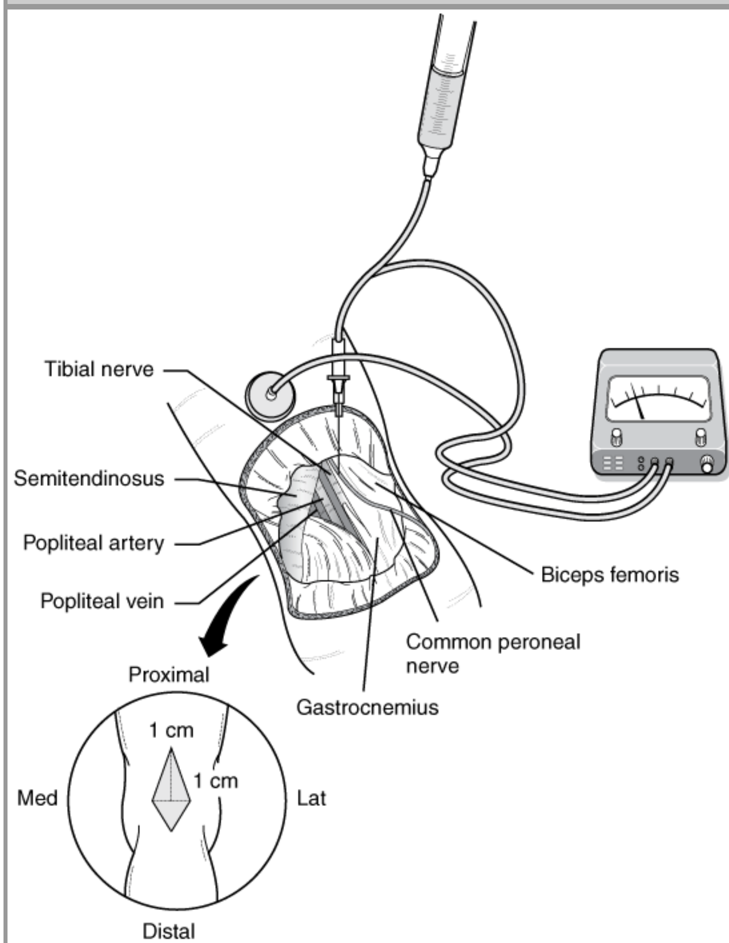
The popliteal block is used for major foot or ankle procedures. The fractures. The popliteal block can be placed by the anesthesiologis

TECHNIQUE

The patient is placed in the lateral decubitus position with a pillow Approximately 7–8 cm superior to the popliteal skin crease and 1

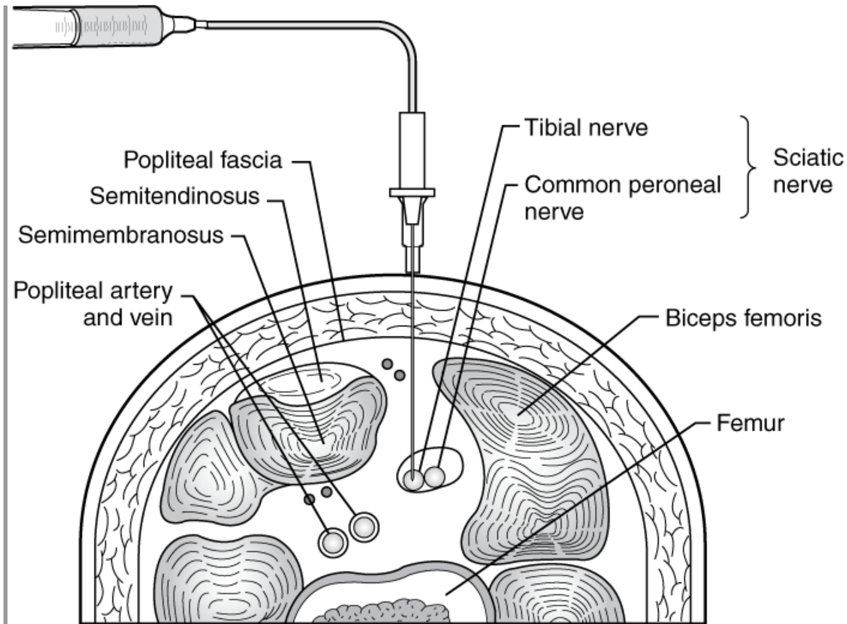
twitch is found, the stimulator is decreased until there is loss of tw
0.5% bupivacaine proximal to the ankle.

Figure 9–18.



Anesthetic technique. The popliteal block is performed with the ne
(Reproduced, with permission, from Rongstad KM, Mann RA, Pries

Figure 9–19.



Anesthetic technique for the popliteal block. The needle tip is posi
(Reproduced, with permission, from Rongstad KM, Mann RA, Pries

Delgado-Martinez AD, Marchal-Escalona JM: Supramalleolar ankle

Jarrett GJ, Rongstad KM, Snyder M: Popliteal nerve block by surge

Provenzano DA, Viscusi ER, Adams SB Jr et al: Safety and efficacy

METATARSALGIA

Metatarsalgia is a general term for pain arising from the metatarsa
pressure is concentrated beneath the metatarsal head area. This e

Etiologic Findings

Metatarsalgia encompasses a broad spectrum of conditions with va
systemic diseases, dermatologic lesions, soft-tissue disorders, or ia

Table 9–1. Causes of Metatarsalgia.

Bone causes	Prominent fibular condyle of the metatarsal head	Long metatarsal	Morton foot	Hypermobile first ray	Posttraumat malalignment of metatarsal

Clinical Findings

SYMPTOMS AND SIGNS

The clinical evaluation begins with a careful history directed towar
clawing of the toes, a long second ray, or swelling around any of t
formation. The metatarsal heads are palpated individually to asses

IMAGING STUDIES

The radiographic evaluation includes weight-bearing anteroposteri
their overall alignment, particularly in cases resulting from previou

Treatment

CONSERVATIVE MANAGEMENT

Conservative management is directed at relieving the pressure be
material and an adequate toe box is appropriate. High-heeled sho
orthotic device, the more comfortable the patient. A hard acrylic o

SURGICAL TREATMENT

The surgical management of metatarsalgia depends on the cause
often be burned off with liquid nitrogen or excised, or pain caused
correct it.

KERATOTIC DISORDERS OF THE PLANTAR SKIN

Friction and pressure over bony prominences, particularly on the
symptomatic and occasionally quite disabling.

Etiologic Findings

Many of the intractable plantar keratoses arise from the bony abn

Clinical Findings

SYMPTOMS AND SIGNS

A careful history of the problem is extremely important, especially
orthotic devices used are all important. The physical examination,
the result of a postural abnormality. Specifically, a rigid plantar-fle
formation beneath the lesser metatarsal heads. Varus posture of t

The nature of the callus itself is important because it helps determ
associated with a long metatarsal. The callus may have arisen afte
from a plantar wart, which can occasionally mimic a plantar callosi

IMAGING STUDIES

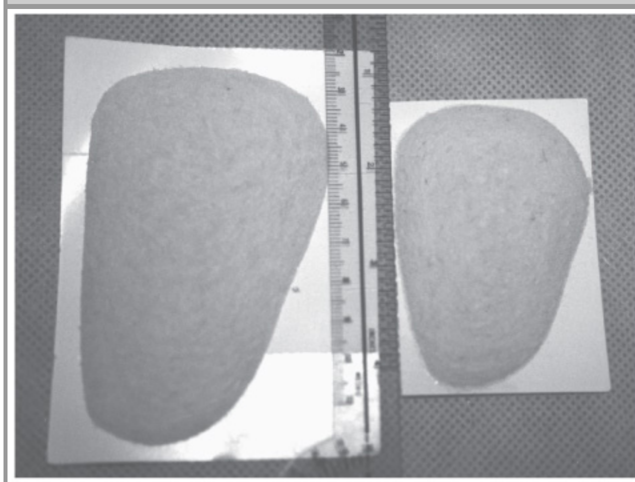
Routine weight-bearing radiographs of the foot are performed and

Treatment

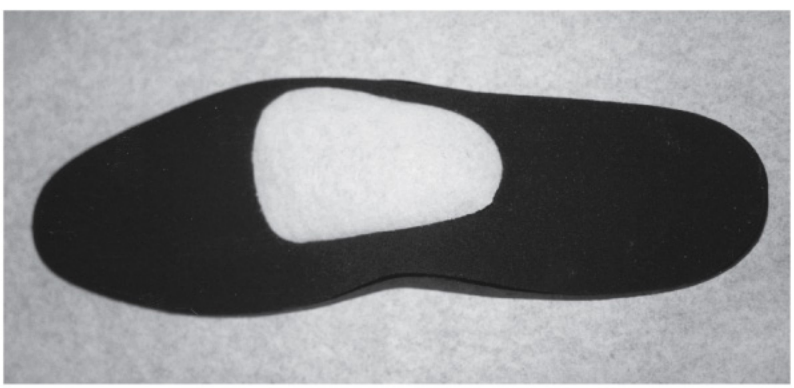
CONSERVATIVE MANAGEMENT

A wide, soft lace-up shoe is recommended, often with the addition
metatarsalgia because the less expensive, commercially available

Figure 9–20.



A



B

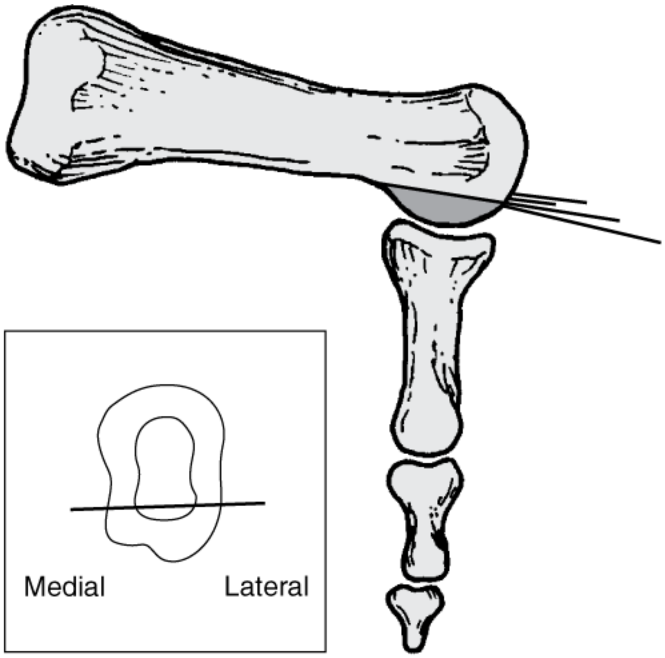
A: A metatarsal pad may help redistribute weight bearing and reli
(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

SURGICAL TREATMENT

The surgical management of metatarsalgia depends on the cause

Localized intractable plantar keratosis beneath a metatarsal head i
treatment is accomplished through a dorsal hockey stick incision o
21). This procedure results in predictable pain relief of the affecte

Figure 9–21.



A plantar condylectomy is performed with resection of one fourth

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

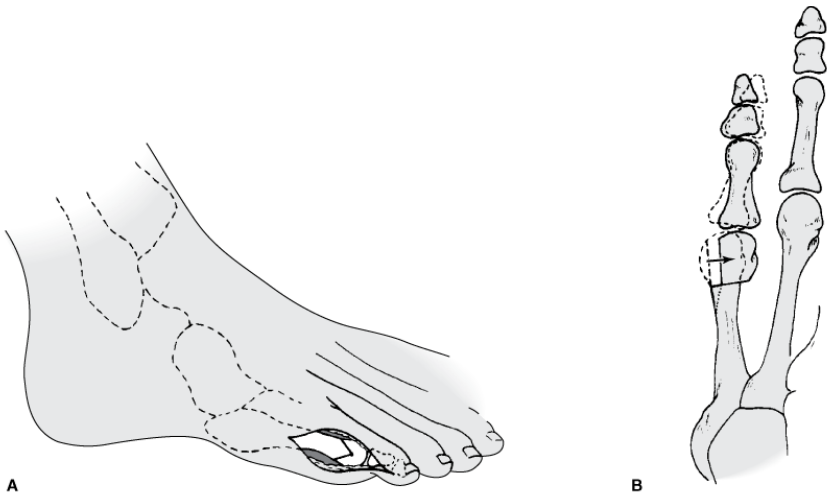
A diffuse callus beneath the second metatarsal that is the result of metatarsal, it may be shortened to the level of a line drawn betwe using one of the techniques previously described, to alleviate the c approximately 5–10%.

Occasionally, a well-localized callus is present beneath the tibial se inadvertent disruption of the plantar medial cutaneous nerve durir

Bunionettes are caused by prominence of the fifth metatarsal head usually alleviates the condition. It is unusual for a transfer lesion t

At times, the fifth metatarsal head is too prominent on the lateral 22), sometimes with slight loss of motion of the metatarsophalang

Figure 9–22.



A: Lateral view of chevron fifth metatarsal osteotomy. **B:** Diagram
(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

A subhallux sesamoid can cause a small callus beneath the interph

Mann RA, DuVries HL: Intractable plantar keratosis. Orthop Clin N

Mann RA, Mann JA: Keratotic disorders of the plantar skin. AAOS I

Yu JS, Tanner JR: Considerations in metatarsalgia and midfoot pair

DIABETIC FOOT

Approximately 22 million people in the United States are diabetic, on diabetics. One report showed a 68% incidence of foot disorders team approach, involving the primary care physician, vascular sur

Pathophysiologic Findings

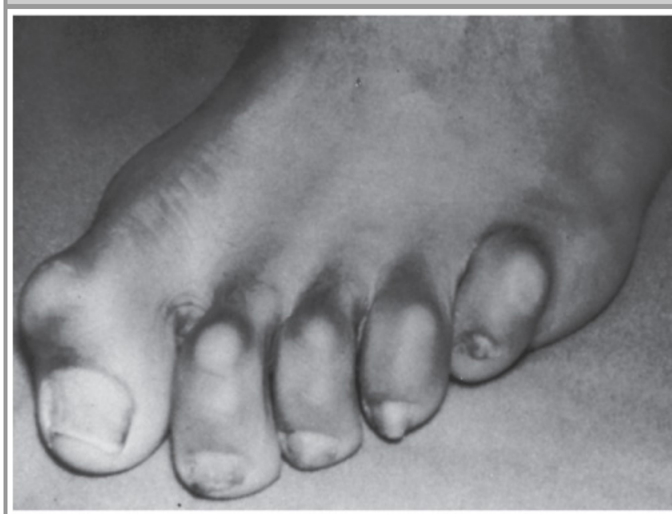
Diabetes is a metabolic disorder that involves all the organ system immunologic with limited ability to fight infection. The most freque disease. Unappreciated local stresses are placed on the skin exter hyperemia, which normally helps clear infections, is blunted by aut prominent and predisposed to ulcerations. (Figure 9–24). Hypergly potential. Elevated blood glucose levels over a long period also lea of glucose molecules changes the flexibility of tissues, especially fi affect healing in diabetics include nutritional deficiencies, diminishe

Figure 9–23.

Ulceration over the dorsolateral aspect of the fifth toe as the resu

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Figure 9–24.



Clawtoe deformity involves hammer toe deformity associated with

(Reproduced, with permission, from Mann RA, Coughlin MJ: *Surge*

History

When a diabetic patient presents to an orthopedist, the four areas delineate why the ulcer occurred and how to optimize the patient's the patient's diabetes, including how long ago the diabetes was dia

Clinical Findings

GENERAL EXAMINATION

Examination of the diabetic patient should begin with inspection of

FOOT EXAMINATION

Any bony prominences are recognized as areas of potential skin br
ability to feel the 10-g Semmes-Weinstein monofilament as well as
as documenting their location. Open wounds should be probed witl
indicates the presence of osteomyelitis.

VASCULAR FINDINGS

Vascular evaluation is essential to ensure that the patient has adec
those patients with less perfusion, one method of assessing the ov
arteries, as measured by Doppler ultrasound with a calf cuff. If the
elevated values of blood pressure in the foot may result from calci
be beneficial in assessing local skin perfusion. This information can

IMAGING STUDIES

Radiographic studies should include weight-bearing radiographs of
neuropathic foot may be identified. Early Charcot (neuropathic) joi
densification.

The presence of bony infection may be delineated on serial radiogr
early osteomyelitis but quite nonspecific. MRI can demonstrate bo

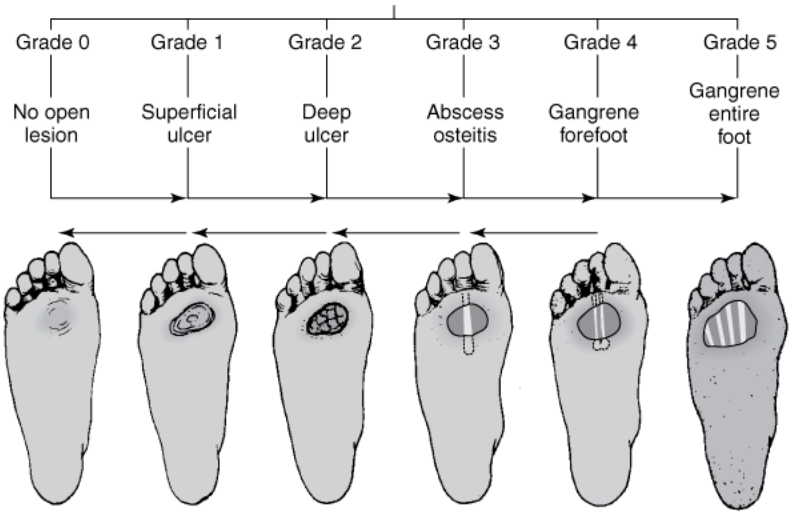
Classification & Treatment of Diabetic Foot Ulcers

The Rancho Los Amigos Hospital classification of diabetic foot ulcer
classification of foot ulcers.

Table 9–2. Classification and Treatment of Diabetic Fo

Grade	Classification	Treatment
0	Foot is "at risk" for developing ulcer. Skin remains intact, but underlying bone deformity places foot at risk for skin breakdown.	Proper footwear plus other preventive measures such as patient education and surgical correction as described in text.

Figure 9–25.



The original Rancho Los Amigos classification by Wagner and Megg
the concept that all lesions of the diabetic foot from grade 1 ulcer
with grades 4 and 5. Grades 4 and 5 are vascular lesions or descr
grades or coincide with any of them, including a forefoot that is ot
grades 0, 1, 2, and 3) and the dysvascularity of the foot (ie, grad
is that there are not necessarily pathways backward and forward

(Reproduced, with permission, from Brodsky JW: The diabetic foot

Figure 9–26.

A

B

Comparison of grade 1 (**A**) and grade 2 (**B**) ulcers (new depth anc
(Reproduced, with permission, from Brodsky JW: The diabetic foot

As a general rule in treating infections of the foot, a balance must
that requires constant wound care.

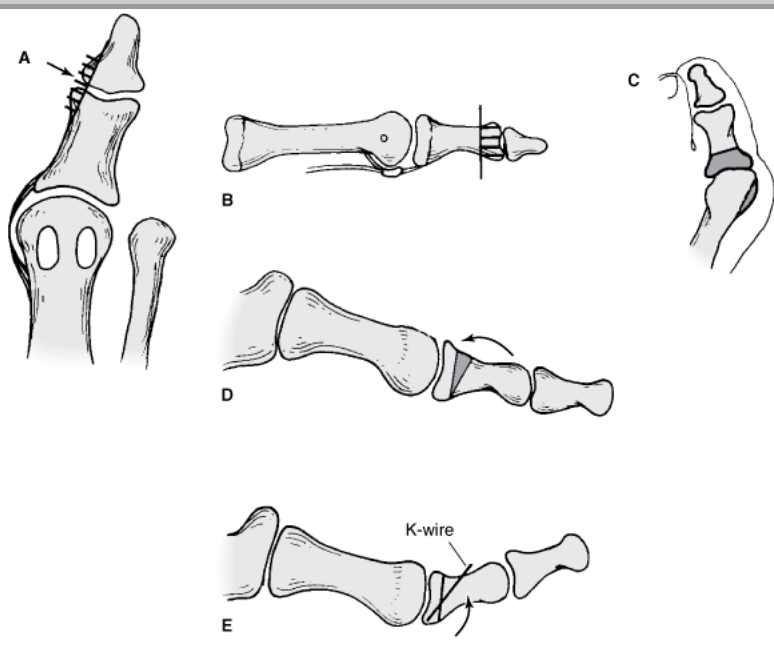
Large wounds heal slowly with the risk of secondary infection, and

SURGICAL TREATMENT FOR RELIEVING BONY PROMINENCE

As previously stated, a major goal of treatment in the ulcerated or
pressure on the skin from the outside. Examples include extradept
should be relieved from the inside by correcting the bony deformit

The hallux may have a prominence beneath the metatarsal head,
relieved by complete or partial removal of the sesamoid. If this do
joint can often be relieved by simple excision of the prominent me

Figure 9–27.



Four procedures for recalcitrant ulceration over the condyles of th
phalanx). **D:** Dorsiflexion osteotomy of the base of the proximal p

(Reproduced, with permission, from Brodsky JW: The diabetic foot

The diabetic patient is subject to clawtoe deformities resulting fror
reduction of the metatarsophalangeal joints and proximal interpha

A collapsed longitudinal arch from Charcot changes causes the clas
osteotomy and arthrodesis for a more complex deformity.

TREATMENT OF OSTEOMYELITIS

Osteomyelitis is a common complication present in a grade 3 diabe
a proximal phalanx is usually treated by resection of the phalanx.
treatment with the reminder to always consider lengthening the te

Osteomyelitis of the midfoot is a complication of a collapsed Charc
with a partial calcanectomy or a more proximal amputation.

Treatment of ulcers should make sense. A patient with a superficia
swelling. A patient with an infected deep wound with osteomyelitis
appropriate treatment plan.

Wound dressings should try to mimic skin. They should try to prov
the needs of the wound, possibly needing infection control and deb
protective cast provides wound protection, edema control, and a n

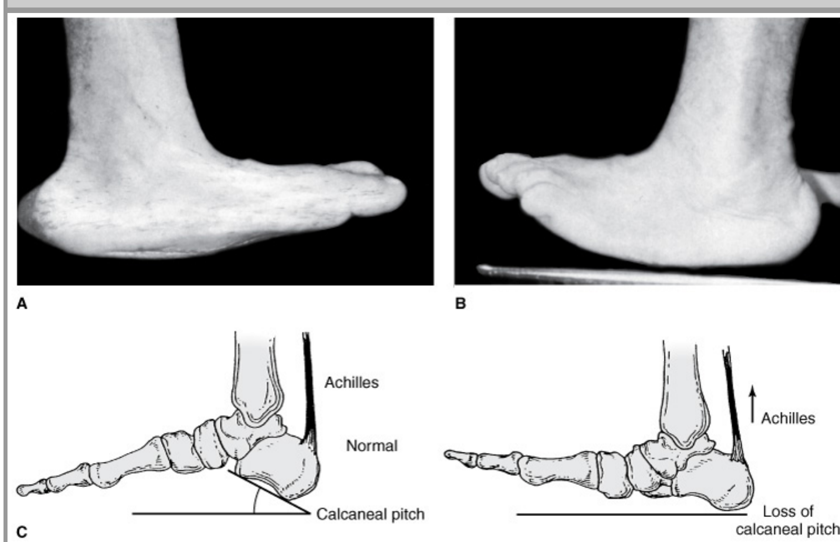
Biological wound healing products that provide wound healing fact
negative suction pressure is applied to a sealed wound, thereby de

A small number of patients who are marginal wound healers benef

CHARCOT FOOT

A Charcot joint is also referred to as a neuropathic, neurotrophic,
of one or more joints in a patient with an inappropriate pain respo
neurotraumatic theory claims that cumulative mechanical strains in
neurovascular theory suggests there is a neurally initiated vascula
lead to the fracture dislocations commonly seen.

Figure 9–28.



A, B: The classic rocker-bottom Charcot foot, with collapse and th
for the Achilles tendon.

(Reproduced, with permission, from Brodsky JW: The diabetic foot

Eichenholtz defined three stages in Charcot arthropathy. Stage 1 is
this stage is to rule out infection. If the patient is neuropathic with
osteomyelitis is very rare; infections in the foot are usually introdu
phase with consolidation and resolution of inflammation. Typical lo
to ulcerization.

Principles of Treatment

There are several important principles to follow in the treatment o

Treatment of Acute Phase

For a patient who presents in the acute phase of Charcot joint, the
plantigrade position. The skin must be checked at weekly intervals
require acute stabilization to obtain a plantigrade foot, it is best to
accomplished by means of an ankle-foot orthosis (AFO) or other a

Treatment of Subacute Phase

In this phase the foot has stabilized, and there is no ongoing bony
fusion of one or several joints is necessary. One of the most comm
midfoot usually is sufficient. Alternatively, an osteotomy and arthr
rate and an extended time to achieve union. In the case of Charco
significant complication rates.

Figure 9–29.

A

B

A: Patient with advanced midfoot Charcot deformity and soft-tissu
ray.

(Reproduced, with permission, from Brodsky JW: The diabetic foot

Andros G: Diagnostic and therapeutic arterial interventions in the

Brem H, Sheehan P, Boulton AJ: Protocol for the treatment of diab

Eldor R et al: New and experimental approaches to treatment of d

Gil H, Morrison WB: MR imaging of diabetic foot infection. Semin M

Lipsky B: Medical treatment of diabetic foot infections. Clin Infect

Perry JE et al: The use of running shoes to reduce plantar pressur

Pinzur M: Surgical versus accommodative treatment for Charcot a

Pinzur MS, Kelikian A: Charcot ankle fusion with a retrograde locke

Wagner FW Jr: A classification and treatment program for diabetic

DISORDERS OF THE TOENAILS

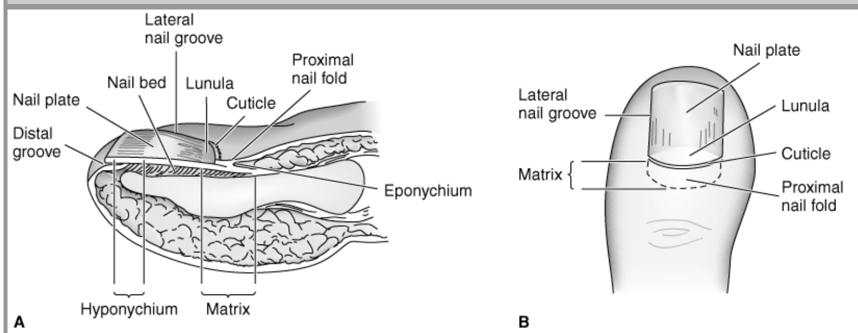
Toenail problems in younger (less than 20 years) patients usually i
nail too short and predisposes it to become ingrown.

Toenail problems in the older age group are more varied, including
exostosis.

Etiologic Findings

The anatomy of the toenail is demonstrated in Figure 9–30. The na
groove, where an ingrown nail occurs at the level of the nail bed o

Figure 9–30.



A: Cross section of the toe demonstrates the components of the t
(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Clinical Findings

SYMPTOMS AND SIGNS

The history of most nail problems is not complex and usually quick

Infection of the Toenails

Infection of the toenails usually begins slowly, with erythema and s
itself.

Mycotic Nail

In the case of the mycotic (fungal) nail, there is usually a long, slo
nail condition develops in which one or both edges of the nail slow
therapy is based on direct microscopy (KOH [potassium hydroxide

Subungual Exostosis

The patient who develops subungual exostosis usually notes pain e
there is actual breakdown of the tissue, giving rise to a rather ugly

IMAGING STUDIES

Radiographs are necessary when evaluating a toenail problem for

Treatment

CONSERVATIVE MANAGEMENT

Chronic Ingrown Toenail

For the chronic ingrown toenail, the margin of the nail is removed
however, to explain to the patient the necessity of permitting the n

Chronic Onychophosis of the Nail

Chronic onychophosis of the nail must be kept debrided. If an ingr

Subungual Exostosis

Subungual exostosis that is symptomatic is treated by excision.

SURGICAL TREATMENT

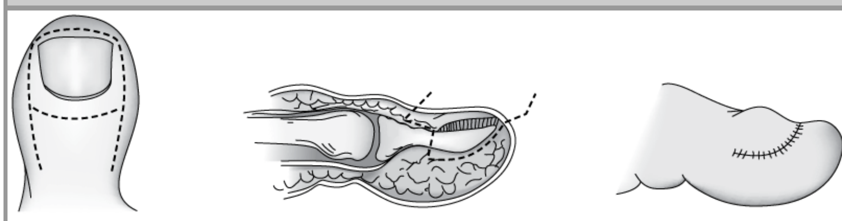
Ingrown Toenail

The surgical management of the recurrent ingrown toenail consist
possible to prevent the possible growth of a nail horn, which occur

Chronic Infection

If chronic infections has caused severe distortion of the nail, the n
out to eliminate the nail and matrix completely (Figure 9–31). Alth
procedure can be carried out under digital block in most patients.
shortening the toe. The tip of the toe is defatted and loosely sutur
some nail matrix beneath the healed flap, which results in an inclu

Figure 9–31.



Syme amputation of toenail. **A:** Elliptical or rectangular incision is
(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Subungual Exostosis

Surgical management of subungual exostosis requires lifting the n
The nail bed is repaired to cover the defect.

Baran R, Dawber RPR: *Diseases of the Nails and Their Manageme*

Coughlin MJ: Toenail abnormalities. In Mann RA, Coughlin MJ, eds:

Mann RA, Coughlin MJ: Toenail abnormalities. In Mann RA, Coughl

Mayeaux EJ: Nail disorders. Prim Care 2000;27:333. [PMID: 1081

Rounding C, Hulm S: Surgical treatments for ingrowing toenails. C

Summerbell RC, Cooper E, Bunn U et al: Onychomycosis: A critica

NEUROLOGIC DISORDERS OF THE FOOT

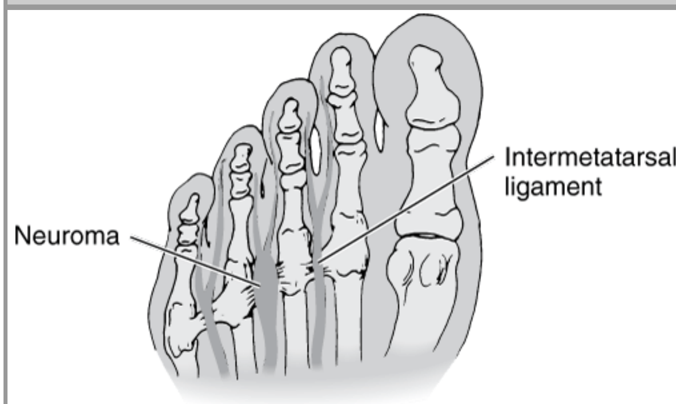
Interdigital Neuroma (Morton Neuroma)

An interdigital neuroma is a painful affliction involving the plantar
symptoms are usually aggravated by ambulation and relieved by r

Etiologic Findings

The precise cause of interdigital neuroma is not determined. It occ
occur just distal to the transverse metatarsal ligament. This findin
explains the higher incidence in women wearing high-heeled shoes
amorphous eosinophilic material that is felt to be consistent with a

Figure 9–32.



An interdigital neuroma impingement occurs beneath the intermet

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Clinical Findings

SYMPTOMS AND SIGNS

Patients with an interspace neuroma usually present with a compla
often radiates into the toes. There can be a palpable mass, and sq
is referred to as a Mulder click. The third interspace is more frequ
metatarsophalangeal joint, and pain in the interspace must be dist
mechanical instability, synovial cysts, or even referred pain from ta

IMAGING STUDIES

Radiographs are not helpful in the diagnosis of an interdigital neur
of nerve enlargement, but this is very user dependent. MRI can be

Treatment

CONSERVATIVE MANAGEMENT

Conservative management begins with wearing a wider soft-soled
spreading the metatarsal heads and lifting them. Approximately a
diminished padding under the metatarsal heads or local skin thinni

SURGICAL TREATMENT

Surgical excision of the nerve is indicated if conservative treatmen
transverse metatarsal ligament. A quite thickened nerve is reassu
is delivered into the interspace by plantar pressure and freed up d
tissue or intrinsic muscles. A compression dressing is used for 3 w
Approximately 80% of patients are totally satisfied with the result
metatarsophalangeal joint was actually involved.

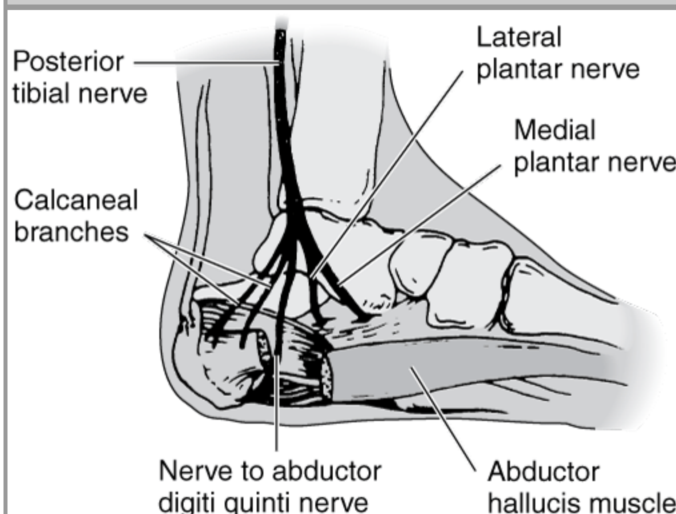
RECURRENT NEUROMA

A recurrent neuroma is indeed a true surgical bulb neuroma that r
the nerve became adherent and trapped beneath the metatarsal h
reexploration for the neuroma is carried out either through a dors

Tarsal Tunnel Syndrome

Tarsal tunnel syndrome is a compressive or traction neuropathy of
posterior aspect of the medial malleolus (Figure 9–33). Tarsal tunr
of nocturnal dysesthesias.

Figure 9–33.



Posterior tibial nerve and major branches.

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Etiologic Findings

Tarsal tunnel syndrome may arise from a space-occupying lesion w
to the lower extremity, probably because of edema or scarring. Ot

especially those that are unstable. As the patient walks, the poster

Clinical Findings

SYMPTOMS AND SIGNS

The diagnosis is entertained after obtaining a history of paresthesi or swelling in the involved tarsal tunnel area. Careful percussion m nerves). Muscle weakness is usually not observed, but loss of sens

Electrodiagnostic studies should be carried out to help confirm the the abductor digiti quinti (latency usually less than 7 ms) should b indicative of tarsal tunnel syndrome. The most accurate study for

The definitive diagnosis of tarsal tunnel syndrome should be basec electrodiagnostic studies. If all three factors are not positive, the c

Treatment

CONSERVATIVE MANAGEMENT

The tarsal tunnel syndrome should be managed with NSAIDs and a also be useful, especially in the patient with unstable valgus.

SURGICAL TREATMENT

Surgical intervention can be considered if conservative manageme release uses an incision behind the medial malleolus that is carried traced distally behind the medial malleolus. The division into its th aspect. There may be one or more medial calcaneal branches. The hallucis muscle until it passes toward the lateral aspect of the foot the tarsal tunnel syndrome.

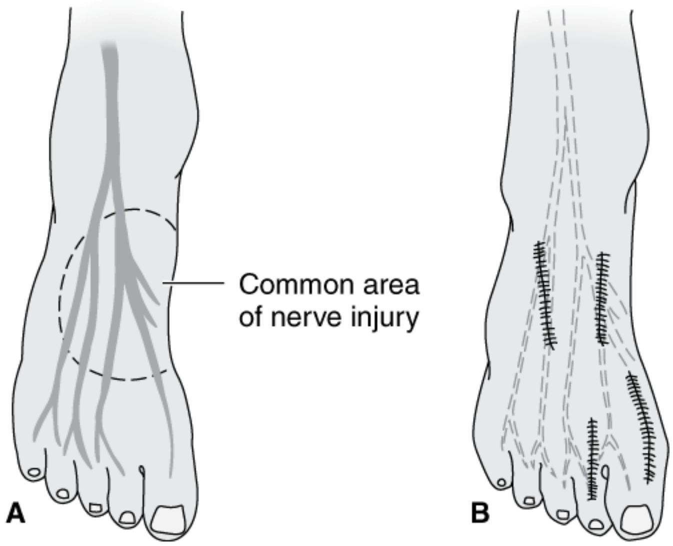
Postoperatively, a compression dressing is applied and weight bear

The results following tarsal tunnel release depend on the pathology also portends good results after surgery. If more diffuse pain is fe Patients with traction neuropathy caused by the unstable valgus fo

Traumatic Neuromas About the Foot

A traumatic neuroma about the foot presents a difficult problem in incisions about the foot, many lesser and occasionally major nerve

Figure 9–34.



A: Common area of traumatic nerve entrapment. **B:** Frequent inci
(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Clinical Findings

The clinical evaluation begins with a careful history of the problem
radiographs are not usually necessary.

Treatment

CONSERVATIVE MANAGEMENT

Attempts to relieve pressure on the neuroma with a large shoe or
conservative measures fail.

SURGICAL TREATMENT

Careful planning must be undertaken prior to the excision of a trau
and trace the nerve proximally into an area that would not be affe
bone, if possible, or beneath a muscle such as the extensor digitor
enough so the top of the boot will not press on the nerve, resultin

The results following resection of a traumatic neuroma are quite v
preferable to bury the end of the nerve into bone, if possible. Rese

Entrapment of the Superficial Branch of the Deep Pero

Osteophyte formation at the talonavicular or metatarsocuneiform j
shoes, depending on the location of the entrapment.

The superficial branch of the deep peroneal nerve passes onto the
talus and navicular and more distally across the metatarsocuneifor

Clinical Findings

SYMPTOMS AND SIGNS

The clinical evaluation begins with a careful history regarding the p
radiates into the first web space. Often the precise location of the

IMAGING STUDIES

Radiographs usually reveal the offending osteophytes, often along

Treatment

CONSERVATIVE MANAGEMENT

Conservative management consists of attempting to keep the pres
nerve usually brings about satisfactory resolution of the condition.

SURGICAL TREATMENT

Depending on the area of entrapment (talonavicular or metatarsoc
inadvertently damaged. The nerve is carefully lifted off of its bed,
immobilized for approximately 3 weeks in a postoperative shoe.

The results following release of the superficial portion of the deep

Bailie DS, Kelikian AS: Tarsal tunnel syndrome: Diagnosis, surgical

Beskin JL: Nerve entrapment syndromes of the foot and ankle. J A

Coughlin M et al: Concurrent interdigital neuroma and MTP joint in

Okafor B, Shergill G, Angel J: Treatment of Morton's neuroma by r

Stamatis ED, Myerson MS: Treatment of recurrence of symptoms

RHEUMATOID FOOT

The foot is involved in 90% of patients with long-standing RA, and
approximately 35% of patients and of the ankle joint in approxima

Etiologic Findings

The changes in the forefoot are caused by chronic synovitis, which
stability for the joint, progressive dorsal subluxation and eventual
proximal phalanx eventually comes to rest on the metatarsal head
result in imbalance of the intrinsic muscles, and severe hammer to

Significant midfoot and hindfoot pathology is also found in patients
involvement of the midfoot.

Clinical Findings

SYMPTOMS AND SIGNS

The clinical evaluation of the rheumatoid patient begins with a car
obtain some indication of the patient's wound-healing capacity in t

The vascular status of the foot and quality of the skin is noted. Th
and a careful evaluation of all the joints about the foot and ankle i
as the degree of stability of the joints. The plantar aspect of the fo
determine the risk of deformity progression.

IMAGING STUDIES

Radiographs help assess the number of joints involved and the deg

Treatment

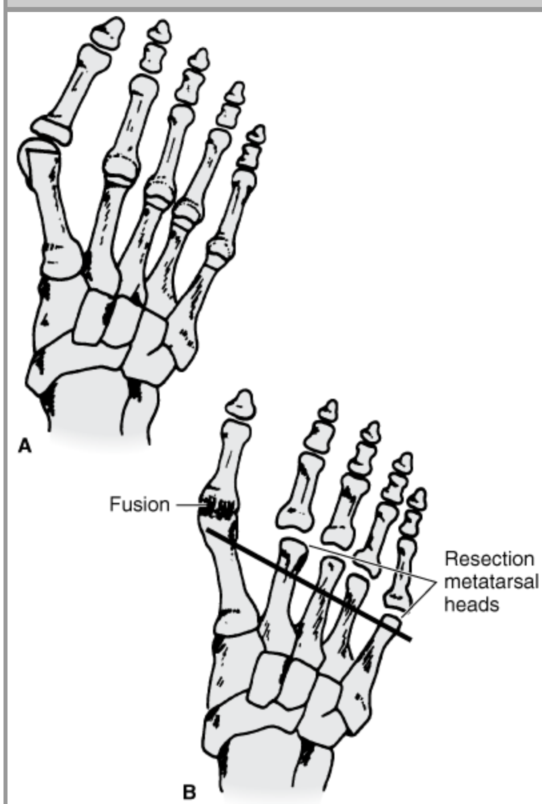
CONSERVATIVE MANAGEMENT

Conservative management includes medical management, carried
the toes, which may be severely contracted dorsally. Frequently, t
stabilization.

SURGICAL TREATMENT

The main goal of surgical management of the forefoot is to create
joint placed in approximately 15 degrees of dorsiflexion in relation
metatarsal heads are excised to decompress the metatarsophalang
toes can be corrected by closed osteoclasis, which often results in
K-wires postoperatively for approximately 4 weeks.

Figure 9–35.



A: Resection of metatarsal heads. **B:** Symmetric resection of meta
(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

The results of this rheumatoid forefoot repair are most gratifying i extensive. Occasionally, wound healing is delayed, particularly if th

Hindfoot and ankle disease is usually managed medically unless th surgical stabilization with arthrodesis is necessary. If only a single is adequate. If significant deformity is present because of subtalar elsewhere in this chapter.

Cracchiolo A III: Surgery for rheumatoid disease. Part I. Foot abn

James D et al: Orthopaedic intervention in early rheumatoid arthri

Kavlak Y et al: Outcome of orthoses intervention in the rheumatoi

Mann RA, Schakel ME: Surgical correction of rheumatoid forefoot d

McGarvey SR, Johnson KA: Keller arthroplasty in combination with

Ostendorf B et al: Diagnostic value of magnetic resonance imaging

HEEL PAIN

Heel pain can be caused by several distinct entities. When evaluat

Table 9–3 presents the causes of heel pain, which are quite variab

Table 9–3. Causes of Heel Pain.

Causes of plantar heel pain	Plantar fascitis	Atrophy of heel pad	Posttraumatic (eg, calcaneal fracture)	Enlarged calcaneal spur	N sy di

Clinical Findings

SYMPTOMS AND SIGNS

The clinical evaluation begins with a careful history of the onset ar extremity may suggest lumbar disk disease as the cause. Patients heel pain can usually be determined by palpating the area of maxi

Plantar fasciitis, the most common cause of plantar heel pain, usua
pain is most severe with the first steps upon arising. The pain is u

Achilles tendonitis/tendinosis typically occurs at one of two discrete
There is usually tenderness in the posterior midline with local incre
tendon. Both of these are more degenerative than true inflammato

Heel pain can also be caused by inflammation of the retrocalcanea

Tarsal tunnel syndrome with involvement of the medial calcaneal b
proximally in the calf.

IMAGING STUDIES

Radiographs may demonstrate calcaneal spur formation or calcifica
Achilles tendon, a condition known as Haglund disease or Haglund
diseases such as Reiter syndrome or a discrete area of uptake as i
question.

Treatment

CONSERVATIVE MANAGEMENT

The conservative management of heel pain depends on the specifi
more resilient heel, and use of a soft orthotic device under the lon
plantar fascia. Plantar fasciitis is treated initially with stretching ex
tendon and plantar fascia stretched often relieves the acute pain p
fascia rupture. Cast immobilization also benefits these refractory p

In general, the treatment of heel pain is often prolonged, requiring
many months to resolve.

Achilles tendinosis is treated with stretching exercises, activity mo

SURGICAL TREATMENT

Patients with plantar fasciitis, in whom symptoms cannot be contro
With surgical release, the success rate is approximately 75%. Cau
of heel numbness and possibly a troublesome neuroma along the n
invasive, still has conflicting literature about its effectiveness.

Surgical treatment of Achilles tendinosis is offered if 6–9 months o
Achilles insertion. If a Haglund deformity is present, it is also resec
graft such as the flexor hallucis longus tendon.

Baxter DE, Pfeffer GB: Treatment of chronic heel pain by surgical

Boyle RA, Slater GL: Endoscopic plantar fascia release: A case seri

Erdimir A Piazza SJ: Changes in foot loading following plantar fasci

Jerosch J et al: Indication, surgical technique and results of endosc

Ogden J et al: Plantar fasciopathy and orthotripsy: The effect of p

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Zhu F et al: Chronic plantar fasciitis: Acute changes in the heel aft

ARTHRODESIS ABOUT THE FOOT & ANKLE

General Considerations

GOALS OF ARTHRODESIS

Arthrodesis is surgical fixation of a joint to obtain fusion of the joir

1. elimination of joint pain;
2. correction of deformity;
3. stabilization of the foot or ankle when adequate muscle function or ligamentous s
4. restoration of function by salvaging a situation in which no reasonable reconstru

PRINCIPLES OF ARTHRODESIS

An arthrodesis about the foot and ankle requires adherence to the

1. To be effective, the arthrodesis must produce a plantigrade foot.
2. Broad, cancellous bony surfaces must be placed into apposition.
3. The arthrodesis site should be stabilized with rigid internal fixation, preferably wit
4. When correcting malalignment of the foot, it is imperative that the hindfoot be pl
5. The surgical approaches should be carried out in such a way as to minimize the r

EFFECTS OF ARTHRODESIS ON JOINT MOTION

Following ankle arthrodesis, residual dorsiflexion and plantar flexio following ankle arthrodesis, and in time, extension of the fusion m

The subtalar joint and transverse tarsal joints must be viewed as a minimally affected. Arthrodesis of the talonavicular joint, however,

A triple arthrodesis eliminates the subtalar and transverse tarsal jo following triple arthrodesis. It is imperative, therefore, to evaluate

Arthrodesis of the tarsometatarsal joints does not significantly affe the interphalangeal joint of the great toe, particularly with poor ali

DISADVANTAGES OF ARTHRODESIS

Although arthrodesis is an effective reconstructive tool, the resulti problem without arthrodesis is preferable whenever possible, such

Ankle Fusion

INDICATIONS

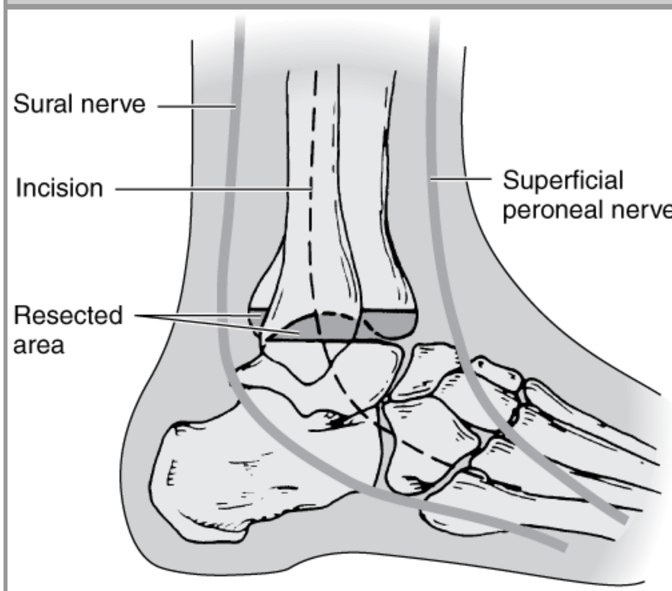
The main indications for ankle arthrodesis are the following:

1. arthrosis of the ankle joint usually secondary to a previous ankle fracture, althou
2. arthritis secondary to rheumatoid disease; and
3. instability with malalignment of the ankle joint as the result of an epiphyseal inju

TECHNIQUE

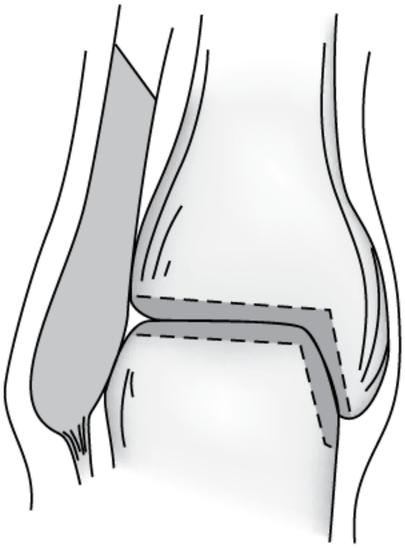
The surgical approach preferred by the authors is a transfibular ap the base of the fourth metatarsal. In this way, the incision avoids the anterior aspect of the ankle joint, to the medial malleolus and The fibula is removed approximately 2 cm proximal to the joint, af should extend to the medial malleolus but not through it. The foot the ankle should be aligned in neutral position, insofar as dorsiflex external rotation. If the two joint surfaces do not easily oppose ea

Figure 9–36.



Technique for ankle arthrodesis. Skin incision is placed between su
(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Figure 9–37.



The fibula is excised approximately 2–2.5 cm proximal to the ankl

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

The two flat surfaces should now be in total apposition, with little
screws should be placed to gain adequate interfragmentary compr
In the immediate postoperative period, a firm compression dressir
leg cast in place for another 6 weeks. Arthrodesis generally occurs

Figure 9–38.

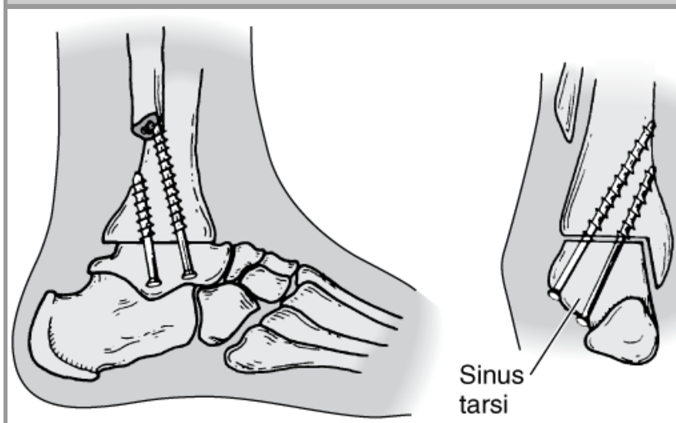


Diagram demonstrating placement of the 6.5-mm screws across t

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

COMPLICATIONS

Nonunion of the ankle joint, although uncommon, does occur. Usin

Malalignment of the ankle joint with the foot in too much internal r
increased stress on the heel (which can usually be treated with ad
screw across the subtalar joint for fear of damaging the posterior t

SPECIAL CONSIDERATIONS

Avascular necrosis of the talus requires excision and tibiocalcaneal
often defects that affect stability because of the previous crushing

Total Ankle Arthroplasty

Total ankle arthroplasty is an alternative to ankle arthrodesis for p
technically difficult with a steep learning curve, there is a higher c
durable in selected patients. Several other prostheses, including th

Subtalar Arthrodesis

INDICATIONS

The main indications for subtalar arthrodesis are the following:

1. arthrosis of the subtalar joint, usually following a calcaneal fracture, but occasion
2. varus or valgus deformity secondary to RA;
3. varus deformity secondary to residual clubfoot or possibly following compartment
4. unstable subtalar joint secondary to poliomyelitis, a neuromuscular disorder, or t
5. symptomatic talocalcaneal coalition without secondary changes in the talonavicul

TECHNIQUE

The incision for subtalar arthrodesis begins at the tip of the fibula
nerve may be present that unfortunately may be cut and give rise

The articular cartilage is removed from the joint surfaces, which in
possibility of fusion. The area around the floor of the sinus tarsi ar

The alignment of the subtalar joint is critical. It must be aligned in

Rigid fixation of the subtalar joint is achieved by using a 7-mm car
subtalar joint is then manipulated into proper alignment, and the g

Following adequate internal fixation, the local bone graft is packed
the morbidity of the procedure.

Postoperatively, a firm compression dressing incorporating plaster
immobilization generally achieves an arthrodesis.

COMPLICATIONS

Nonunion of the subtalar joint is uncommon, although it can occur.
a solid union.

Misalignment of the subtalar joint may also be a complication. An e
midfoot and occasionally the knee joint. A varus deformity of the s
base of the fifth metatarsal.

SPECIAL CONSIDERATIONS

The patient with RA or posttraumatic complications may have later
lateral aspect of the talus and place it under the tibia in a proper w

Special attention to the peroneal tendons is necessary when a sub
tendons beneath the fibula. This protrusion must be carefully excis
calcaneus to provide tendon sheath and protect the peroneal tendo

Occasionally a bone block distraction arthrodesis of the subtalar jo
dorsiflexion. Placing a tricortical block of iliac crest into the posteri

Talonavicular Arthrodesis

INDICATIONS

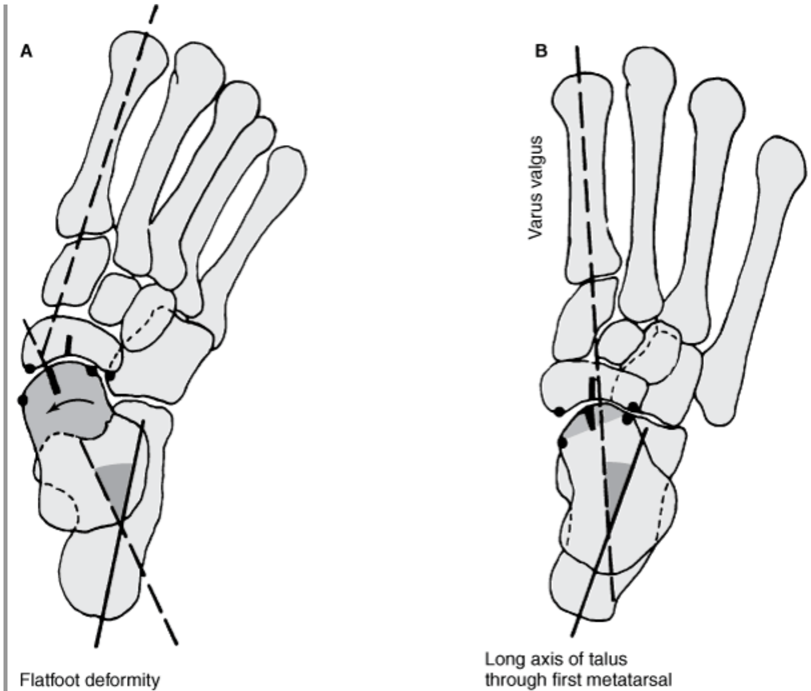
Talonavicular arthrodesis is indicated in the following conditions:

1. posttraumatic injury, RA, or primary arthrosis;
2. unstable talonavicular joint secondary to rupture of the posterior tibial tendon ar
3. double or triple arthrodesis of the hindfoot.

TECHNIQUE

The talonavicular joint is approached through a medial or dorsome
removed with a curet or curved osteotome. Distraction of the joint
essentially eliminates motion in the subtalar joint. The fusion posit
joint is carried out. Proper alignment of this joint is particularly cri
with a single large screw (6.5 mm), two smaller screws (4.0 mm),

Figure 9–39.



Talonavicular fusion. **A:** Changes that occur in the talonavicular joi
once again centered over the head of the talus.

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Postoperatively the patient is immobilized in a non–weight-bearing

The talonavicular joint has a relatively high incidence of nonunion,
should approach 90%.

COMPLICATIONS

Complications of nonunion and misalignment are similar to those d

SPECIAL CONSIDERATIONS

An isolated talonavicular joint fusion usually produces a satisfactor
calcaneocuboid joint at the same time to obtain a more stable trar

Double Arthrodesis (Calcaneocuboid & Talonavicular J

INDICATIONS

Double arthrodesis today is a procedure that provides the same de
three joints function together. This procedure is also indicated in th

Figure 9–40.

Double arthrodesis consisting of a talonavicular and calcaneocuboi

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Indications for double arthrodesis are as follows:

1. arthrosis of the talonavicular and calcaneocuboid joints (eg, following trauma);
2. unstable talonavicular and calcaneocuboid joint following rupture of the posterior
3. arthrosis of the talonavicular joint or calcaneocuboid joint in an active individual,

TECHNIQUE

The talonavicular joint is approached through a medial or dorsome are exposed, the joint surfaces are denuded of articular cartilage a

The alignment when carrying out a double arthrodesis is extremely fixation of the arthrodesis site. The desired position is 5 degrees o fixation of the talonavicular joint is done first with the insertion of

COMPLICATIONS

Complications of nonunion and malalignment are similar to those c

Triple Arthrodesis

The triple arthrodesis is a fusion of the talonavicular, calcaneocubo commonly used when limited fusions are inadequate.

Figure 9–41.

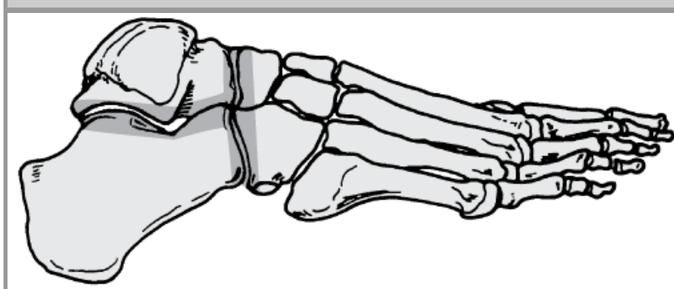


Diagram of a triple arthrodesis.

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

INDICATIONS

Indications for triple arthrodesis are as follows:

1. arthrosis secondary to trauma involving the subtalar, talonavicular, or calcaneocu
2. arthrosis or instability of the talonavicular or calcaneocuboid joints in association
3. instability of the foot secondary to posterior tibial tendon dysfunction with a fixed
4. unstable hindfoot secondary to poliomyelitis, nerve injury, or RA;
5. symptomatic, unresectable calcaneonavicular bar; and
6. malalignment of the hindfoot secondary to trauma such as a crush injury or com

TECHNIQUE

The triple arthrodesis is carried out as previously described for sub
adduction of the transverse tarsal joint, and correction of forefoot

COMPLICATIONS

The main complication is failure of fusion of one of the joints, whic
technically is a difficult procedure. The sural nerve may become en

Tarsometatarsal Arthrodesis

Arthrodesis in the tarsometatarsal area may involve a single tarsor
joints. A careful determination of the involved joints is important w
the involved area precisely.

INDICATIONS

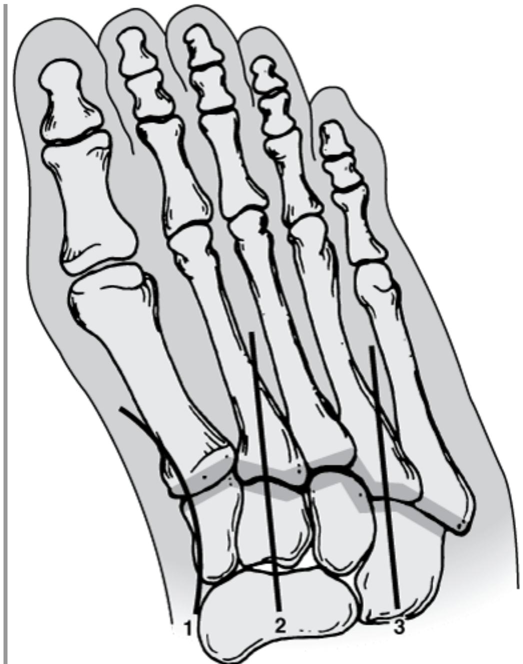
The indications for a tarsometatarsal fusion are as follows:

1. hypermobility of the first metatarsocuneiform joint associated with a hallux valgu
2. arthrosis involving one or more of the tarsometatarsal joints either resulting fror
3. arthrosis associated with a deformity resulting from an old Lisfranc fracture-dislo

TECHNIQUE

The surgical approach to the first metatarsocuneiform joint is thro
and all of the second and third metatarsocuneiform joints can be a
be fused as well. Cautious dissection is necessary because there a
joint in this approach. If the fourth and fifth metatarsocuboid joint
depending on the extent of the fusion mass. The bones are heavily
metatarsocuneiform joint is aligned and fixed using 4-mm cancello
first metatarsocuneiform joint is one brought from the dorsal aspe
correct any dorsiflexion or abduction deformity that is present.

Figure 9–42.



Longitudinal incisions used for a tarsometatarsal arthrodesis.

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Postoperatively, the joint is placed in a short leg, non–weight-bear

COMPLICATIONS

The possibility of nonunion exists, but with interfragmentary comp swelling and tension is placed against the incisions. It is critical po: skin grafting is required.

A tarsometatarsal fusion involving multiple joints may cause a plar

Staples should be avoided as a means of internal fixation of the ta

First Metatarsophalangeal Joint Arthrodesis

See the discussion of hallux valgus at the beginning of the chapter

Interphalangeal Joint Arthrodesis (Hallux Arthrodesis

INDICATIONS

Interphalangeal joint arthrodesis is usually indicated for the followi

1. arthrosis, usually secondary to trauma or occasionally following a first metatarso
2. stabilization of the interphalangeal joint when carrying out a transfer of the exte

TECHNIQUE

The interphalangeal joint is approached through a dorsal transvers phalanx and the proximal portion of the distal phalanx are remove crossed K-wires, or both. A postoperative shoe is used, with weigh

COMPLICATIONS

Nonunion of interphalangeal joint fusion is uncommon. If it does oc

Buchner M, Sabo D: Ankle fusion attributable to posttraumatic art

Buck P et al: The optimum position of arthrodesis of the ankle. J E

Clain MR, Baxter DE: Simultaneous calcanealcuboid and talonavicu

Harper MC: Talonavicular arthrodesis for the acquired flat foot in t

Hintermann B et al: The HINTEGRA ankle: rationale and short-terr

Knecht S et al: The Agility Total Ankle Arthroplasty J Bone Joint Su

Kofoed H: Scandinavian Total Ankle Replacement (STAR). Clin Orth

Kofoed H, Sorensen TS: Ankle arthroplasty for rheumatoid arthriti

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Mann RA, Beaman DN, Horton GA: Isolated subtalar arthrodesis. F

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Robinson JF, Murphy GA: Arthrodesis as salvage for calcaneal malu

Winson IG, Robinson DE, Allen PE: Arthroscopic ankle arthrodesis.

CONGENITAL FLATFOOT

Congenital flatfoot is the term used to describe a flatfoot present s flatfoot is probably a normal variant of the longitudinal arch. This c These individuals have a fairly flexible foot until adolescence, wher

The patient with a tarsal coalition frequently presents with a peron peritalar joints. A tarsal coalition is the union of two or more tarsa hindfoot. Coalitions are usually not symptomatic until adolescence, symptomatic in the early to mid teenage years and may be unilate

The patient with generalized dysplasia, such as Marfan syndrome c

Clinical Findings

SYMPTOMS AND SIGNS

The clinical evaluation begins with the patient in a standing positio
valgus position. A tarsal coalition or an accessory navicular may be
are present bilaterally.

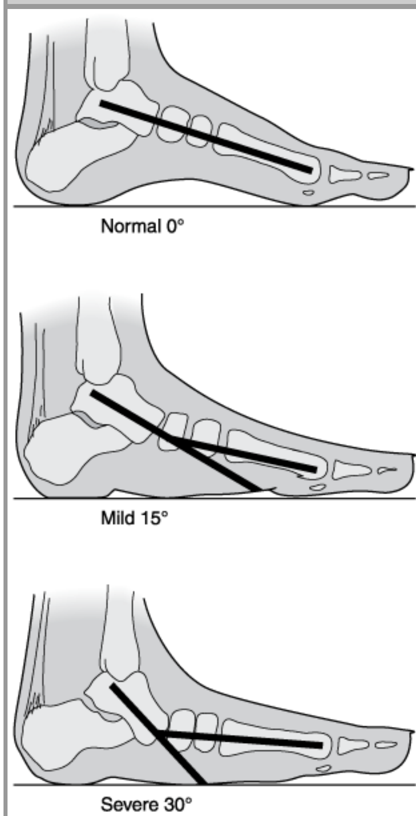
The physical examination of these patients is extremely important
demonstrates an equinus contracture. To test adequately for tight
dorsiflexion, permitting lateral subluxation of the talonavicular join

The patient with tarsal coalition usually demonstrates restricted hi
active inversion of the subtalar joint to occur. On occasion, clonus
stressing of the posterior tibial tendon aggravates the condition. T
patient with generalized dysplasia demonstrates marked hypermob

IMAGING STUDIES

The radiographic evaluation is useful in differentiating the various
the calcaneus may even be in a mild degree of equinus position. O
flatfoot, and 0–15 degrees in mild flatfoot (Figure 9–43).

Figure 9–43.



Measurement of flatfoot deformity by using the lateral talometata

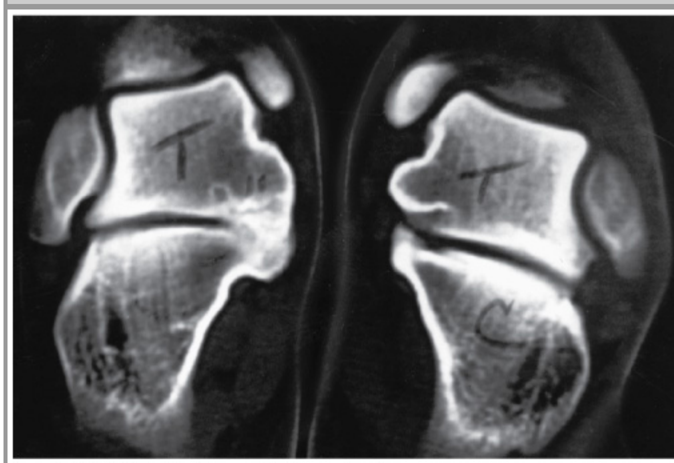
(Reproduced, with permission, from Bordelon RL: Correction of hy

The calcaneonavicular coalition is best observed on an oblique radi
demonstrated on a CT scan taken in the coronal plane (Figure 9–4
size of the fragment (Figure 9–46). In a patient with a residual co
often demonstrates complete collapse of the longitudinal arch.

Figure 9–44.

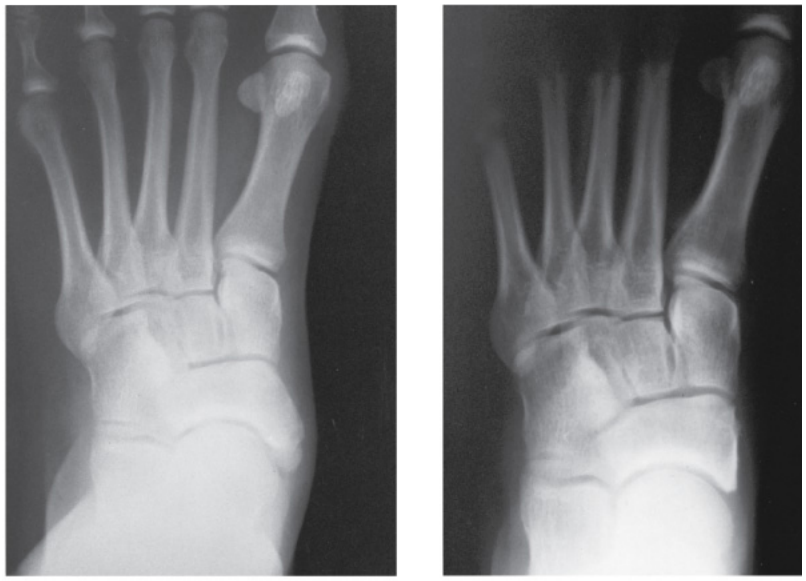
Oblique view of the foot at 45-degree angle demonstrating calcan
(Reproduced, with permission, from Mann RA, Coughlin MJ: *Surge*

Figure 9–45.



CT scan demonstrating osseous coalition on one side (left) and fib
(Reproduced, with permission, from Mann RA, Coughlin MJ, eds: S

Figure 9–46.



Large accessory navicular. **A:** Preoperatively, a cartilaginous plate
(Reproduced, with permission, from Mann RA, Coughlin MJ, eds: S

Treatment

CONSERVATIVE MANAGEMENT

Conservative management is undertaken for congenital flatfoot de
support and Achilles stretching exercises may be of some benefit.

The tarsal coalition can be treated conservatively with a short leg
Flatfoot with an accessory navicular may respond to modification c

Residual flatfoot resulting from congenital problems can be treatec

SURGICAL MANAGEMENT

Surgical procedures are never appropriate for asymptomatic flatfo
may benefit from lengthening of the Achilles tendon. A lateral colu
valgus and forefoot abduction and should be done as late into grov

A tarsal coalition that does not respond to conservative manageme
Talocalcaneal coalitions are resectable throughout the adolescent y
adolescent or any bar in an adult patient is an indication for subtal
coalition is identified, and it is resected to expose the area of norm
excision of the accessory navicular and plication of the posterior ti

Residual congenital deformity or generalized dysplasias usually do

Coleman S: *Complex Foot Deformities in Children.* Lea and Febige

Frischhut B et al: Foot deformities in adolescents and young adult

Giannini S et al: Operative treatment of flatfoot with talocalcaneal

Gonzalez P, Kumar SJ: Calcaneonavicular coalition treated by rese

Varner KE, Michelson JD: Tarsal coalition in adults. Foot Ankle Int 2

ACQUIRED FLATFOOT DEFORMITY

Acquired flatfoot deformity is a condition affecting a foot that at or
flatfoot deformity, present since birth. Acquired flatfoot deformity

1. posterior tibial tendon dysfunction;
2. arthrosis of the tarsometatarsal joints, which may be primary or secondary to a
3. Charcot changes in the midfoot resulting from a peripheral neuropathy; or
4. talonavicular collapse resulting from trauma or RA.

Acquired flatfoot deformities are complex deformities that affect d
the hindfoot, or all three. The extent of the deformity varies widel

Clinical Findings

SYMPTOMS AND SIGNS

A careful history is important to help distinguish among differing c
patients with tarsometatarsal joint arthrosis, a Lisfranc fracture-di
diabetes. The patient with collapse of the talonavicular joint gives

The physical examination begins by observing the foot with the pa

The patient with posterior tibial tendon dysfunction demonstrates
asked to stand on tiptoe, the involved calcaneus remains in valgus
commonly known as the "too many toes sign."

Arthrosis of the tarsometatarsal joints creates a deformity of abdu
aspect of the tarsometatarsal joints.

A Charcot foot presents with varying degrees of swelling and defo
to a severe rocker-bottom deformity. It is important to palpate for

In the patient with RA, most of the changes occur within the talon
usually present as well.

The posttraumatic deformity may vary, depending on precisely wh
medial aspect of the foot. There is usually little or no motion in the

IMAGING STUDIES

Radiographs usually differentiate the cause of the problem. In the
arthrosis demonstrates typical degenerative changes at the affecte
dramatic bone destruction and joint dislocations (Figure 9–47). Th

Figure 9–47.

Charcot midfoot changes resulting in joint dislocations and a rocke

Treatment

CONSERVATIVE MANAGEMENT

Conservative management is aimed at providing support to the lor
potential for skin breakdown, particularly in the neuropathic foot. /

SURGICAL TREATMENT

The surgical management of these various conditions is specific fo
flexor digitorum longus tendon transfer. A calcaneal osteotomy is p
correct a flexible flat foot with significant abduction of the forefoot

The patient with Charcot foot is treated in a short leg cast until th
AFO. In extreme rocker-bottom deformities, midfoot correction wi
arthrodesis if there is a hindfoot or midfoot deformity.

The posttraumatic foot with involvement of the talonavicular joint

The patient with arthrosis of the tarsometatarsal joints responds w

Castro MD: Arthrodesis of the navicular. Foot Ankle Clin 2004;9(1)

Guyton GP et al: Flexor digitorum longus transfer and medial displ

Mann RA, Thompson FM: Rupture of the posterior tibial tendon ca

Thomas RL et al: Preliminary results comparing two methods of la

Trepman E et al. Current topics review: Charcot neuroarthropathy

Trnka HJ: Dysfunction of the tendon of tibialis posterior. J Bone Jo

CAVUS FOOT

Cavus foot deformity is characterized by an abnormal elevation of
further reducing the forefoot weight-bearing area. Generalized stif

Etiologic Findings

The various causes of cavus foot deformity include the following:

1. anterior horn cell disease, such as poliomyelitis, diastematomyelia, and spinal cor
2. nerve disorders, such as Charcot-Marie-Tooth disease and spinal dysraphism;
3. muscular diseases, such as muscular dystrophy;
4. long tract and central diseases, such as Friedreich ataxia and cerebral palsy;
5. idiopathic conditions, such as residual clubfoot, arthrogryposis, and cavus foot of
6. posttraumatic disorders following injuries, such as compartment syndrome or cru

Anatomy

Cavus foot deformity is extremely variable in its presentation, fror

Posterior Cavus Deformity

This deformity mainly involves the calcaneus, which has a dorsifle
varus deformity of the heel is usually present as well.

Anterior Cavus Deformity

In anterior cavus deformity, there is a forefoot equinus deformity
plantar flexion. Some degree of adduction of the forefoot is usuall

Combined Cavus Deformity

In a combined cavus deformity, which is the most severe, there ar

Clinical Findings

SYMPTOMS AND SIGNS

A careful history regarding the onset of the condition and progress
in the adolescent, because it may indicate a spinal cord abnormalit

The degree of deformity of the foot must be examined with the pa
the joints of the foot and ankle should be carefully measured. The
joints, and lesser toes must be ascertained. The presence of a tigh

IMAGING STUDIES

Weight-bearing radiographs of the foot and ankle are obtained to l

Treatment

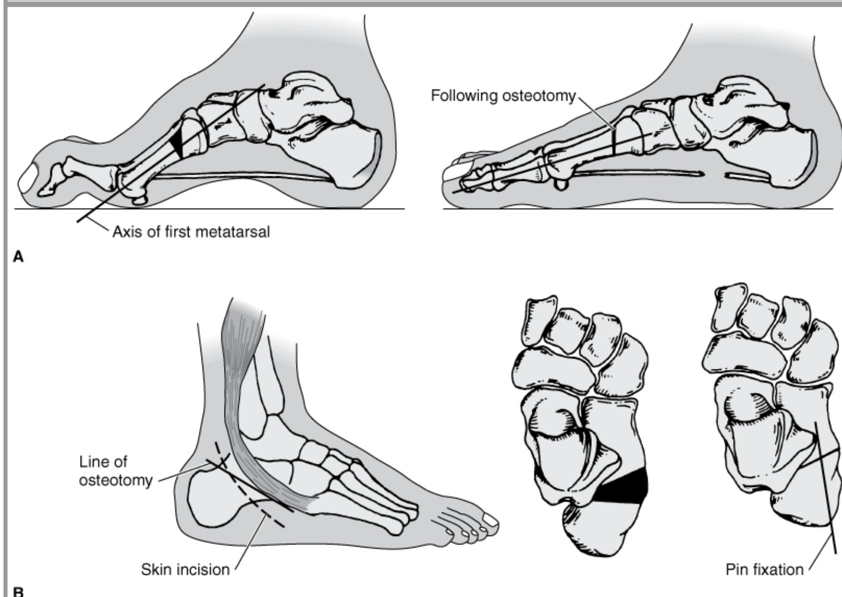
CONSERVATIVE MANAGEMENT

Conservative care is tailored to the severity of the cavus deformity
helps decrease the stress on the metatarsal heads. A significant m

SURGICAL TREATMENT

Surgical treatment for the cavus foot is aimed at correcting the sit
respond to release of the plantar fascia, dorsiflexion osteotomy of
as much flexibility of the foot as possible (Figure 9–48).

Figure 9–48.

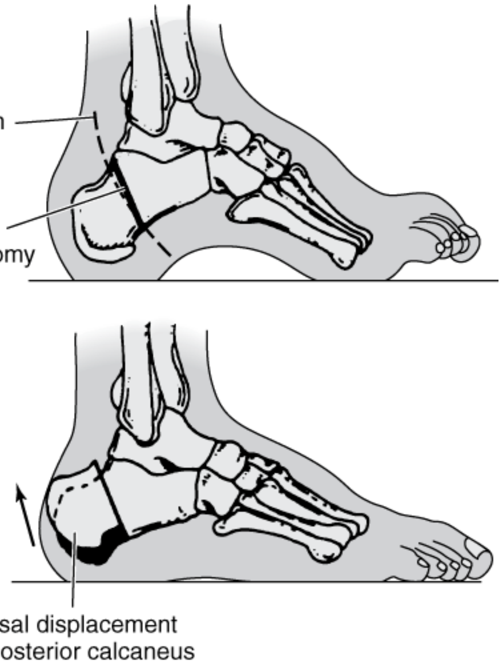


Technique for correction of cavus foot. **A:** For first metatarsal oste
correct the cavus deformity by flattening the arch. **B:** Heel varus

(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

A more severe deformity involving dorsiflexion of the calcaneus ca
49). Forefoot deformity is treated with osteotomy of the first and
foot.

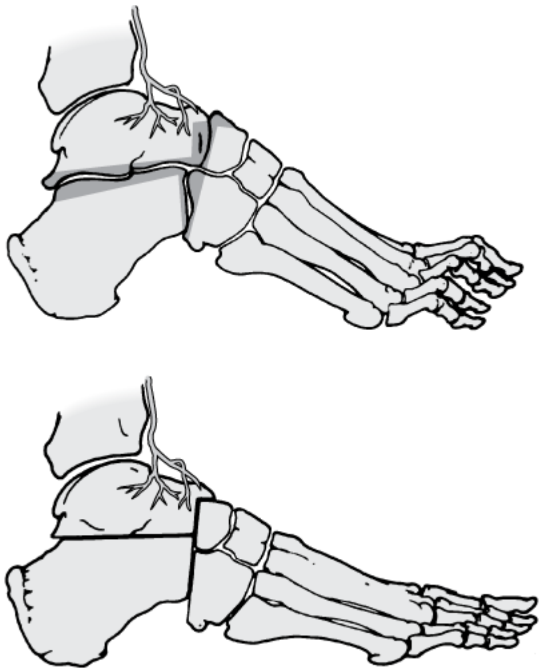
Figure 9–49.



Techniques of calcaneal osteotomy. In the treatment of pes cavus,
(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

Severe deformities not amenable to procedures that retain joint m
longitudinal arch (Figure 9–50). A first metatarsal osteotomy may

Figure 9–50.



A diagram of a beak-type triple arthrodesis. This mortises the nav
(Reproduced, with permission, from Mann RA, Coughlin MJ: *The V*

The lesser toes may have either fixed or flexible clawtoe deformiti
the hammer toe, followed by extensor tendon release and the Girc
Hyperextension of the first metatarsophalangeal joint is corrected

Figure 9–51.

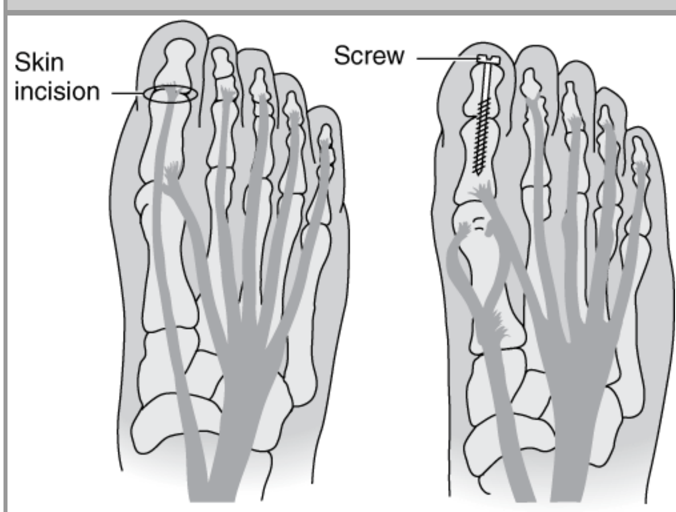


Diagram of the first toe Jones procedure. This procedure moves th

(Reproduced, with permission, from Mann RA, Coughlin MJ, eds: S

Breusch SJ et al. Function after correction of a clawed great toe by

Giannini S et al. Surgical treatment of adult idiopathic cavus foot w

Siffert RS del Torto U "Beak" triple arthrodesis for severe cavus de

Sammarco GJ, Taylor R Cavovarus foot Treated with combined calc

ORTHOTIC DEVICES FOR THE FOOT & ANKLE

Orthotic devices are used to redistribute stresses on the foot as it
to relieve pressure and provide increased comfort for the foot. Ort
may cup the foot (UCBL insert), or may extend across the ankle to

Orthotic Shoe Sole Devices

A variety of heel and sole corrections are available to accommodat
or fixed deformities. A wide heel is used to increase the stability of

Orthotic Insole Devices

Insole orthotic devices can be used for flexible deformities to alter
include a soft felt pad to relieve pressure on the metatarsal heads
the patient may need a larger or deeper shoe.

University of California Biomechanics Laboratory Inse

The principle of the UCBL insert is to correct a foot deformity such
theory, this orthotic device is excellent for controlling the rearfoot
prominence can chafe against the polypropylene material, resultin

Ankle-Foot Orthosis

An AFO is a molded polypropylene device that passes along the po
Ankle problems such as arthrosis or dorsiflexion weakness require
the subtalar joint. When the problem involves the transverse tarsa
managing tarsometatarsal arthritis, the footpiece is carried to the
are essential to minimize the risk of ulcers forming over a bony pr

Figure 9–52.

A

B

Types of ankle-foot orthoses (AFOs). **A:** A standard AFO with a tri
the stability of the foot and ankle within the brace.

(Reproduced, with permission, from Mann RA, Coughlin MJ, eds: S

Double Upright Orthosis

The double upright orthosis with a hinged ankle may be used wher
The hinge mechanism of the ankle joint may be changed, dependi
brace can be modified with a spring load to provide dorsiflexion fo

Prescriptions for Orthotic Devices

The following are typical prescriptions for orthotic devices.

METATARSALGIA OR ATROPHY OF PLANTAR FAT PAD

Treatment

A full-length well-molded orthosis for metatarsal arch support is us

Explanation

In the treatment of metatarsalgia or atrophy of the plantar fat pac
to provide extra cushioning for the foot.

RUPTURED POSTERIOR TIBIAL TENDON WITH MODERATELY

Treatment

AFO with trim-line cut to permit 30% ankle joint motion is molded

Explanation

With a moderately advanced flexible flatfoot deformity, an in-shoe
the patient. The longitudinal arch is molded to support the foot in
beneath the longitudinal arch to prevent it from collapsing is decre

POSTERIOR TIBIAL TENDON INSUFFICIENCY WITH MILD FL

Treatment

Use a well-molded longitudinal arch support, with a 5-degree varu

Explanation

Insufficiency of the posterior tibial tendon that has not produced a
likewise helps tilt the hindfoot from valgus deformity closer to neu

DROPFOOT SECONDARY TO PERONEAL NERVE INJURY

Treatment

An AFO with a full footpiece is molded to the longitudinal arch.

Explanation

A dropfoot secondary to a peroneal nerve injury responds well to a

DIABETIC NEUROPATHY WITH CLAWFOOT DEFORMITY

Treatment

An extra-depth shoe with a molded Plastazote liner is backed with

Explanation

The patient with clawfoot deformity requires a shoe that has extra
providing full contact to the plantar aspect of the foot. Plastazote l

Bordelon RL: Orthotics, shoes, and braces. Orthop Clin North Am 1

Major RE et al: A new structural concept in moulded fixed ankle fo

Pfeffer G et al: Comparison of custom and prefabricated orthoses

Pinzur M: Surgical versus accommodative treatment for Charcot a

Raikin SM et al: Biomechanical evaluation of the ability of casts an

LIGAMENTOUS INJURIES ABOUT THE ANKLE JOINT

Ankle ligament injuries represent the most common musculoskelet
structures around the ankle joint should not be overlooked, as disc

Functional Anatomy

The lateral collateral ligament structure of the ankle consists of thr

When the ankle joint is in plantar flexion, the ATFL is positioned in
long axis of the fibula and is therefore subject to injury. If the app
by an external rotational force to the foot. The deltoid ligament is
conjunction with a syndesmosis ligament injury, with lateral ankle

Clinical Findings

CLASSIFICATION

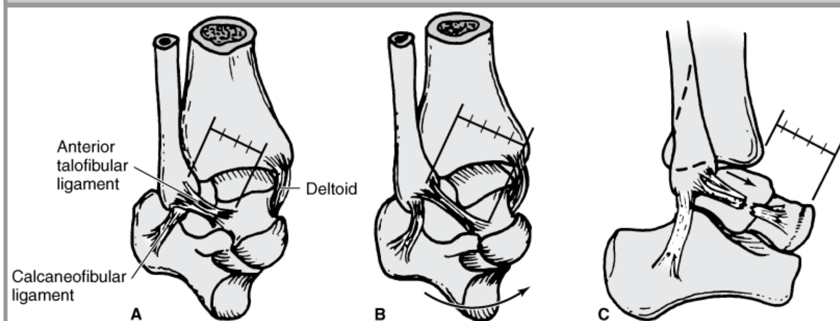
Lateral collateral ankle ligament injuries are divided into three deg
A grade III sprain involves injury and significant laxity of both the

SYMPTOMS AND SIGNS

A past history of injuries of the ankle and problems with chronic ar
or soft-tissue structures. The ATFL, PTFL, CFL, and syndesmosis li
the base of the fifth metatarsal. Other areas where an injury must

A patient with significant medial joint pain with or without lateral li
and radiographic stress examinations. To perform an anterior drav
feeling of subluxation is present if a significant ligament injury has
dorsiflexion, a talar tilt maneuver tests the stability of the CFL. If

Figure 9–53.



Mechanics of carrying out a stress test of the lateral ankle ligamer
by firmly inverting the calcaneus. **C:** The anterior talofibular ligam

(Reproduced, with permission, from Mann RA, Coughlin MJ, eds: S

Deltoid ligament insufficiency may cause a feeling of instability and

Injury to the syndesmosis ligament complex is suspected if the reg
Pain elicited by squeezing the tibia and fibula together in the midc
mortice occurs with direct lateral force on the foot.

IMAGING STUDIES

Standard anteroposterior, lateral, and oblique radiographs of the a
anteroposterior view is taken while a talar tilt maneuver is perform

If a syndesmosis ligament injury is suspected, careful attention mu

MRI or CT scan may be helpful in some instances if there is a high
may be of benefit.

Treatment

CONSERVATIVE MANAGEMENT

Acute grade I ligament tears are treated with a lateral stabilizing a
discontinued in 1 month.

Grade II ligament tears are treated with protected weight bearing
exercise (jogging) may resume after 2–4 weeks.

In a grade III ligament tear, the ankle is immobilized with a remov
biomechanical ankle platform system (BAPS) board.

Treatment of isolated deltoid ligament sprains depends on the sev
casted for 3–4 weeks.

Syndesmosis ligament tears, if mild, can be treated with weight be
to the ankle joint, treatment depends on the radiographic appeara
show a widened mortise, the patient requires surgical repair of the

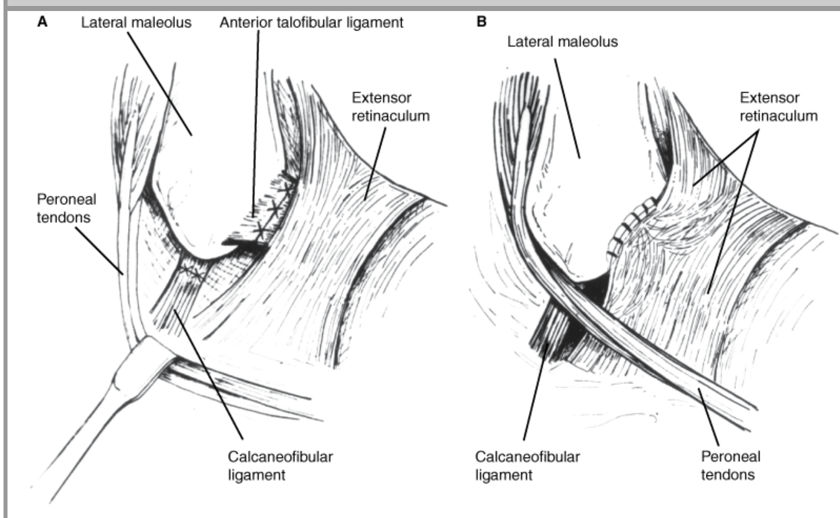
SURGICAL TREATMENT

The surgical treatment of an acute ligamentous injury is indicated
severe ankle sprains may cause chronic pain or functional instabilit

The indication for a lateral ligament reconstruction is functional lig
therapy and use of a lateral stabilizing brace. A patient with functi

Although many lateral ankle reconstruction procedures are describ
are plicated and reattached to their anatomic positions (Figure 9–5
harvest the peroneus brevis tendon. In patients who have severe

Figure 9–54.



Modified Broström anatomic reconstruction. **A:** Imbrication of ante

(Reproduced, with permission, from Coughlin MJ, Mann RA, eds: S

Chronic lateral ankle pain following an ankle sprain may be caused
subtalar joint instability, subtalar joint chondral damage or synovit

physical examination, an MRI or CT scan may be helpful for disting

Surgical treatment may help relieve symptoms of chronic lateral a
Subtalar joint instability is addressed with a Broström procedure. A
Scar tissue in the lateral gutter can be treated with arthroscopic d

Chronic instability of the deltoid ligament or syndesmosis ligament
damaged ligament, with the addition of internal fixation for chroni

Coughlin MJ et al: Comprehensive reconstruction of the lateral ank

DiGiovanni BF et al: Acute ankle injury and chronic lateral instabili

Hintermann B et al: Medial ankle instability: An exploratory, prosp

Hoiness P, Stromsoe K: Tricortical versus quadricortical syndesmos

Krips R et al: Long-term outcome of anatomical reconstruction ver

Messer TM et al: Outcome of the modified Broström procedure for

Pijnenburg ACM et al: Treatment of ruptures of the lateral ankle li

ARTHROSCOPIC EXAMINATION OF THE FOOT & ANKLE

Arthroscopy is an important tool for use in diagnosis and treatmen
method for diagnosing and treating some subtalar joint abnormalit

Advantages of Ankle Arthroscopy over Ankle Arthroto

Arthroscopy of the ankle joint offers distinct advantages over oper
performed to stress ligaments or identify areas of soft-tissue or bo

Indications

Table 9–4 lists the indications for ankle joint arthroscopy. In additi

Table 9–4. Proven Indications for Ankle Arthroscopy.

Loose body removal	Irrigation and debridement for infection	Shavin osteoph

THERAPEUTIC INDICATIONS

Loose Bodies

Intraarticular loose bodies are generally easy to identify and remo
lesion. They cause pain or locking symptoms of the ankle and are

Ankle Joint Infection

Arthroscopic irrigation, drainage, and synovectomy is an excellent

Synovitis

Synovitis may be present as a result of inflammatory arthritis (RA
inflamed synovium often relieves symptoms. Synovectomy is more

Osteophyte Formation

Repetitive trauma or early osteoarthritis can lead to osteophyte fo

Other Lesions Within the Joint

Chondral or osteochondral lesions, whether caused by trauma or c

Patients who present with ankle pain over the anterolateral joint li
debridement of scar tissue from the lateral gutter.

Ankle Arthrodesis

Techniques for arthroscopically assisted ankle arthrodesis are well
technically demanding procedure and cannot be used to correct ar

Ankle Arthritis

Arthroscopic debridement of the arthritic ankle joint is not benefici

Ankle Fractures

Arthroscopically assisted fixation of ankle fractures is described an
treatment of most routine ankle fractures is probably not indicate

DIAGNOSTIC INDICATIONS

Ankle arthroscopy can be a valuable diagnostic tool when the caus
warrant arthroscopic exploration to help make a diagnosis. Chondr
instability for which a cause cannot be found may be aided by diag

Table 9–5. Refractory Conditions Diagnosed by Arthro

Chondromalacia	Synovitis	Locking of the joint	Chronic stiffness	Insta

Technique of Ankle Arthroscopy

The patient is placed supine on the operating table with the foot p
General or spinal anesthesia is necessary for full relaxation of the

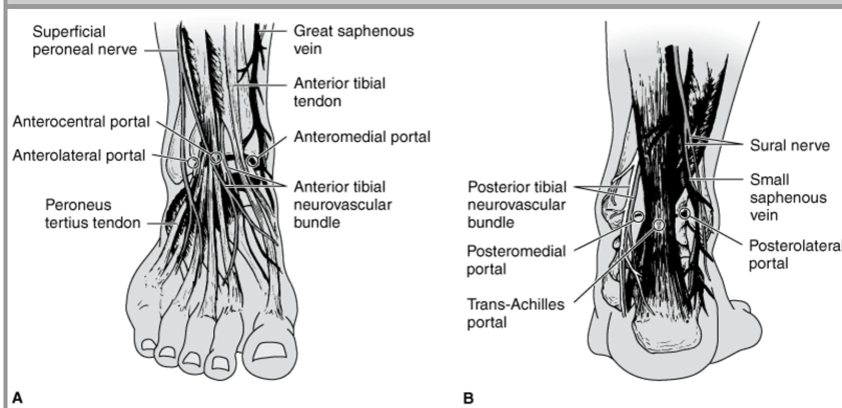
Figure 9–55.

Soft strap type of distractor used during ankle arthroscopy.

The use of distraction greatly enhances arthroscopic procedures, p
used (see Figure 9–55) Invasive distractors require placement of p
distractor.

Most ankle arthroscopies are performed using two anterior portals
the tendons, nerves, and vessels is essential to prevent damage to
peroneal nerve. The anteromedial portal is placed just medial to th

Figure 9–56.



A: The anterior portals used for ankle arthroscopy are illustrated.

(Reproduced, with permission, from Ferkel RD: Arthroscopy of the

Initially, the entire joint is explored systematically, to ensure that a
medial and lateral gutters are explored, paying special attention to

observed closely for signs of laxity while varus and valgus forces a
evaluated.

After a thorough diagnostic examination, surgical procedures are p

Postoperatively, a compression dressing is applied with a posterior

Complications

Although several complications are reported, the most common is
the sites of distraction pins are all described but are very uncomm

Subtalar Joint Arthroscopy

The subtalar joint is technically challenging for arthroscopy, given
chondral lesions, synovitis, and focal degenerative changes may re

For subtalar joint arthroscopy, the patient can either be placed sup
portions of the posterior facet and the interosseous ligament can b
about the technique of subtalar joint arthroscopy.

Frey C et al: Arthroscopic evaluation of the subtalar joint: Does sir

Henderson I, La Valette D: Ankle impingement: Combined anterior

Kim SH, Ha KI: Arthroscopic treatment for impingement of the ant

Okuda R et al: Arthroscopic findings in chronic lateral ankle instab

Philbin TM et al: Arthroscopy for athletic foot and ankle injuries. C

Schimmer RC et al: The role of ankle arthroscopy in the treatment

Stroud CC: Arthroscopic arthrodesis of the ankle, subtalar, and firs

Thordarson DB et al: The role of ankle arthroscopy on the surgical

Tendon Injuries: Introduction

Tendon injuries about the foot and ankle are common causes of di
further predisposes them to injury. Injury to tendons may be caus

ACHILLES TENDON INJURIES

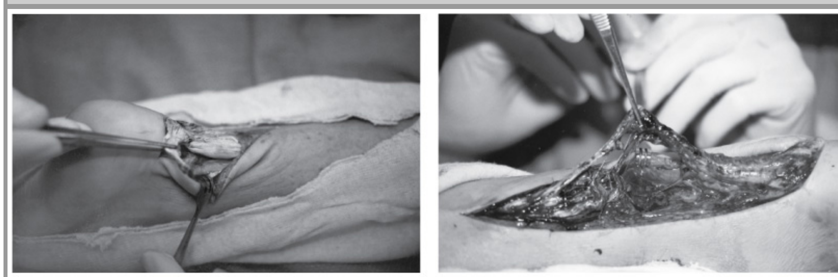
Achilles tendon abnormalities are extremely common, especially ar
tendinitis was previously discussed in the section on heel pain.

Achilles Tendon Rupture

Pathogenesis

The mechanism of injury is usually mechanical overload from an e
to the insertion of the Achilles tendon, at the site of its poorest blo
recreational athlete. These factors suggest that insufficient conditi

Figure 9–57.



A

B

Examples of acute Achilles tendon ruptures. **A:** Complete rupture
(Reproduced, with permission, from Plattner P, Mann RA: Disorder

Clinical Findings

SYMPTOMS AND SIGNS

The patient describes sudden pain in the calf after attempting a pu
plantar flexion is markedly weak compared with the unaffected sid
flexion of the foot if the Achilles tendon is intact or partially torn b

IMAGING STUDIES

Plain radiographs are not helpful in diagnosing Achilles tendon tear
remains in continuity (Figure 9–58). However, MRI is rarely neede

Figure 9–58.

MRI of Achilles tendon rupture.

Treatment

Methods for treating Achilles tendon rupture include primary repai

Cast treatment for Achilles tendon ruptures is recommended for m
rerupture. For the vast majority of patients, either treatment metl

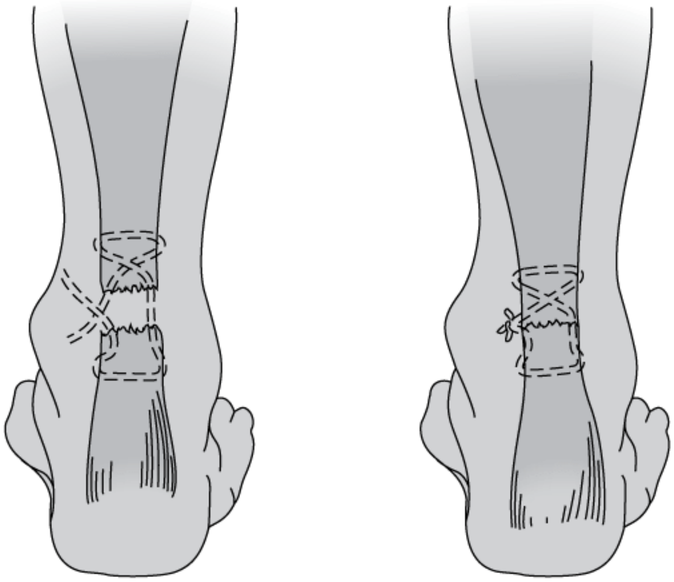
NONSURGICAL TREATMENT

Once an acute rupture is diagnosed, the patient should be placed i
although this is not routine. After 4 weeks, the cast is changed, wi
walking cast for 4 weeks. Supervised strengthening activities then

SURGICAL TREATMENT

The surgical approach is on the medial side of the Achilles tendon
woven through 3–4 cm of each tendon edge using a Bunnell or Ke
repair.

Figure 9–59.



Suture techniques used to reapproximate the ruptured Achilles te
(Reproduced, with permission, from Mann RA, Coughlin MJ, eds: S

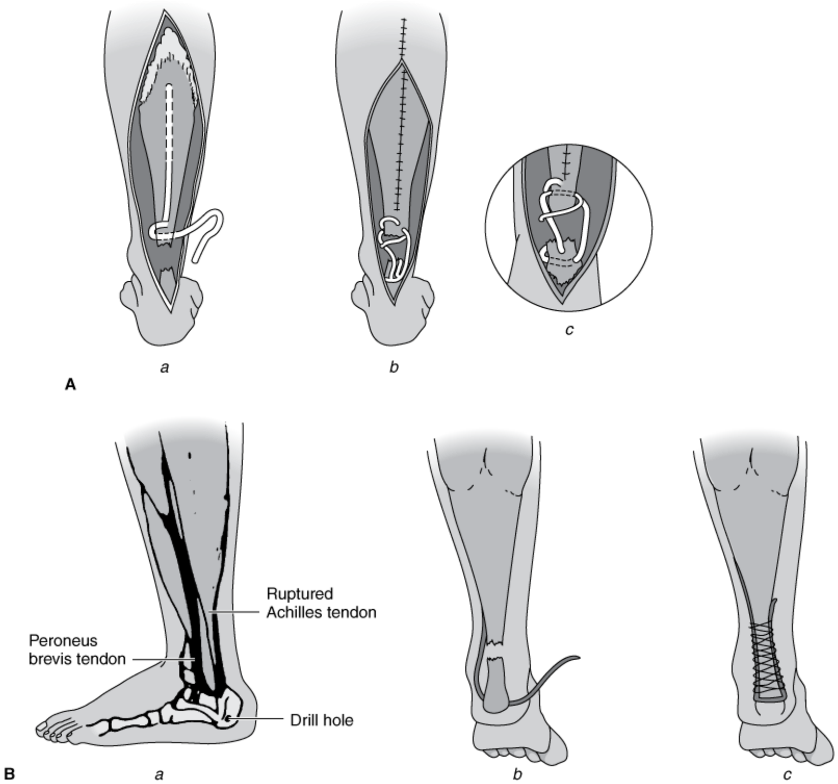
Postoperatively, a hard cast is used for 3 weeks, followed by a ren
cast is discontinued at 6–8 weeks, and supervised strengthening e

The primary risk of surgical repair is wound healing problems, whi

TREATMENT OF CHRONIC RUPTURES OR RERUPTURES

Chronic Achilles tendon ruptures, more than 6 weeks old, or rerup
address this problem, including a variety of synthetic and interpos

Figure 9–60.

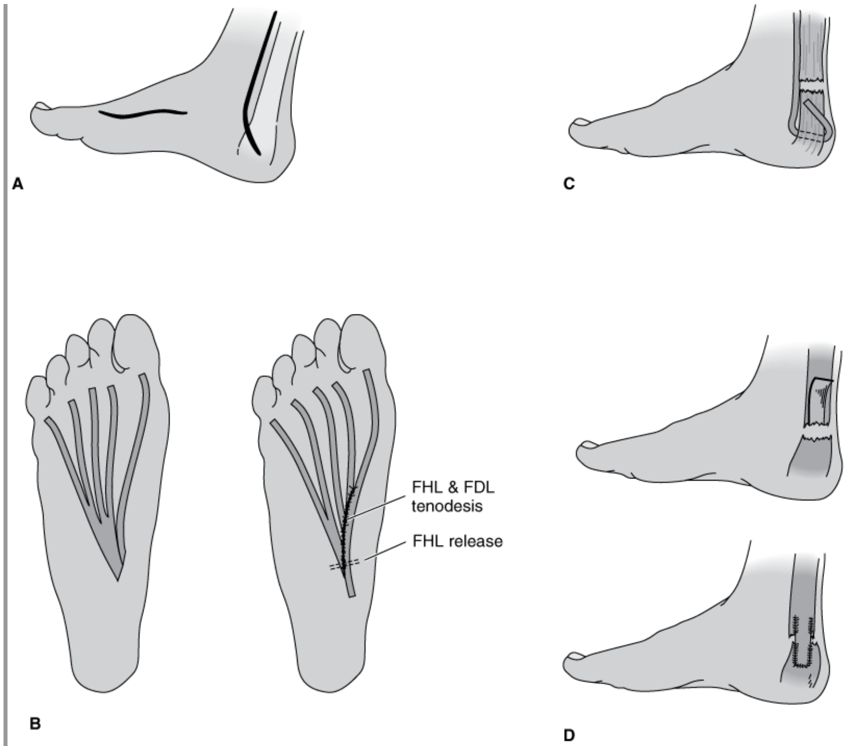


Various methods of reconstruction for untreated Achilles tendon ru
across the gap. *c:* Enlarged diagram of *b.* **B:** Repair using peroneu
transferred through the drill hole. *c:* The tendon is sutured to itse

(**A:** Reproduced, with permission, from Bosworth DM: Repair of de
the Foot and Ankle, 6th ed. Mosby-Year Book, 1993.)

Small defects can be bridged by turning down a strip of gastrocne
lengthening, transfer of the flexor hallucis longus tendon can be p
proximal tendon is secured to the calcaneus through a drill hole or
61).

Figure 9–61.



Delayed repair of ruptured Achilles tendon using flexor digitorum l
in calcaneus. **D:** Augmentation of spanned gap by turndown of fas

(Reproduced, with permission, from Plattner P, Mann RA: Disorder

The postoperative course for these procedures includes 6 weeks o

POSTERIOR TIBIAL TENDON INJURIES

This topic is covered in the section on acquired flatfoot deformities

PERONEAL TENDON INJURIES

Peroneal tendon injuries fall into the categories of peroneal tendon

Peroneal Tendonitis

Pathogenesis

Inflammation of the peroneal tendons may be caused by acute tra
fibula, or a severe inversion sprain of the ankle. Most tendonitis is
tubercle. Tendonitis of the peroneus longus may be associated wit

Clinical Findings

SYMPTOMS AND SIGNS

The patient complains of pain over the lateral aspect of the ankle,
located along the course of the peroneal tendons. Pain and weakn

IMAGING STUDIES

An MRI scan may help distinguish between tendonitis and a tendo

Treatment

NONSURGICAL

If symptoms are mild, the recommended treatment includes NSAI
Occasionally, a diagnostic injection with bupivacaine is given into t

SURGICAL

Operative intervention is recommended for patients who fail conse
is encouraged.

Peroneal Tendon Tears

Pathogenesis

The majority of peroneal tendon tears are attritional in nature, ca
predispose to a longitudinal split of the tendons. Laxity of the ten
but usually there is some degree of preexisting degeneration withi

Clinical Findings

Clinical presentation is similar to that of peroneal tendonitis, but w

Treatment

NONSURGICAL

Initial treatment is similar to that of peroneal tendonitis, but it is l

SURGICAL

Surgical repair of a peroneal tendon tear is indicated when nonope
of the tendon that demonstrate significant degeneration are remo

Peroneal Tendon Subluxation and Dislocation

Pathogenesis

Peroneal tendon dislocation is caused by a sudden forceful dorsifle
tendons in place along the posterior border of the distal fibula. Th
peroneal tendons to dislocate anteriorly. If this condition goes unre

Clinical Findings

SYMPTOMS AND SIGNS

The patient usually recalls an acute episode of trauma and freque
felt to pop out of place. On examination, resisted eversion of the a

IMAGING STUDIES

Radiographs may show a small piece of bone lateral to the distal fi

Treatment

NONSURGICAL

Treatment of acute peroneal tendon dislocations consists of casting
recurrently subluxates, only surgical treatment will keep it in posit

SURGICAL

Surgical repair is recommended for an athletic individual following repairing the superior peroneal retinaculum to the fibula, either th calcaneofibular ligament over the tendons. At the time of surgical prevent recurrent dislocations. Postoperatively, the patient is imm

ANTERIOR TIBIAL TENDON RUPTURE

Pathogenesis

Rupture of the anterior tibial tendon occurs infrequently, and most metatarsocuneiform joint. The rupture usually occurs at the distal

Clinical Findings

SYMPTOMS AND SIGNS

Patients with a degenerative rupture present with complaints of pa symptoms have been bothersome for several months. Physical exa

Imaging Studies

If the diagnosis is in doubt, MRI scan can accurately determine if t

Treatment

NONSURGICAL

In the case of a less active patient, nonsurgical treatment appears

SURGICAL

Acute tendon rupture in an active individual should be surgically re perform a primary repair.

Brandes CB, Smith RW: Characterization of patients with primary

Haji A et al: Percutaneous versus open tendo Achilles repair. Foot

Jaakkola JI et al: Early ankle motion after triple bundle technique

Tan V et al: Superior peroneal retinaculoplasty: A surgical techniqu

van der Linden-van der Zwaag HM et al: Results of surgical versus

Wong MW, Ng VW: Modified flexor hallucis longus transfer for Achi

OSTEOCHONDRAL LESIONS OF THE TALUS

Osteochondral lesions of the talus (OLTs) are defects of cartilage a
difficult problem.

Pathogenesis

OLTs, also known as osteochondritis dissecans lesions, are general
origin is thought to involve ischemia, often with an episode of trau
cartilaginous.

Clinical Findings

SYMPTOMS AND SIGNS

Patients usually present with several months of ankle pain followin
may be diffuse. Occasionally, there is a sensation of locking in the
injuries about the ankle joint.

IMAGING STUDIES

Radiographs are often normal in OLTs. MRI scan is the imaging pr

Figure 9–62.

MRI scan of extensive osteochondral lesion of the talus.

Treatment

NONSURGICAL

A 6-week trial of cast immobilization is warranted if the MRI scan s

SURGICAL

The surgical treatment method depends on the type of lesion. Acu
stimulate vascular ingrowth and fibrocartilage formation. OLTs with
overlying cartilage, drilling and bone grafting can be performed un

New techniques were developed for larger lesions or ones that fail
Intermediate-term follow-up data shows good results in most patie

Barnes CJ, Ferkel RD: Arthroscopic debridement and drilling of ost

Hangody L: The mosaicplasty technique for osteochondral lesions

Hunt SA Sherman O: Arthroscopic treatment of osteochondral lesi

Petersen L et al: Autologous chondrocyte transplantation of the an

Robinson DE et al: Arthroscopic treatment of osteochondral lesion

Takao M et al: Arthroscopic drilling with debridement of remaining

HAND SURGERY: INTRODUCTION

Function of the Hand

The hand is a vital part of the human body, allowing humans to di capabilities of the hand are many because the hand is ultimately a capacity for adaptability allowed primitive humans to make stone t

The human hand is capable of prehension, which involves approac grasp, and ultimately releasing the object. When a power grasp is palm while the thumb metacarpal and proximal phalanx stabilize t pattern, the object is secured between the pulp of the thumb dista

The hand can touch objects or other human beings while sensing t gnosis is sophisticated enough to allow blind individuals to read th from another. The hand is also an instrument of communication, w drawing, writing, or typing.

General Considerations in Treatment of Hand Disorde

Treatment of hand disorders requires an understanding of normal attempts to restore the normal anatomy, but when that is not pos appearance of the hand is vital because the hand is usually uncov often a source of embarrassment. Effective treatment requires a r appearance of the hand. Complex reconstruction that restores pre ineffective if the patient is so reluctant to expose the hand that he leading to awkward motion of an otherwise supple hand may caus

DIAGNOSIS OF DISORDERS OF THE HAND

History

When a patient seeks evaluation of a hand disorder, the physician specific to hand function and injury. The chief complaint as percei sentences. The patient's hand dominance, age, gender, and occup hand dexterity or strength. The approximate date of onset of sym discomfort, the exact date and mechanism of injury should be not patient should be questioned about prior treatment and his or her

Complaints should then be further detailed, such as the nature of symptoms are present, and whether the pain is worse upon awak should be asked whether symptoms include numbness or tingling. unscrewing jar tops, should be noted. If the patient complains pri

whether similar symptoms are occurring on the opposite side. Fina
impact of altered appearance should be discussed.

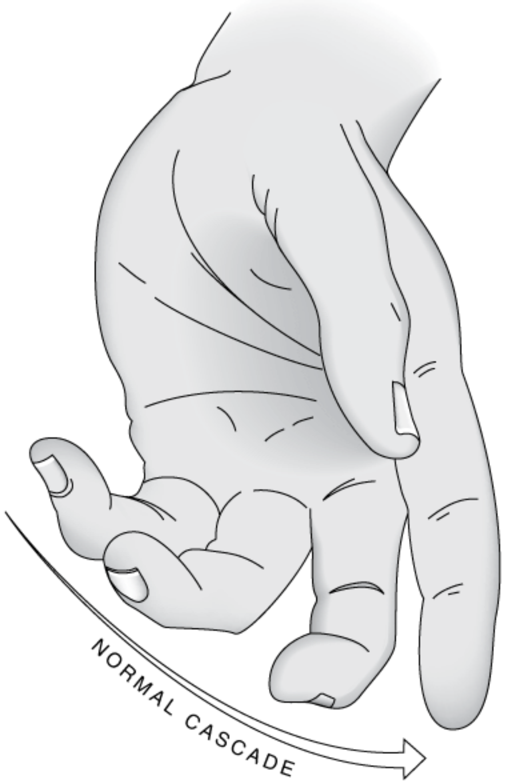
The medical history should include any prior hand injuries and any inflammatory arthropathies, diabetes, other endocrine disorders, r should be questioned about recent pregnancies. A careful history s patients with hand problems.

Examination of the Hand

GENERAL EXAMINATION

Examination of the hand should begin with observation. Vascular c Some hint of nerve function can be obtained by observing pseudor finger pulps. The extent and timing of injury is suggested by the c and the wrist may signal tendon or bone disruption. Normally, a ca are observed next to radial digits (Figure 10–1).

Figure 10–1.



Normal cascade of digital flexion posture. When the wrist is in slig progressively less flexion from the little finger to the index finger.

(Reproduced, with permission, from Carter PR: *Common Hand Inj*

A diagram of the hand is often helpful in documenting the abnorm
subjective areas of decreased sensation can be noted on the diagr

Next, the hand, wrist, and forearm are gently palpated. The temp
the skin is blanched in the paronychial region, circulation should re
carefully noted.

RANGE OF MOTION

The passive and active range of motion (ROM) of the shoulder, elb
of the wrist and fingers is indicated in Table 10–1. In documenting
to the right. When the range of passive extension and flexion is di
are noted in parentheses next to the corresponding active ROM va
thus be recorded as 20/70 (15/80), indicating an arc of active mot
15 to 80 degrees.

Table 10–1. Normal Range of Motion in Joints of Arm

Elbow: Extension and flexion 0°/135°	Forearm: Supination and pronation 90°/90°	Wrist: Flexion and extension 80°/70°	Radial deviation and ulnar deviation 20°/30°	Finger	MP: Extension and flexion 0°/90°	PIP Exte and flexio 0°/1

MP = metacarpal phalangeal; PIP = proximal interphalangeal; DIP
interphalangeal.

MUSCLE FUNCTION

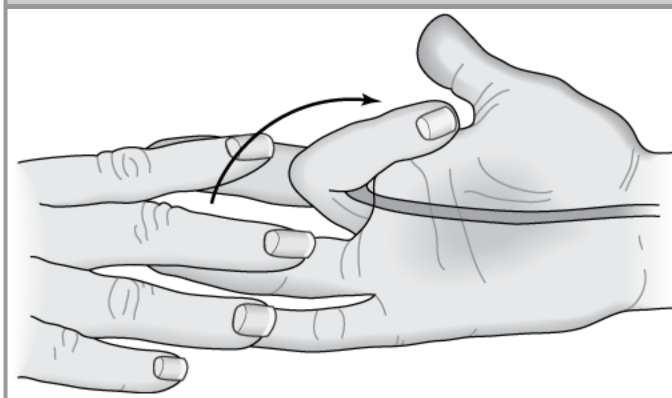
The integrity of individual muscles should be documented. The flex
the middle phalanx and asking the patient to flex the distal interph
superficialis of each finger is tested by keeping all fingers except t
asked to flex the finger being evaluated at the proximal interphala
longus is tested by asking the patient to flex the interphalangeal jo

Figure 10–2.

Testing of flexor digitorum profundus integrity. If the distal interpl
interphalangeal joint is stabilized, the profundus tendon is not sev

(Reproduced, with permission, from American Society for Surgery
Churchill Livingstone, 1983.)

Figure 10–3.



Testing of flexor digitorum superficialis integrity. If the proximal ir
fingers are held completely extended, the sublimis tendon is not s

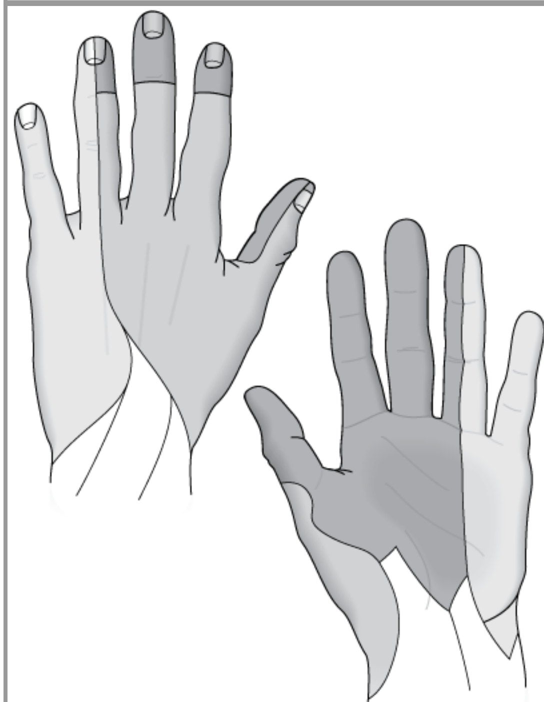
(Reproduced, with permission, from American Society for Surgery
Churchill Livingstone, 1983.)

The function of the extrinsic extensors is tested by asking the pati
If the examiner simply asks the patient to open the hand, the prox
contraction of the interosseous muscles, which may mislead the ex
Interosseous muscle function is screened by asking the patient to
muscle force while palpating the contraction of the hypothenar and

SENSORY FUNCTION

Examination of sensory function requires evaluation of the integrit
component proper digital nerves to each side of each finger. Each
of the hand supplied predominantly by that nerve (Figure 10–4). T
index finger, whereas the ulnar nerve provides sensory fibers from
first web space is innervated by the superficial branch of the radia

Figure 10–4.



Sensory distribution in the hand. Light shading = ulnar nerve; me
nerve.

(Reproduced, with permission, from Way LW, ed: *Current Surgical*

Two-Point Discrimination

The integrity of each digital nerve may be evaluated using either a
point discrimination. The two points of the testing instrument are l
between touching the skin with one or two points. The points may
longitudinally moved (moving two-point discrimination) against the
points should be pressed against the finger until the skin just begi
smallest distance between the two points that the patient can corr
increased sensory cues provided by movement, moving two-point
point discrimination. Static two-point discrimination is normal if the
15 mm or greater.

MOTOR FUNCTION

Examination of motor function may be organized by considering gr
Proximally, the median nerve innervates the pronator teres, flexor
superficialis muscles. The anterior interosseous nerve branch of th
the index and middle fingers, flexor pollicis longus, and pronator q
thenar musculature innervates the opponens pollicis, abductor poll
The index- and long-finger lumbricals are innervated by median m
median nerve to the index and middle fingers.

Table 10–2. Innervation of the Hand and Forearm.

Median nerve	Proximal median nerve: pronator teres, flexor carpi radialis, flexor digitorum superficialis	Anterior interosseous nerve: flexor pollicis longus, index and middle flexor digitorum profundus, pronator quadratus	Distal median nerve: index and middle lumbrical, opponens pollicis, abductor pollicis brevis, flexor pollicis brevis	Ulnar nerve	Proximal ulnar nerve: flexor carpi ulnaris, ring and small flexor digitorum profundus

The ulnar nerve innervates the flexor carpi ulnaris and flexor digit
Within the hand, the ulnar nerve innervates the hypothenar muscu
deep motor branch of the ulnar nerve innervates the dorsal and pa
fingers, deep portion of the flexor pollicis brevis, and adductor pol

The radial nerve innervates the triceps, brachioradialis, extensor c
muscles. The posterior interosseous division of the radial nerve the
extensor indicis proprius, extensor digiti minimi, extensor carpi ulr
brevis.

Muscle strength should be graded according to the British muscle
normal strength, 4/5 less than normal strength but with ability to
gravity, 2/5 resistance with gravity eliminated, and 1/5 only a trac

Diagnostic Studies

A number of studies may be helpful in establishing the proper diag
technique should be based on a careful history and physical exami

IMAGING STUDIES

In most instances, radiographic evaluation includes anteroposterio
radiograph of the finger and wrist cannot be overemphasized beca
subluxation and carpal instability, are not evident on oblique views
patterns. Tangential views are useful in assessing a carpometacarp
fracture of the hook of the hamate.

Stress views allow assessment of ligamentous stability. This is part
of the thumb metacarpophalangeal joint.

Ligamentous stability of the wrist may also be evaluated by radial
Grip views and ulnar deviation views may demonstrate a gap betw
simple anteroposterior and lateral studies.

ELECTRODIAGNOSTIC STUDIES

Electrodiagnostic studies include both nerve conduction studies an
motor (proximal to distal) and sensory (distal to proximal) conduct

COMPUTED TOMOGRAPHY SCAN

A CT scan allows excellent visualization of the distal radioulnar join
should be viewed in pronation, neutral, and supination. CT scannir
healing of scaphoid fractures.

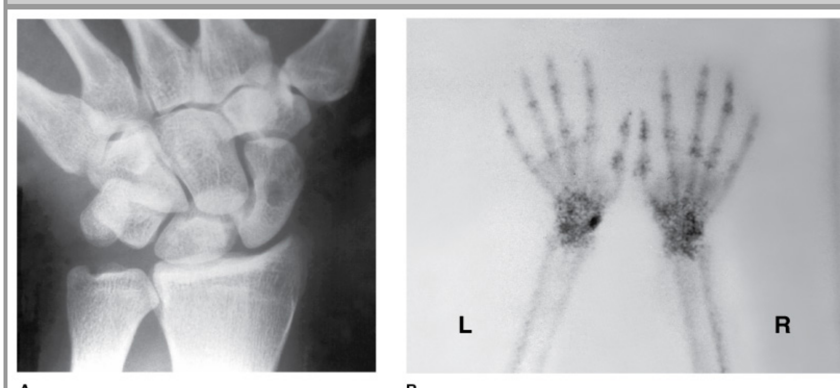
MAGNETIC RESONANCE IMAGING

MRI provides direct visualization of soft-tissue structures. The inte
which is particularly helpful in patients with persistent symptoms f
avascular necrosis is also facilitated by MRI. MRI scans also allow v
intercarpal ligament tears.

BONE SCAN

The technetium-99 MDP bone scan is a useful physiologic test in th
rule out bone involvement and can be used to localize inflammator
10–5).

Figure 10–5.



Radiograph (**A**) and bone scan (**B**) demonstrating increased activi
symptomatic cyst.

WRIST ARTHROSCOPY

Arthroscopic examination of the wrist allows for direct visualizatior fibrocartilage complex. The effect of stress maneuvers on intercar particularly helpful in the debridement or repair of the triangular f scapholunate or lunotriquetral ligaments may be debrided. Intraar aligned and pinned under direct observation.

Bernstein MA, Nagle DJ, Martinez A et al: A comparison of combin and arthroscopic wafer distal ulna resection versus arthroscopic tr shortening osteotomy for ulnocarpal abutment syndrome. Arthros

Cerezal L, del Pinal F, Abascal F et al: Imaging findings in ulnar-sic [PMID: 11796902]

Kocharian A, Adkins MC, Amrami KK et al: Wrist: improved MR im 2002;223:870. [PMID: 12034961]

Morley J, Bidwell J, Bransby-Zachary M: A comparison of the findir the investigation of wrist pain. J Hand Surg 2001;26B:544. [PMID

Potter HG, Weiland AJ: Magnetic resonance imaging of triangular f 2002;27(2):363. [PMID: 11901408]

Slutsky DJ: Wrist arthroscopy through a volar radial portal. Arthro

SPECIAL TREATMENT PROCEDURES FOR HAND DISORI

Replantation

Replantation is the reattachment of a body part that was totally se continuity. Revascularization is the reconstruction of damaged bloc from becoming necrotic.

Initial Care of Patient

Effective treatment of the patient and the ischemic or detached bc to a surgeon at a center capable of mobilizing resources for early s amputated part in a sponge soaked with either normal saline or Ri placed into a plastic bag, which is sealed and immersed in an ice-v part be placed directly into ice water or exposed to dry ice.

A tourniquet is usually not required to control bleeding. A compres
attempt should be made to ligate bleeding vessels because it migh
amputated part is not cooled, ischemia is poorly tolerated and suc
parts may be replanted up to 12 hours after injury.

Indications & Contraindications

Replantation is indicated for severed thumbs or multiple digits, tra
level amputations, and amputations of almost any body part in a c
moderately avulsed parts can be considered for replantation. The
ischemic muscle mass and the more urgent the need for revascula

Contraindications to replantation include severely crushed or mang
with arteriosclerotic vessels; amputations in patients with other se
warm ischemic times, particularly at proximal levels.

In adults, replantation of a single finger proximal to the insertion c
because of the likelihood of stiffness. Limited tendon function in th
digitorum superficialis and profundus tendon disruption, phalangea
this level may be considered in children or for aesthetic reasons.

Surgical Procedure

The preferred method of anesthesia is axillary block because this t
vasodilation. The surgical sequence of replantation begins with a w
of arteries, veins, and nerves. The soft tissue is then meticulously
with sufficient stability to allow institution of early postoperative m

The extensor tendons are repaired first and then the flexor tendor
performed, followed by repair of the nerves and anastomosis of th
repaired. Skin should be closed loosely, with care taken to approxi

In replantations proximal to the distal forearm, fasciotomies of all
replantation. The patient should be returned to the operating roon
additional necrotic tissue debrided.

Postoperative Care

Postoperatively, the hand is protected in an elevated, loose, bulky
period to diminish the likelihood of anastomosis thrombosis. Low-n
the recommended regimens. Some patients, particularly children,
spasm. Vasospastic agents such as nicotine, caffeine, theophylline,
after replantation or revascularization. The patient should be place
monitoring of the replanted or revascularized part may be supplen
probe.

In those replanted or revascularized parts that show impending fa
dressing should be loosened. Hand position should be changed to r
bolus of 3000–5000 U. The patient must be kept well hydrated an

the patient may be returned to the operating room for exploration
when carried out within 48 hours of injury.

Technical problems involving vascular anastomoses are most often
lumen, poor proximal flow secondary to spasm, or undetected inti
segment of the vessel should be resected and a vein graft interpo
intermittent application of leeches (*Hirudo* species) for 1–5 days m
drainage is reestablished.

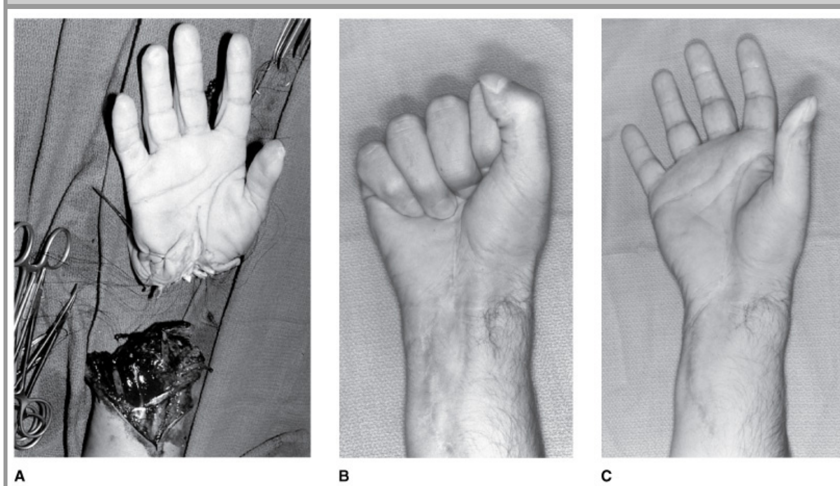
Prognosis

Approximately 85% of replanted parts remain viable. Sensory rec
approximately 50% of adults. Patients with viable replanted or rev
the first 2 or 3 years after replantation. ROM in replanted digits la
approximately half of the normal side.

In most children, normal sensation is regained after digital replant
approximately 80% of normal longitudinal growth. Although the fu
rate is lower in children because of the greater technical demands
tone.

Because nerves transected in the proximal arm must regenerate o
return is seen in the forearm and hand in proximal limb replantati
replantation may be converting a traumatic above-elbow amputati
provide dramatic restoration of hand function when the level of ini
level (Figure 10–6).

Figure 10–6.



Replantation of hand. Intraoperative view (**A**). Following operatio

Amputation

The purpose of amputation is to preserve maximal function consist
appearance. Priority should be given to preserving functional lengt
development of symptomatic neuromas.

Phalangeal Amputation

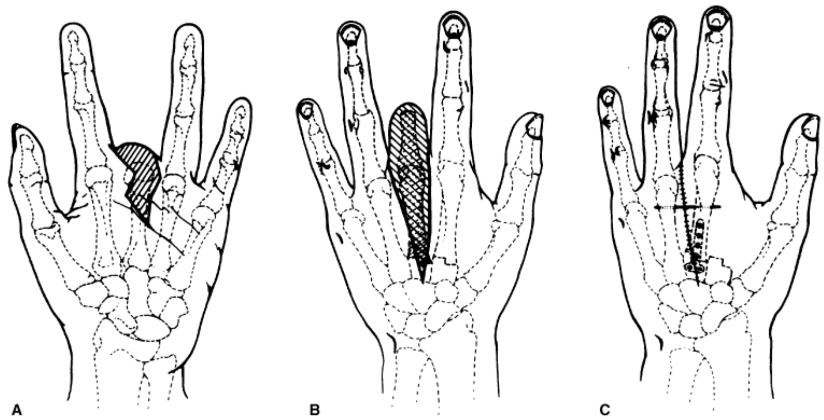
Digital amputation may be carried out through a phalanx or an int
or distal interphalangeal joint, the distal articular surface is reshap
normal insertion of a tendon was amputated, the tendon should be
The flexor and extensor tendons should never be sewn over the ar
should be identified, gently drawn distally, and transected proxima
skin scar. If possible, the thick well-padded skin of the palmar surf
stump. A nontender, shortened, well-padded digit is preferable to

Ray Resection

Amputations through the proximal portion of the proximal phalanx
finger may leave an unsightly bony prominence on the border of th
ring finger may create an awkward interdigital gap that allows sma
phalanges and metacarpal may be employed to close traumatic wo
malignant tumors. The aesthetic and functional advantages of ray
breadth and, hence, diminution of grip strength.

Index-ray resection creates a normal-appearing web between the
finger metacarpal leaves a smooth ulnar contour. Little-finger ray r
grip strength over cosmesis. Resection of the middle- or ring-finge
or metacarpal transposition. Resection of the middle ray through t
the corresponding distal portion of the index ray to the middle-ray
closed by either osteotomizing the little-finger metacarpal and mov
radialward across the hamate by tight repair of the deep transvers
fingers.

Figure 10–7.



Middle-ray resection and index-ray transposition. **A:** Converging c
redundancy. **B:** Corresponding step-cut osteotomies are fashioned
metaphyses. **C:** The transposed index finger is fixed to the middle
ring-finger metacarpal.

(Reproduced, with permission, from Chapman MW, ed: *Operative*

Adani R, Marcoccio I, Castagnetti C et al: Long-term results of rep
Surg 2003;51:564. [PMID: 14646649]

Melikyan EY, Beg MS, Woodbridge S et al: The functional results of

Nuzumlali E, Orhun E, Ozturk K et al: Results of ray resection and
interphalangeal joint. J Hand Surg 2003B;28:578. [PMID: 145998

Wilhelmi BJ, Lee WP, Pagensteert GI et al: Replantation in the mut

Yu JC, Shieh SJ, Lee JW et al: Secondary procedures following digi
2003B;56:125. [PMID: 12791355]

ANATOMY

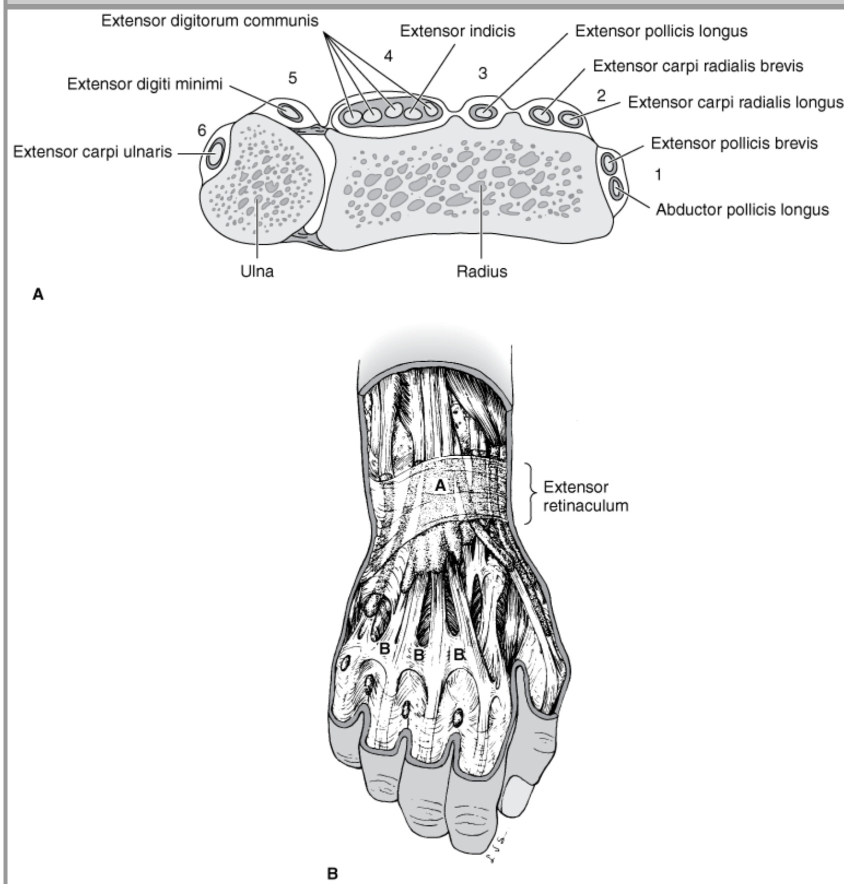
Control of digital posture requires a complex balance of extrinsic a
outside of the hand and their insertion on the hand or carpus, whe
the hand. Extrinsic muscles are either flexors or extensors, and in
extension.

EXTRINSIC EXTENSOR MUSCLES

The extrinsic extensors run through six different fibroosseous retir
first (most radial) compartment contains the abductor pollicis long
longus inserts at the base of the thumb metacarpal and radially ab

on the dorsum of the proximal aspect of the proximal phalanx of t
of the thumb.

Figure 10–8.



The six dorsal compartments of the wrist. **A:** Cross-section of pro
(Reproduced, with permission, from Reckling FW et al: *Orthopaed*
1990.)

B: Dorsal view. A = extensor retinaculum over the compartments
(Reproduced, with permission, from Way LW, ed: *Current Surgical*

The second extensor compartment contains the extensor carpi rad
extensor carpi radialis longus, inserting on the index metacarpal,
carpi radialis brevis, inserting into the base of the middle metacar

The third compartment contains the extensor pollicis longus, which
compartment and turns abruptly radialward about Lister tubercle,
insertion is on the distal phalanx, the extensor pollicis longus prov

The oblique course of the extensor pollicis longus tendon provides
pollicis longus.

The fourth extensor compartment contains the extensor indicis pro
fifth compartment contains the extensor digiti quinti. These three
metacarpophalangeal, proximal interphalangeal, and distal interph
the extrinsic digital extensors is on the dorsal proximal aspect of t
provided by extrinsic extensor force transmitted through the sagit
through the conjoined lateral bands that are composed of tendinou

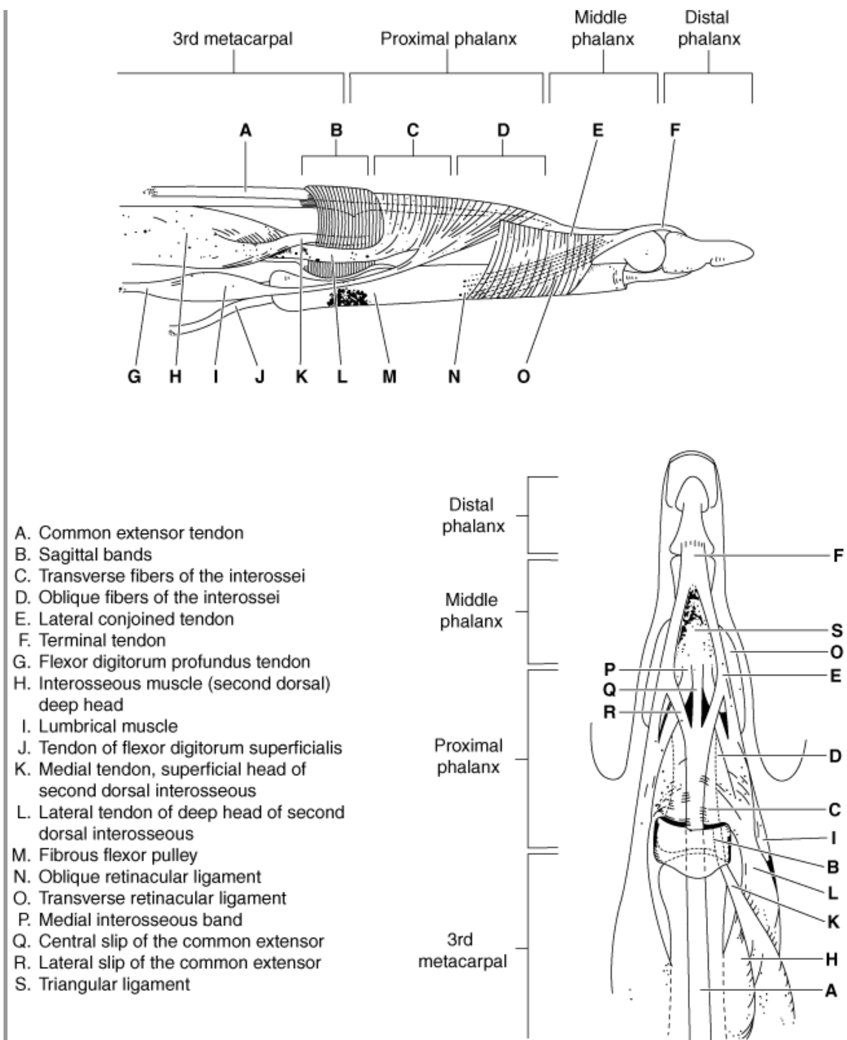
The extensor indicis proprius inserts on the index finger ulnar to th
communis inserts on the index, middle, ring, and, in some cases, l
little finger ulnar to the extensor digitorum communis insertion.

The extensor carpi ulnaris tendon runs through the sixth compartr
provides wrist extension and ulnar deviation.

The extensor digitorum communis tendons of the middle, ring, and
over the dorsum of the hand proximal to the metacarpophalangea
may be recognized at the wrist level as possessing the most distal

The digital extensor tendons are stabilized over the midline of the
band fibers (Figure 10–9). The sagittal band fibers insert onto the
volar plate. The sagittal band fibers form a sling that allows proxin
proximal phalanx, permitting metacarpophalangeal joint extension
holding the extrinsic extensor tendon balanced over the prominenc
the extrinsic extensor as far as possible away from the center of r
the greatest mechanical efficiency. With rupture or attenuation of
to the ulnar side of the metacarpal head.

Figure 10–9.



Extensor hood mechanism. The dorsal hood apparatus provides pc
muscles of the hand.

(Modified and reproduced, with permission, from Way LW, ed: *Cur*
Lange, 1994.)

EXTRINSIC FLEXOR MUSCLES

The extrinsic finger flexors are the flexor digitorum profundus and
profundus inserts on the proximal volar aspect of the distal phalan
proximal interphalangeal and metacarpophalangeal joints. The flex
interphalangeal and metacarpophalangeal joints. It lies palmar to t
the level of the metacarpophalangeal joint, and passes dorsal to th
inserting into the middle phalanx. Although the extrinsic flexors pr
after most of their excursion is expended flexing the interphalange

INTRINSIC MUSCLES

The intrinsic muscles that control finger posture are the dorsal and
These muscles are responsible for primary flexion, abduction, and
extension of the proximal interphalangeal and distal interphalange

The index metacarpal is abducted by the first dorsal interosseous
The middle finger is radially abducted by the second dorsal interos
interosseous muscle. The ring finger is adducted by the second vo
interosseous muscle. The little finger is adducted by the third vola
quinti muscle.

The first, second, and fourth dorsal interossei have both superficia
to a tendon of insertion on the proximal phalanx tubercle. The dee
and thus contributes to metacarpophalangeal joint flexion and pro
dorsal interosseous usually has a single muscle belly, which inserts
interosseous muscles is also into the hood apparatus (see Figure 1

All interosseous muscles course palmar to the axis of motion of the
intermetacarpal ligament. Their tendinous insertions are into the la
the proximal and distal interphalangeal joints. When the metacarp
extending the interphalangeal joints than when the metacarpophal

The four lumbrical muscles insert into the radial lateral band of the
originate from the flexor digitorum profundus tendons of the corre
dorsal or palmar interosseous muscles because they lie palmar to
muscles modulate flexor and extensor digital tone and may have a
muscle belly draws the profundus tendon proximally and shifts the
dorsal hood fibers that extend the proximal and distal interphalang
proximal profundus distally and reduces tension on the flexor digit
distal interphalangeal joint extension is facilitated.

The abductor digiti quinti, like the first, second, and fourth interos
inserts directly onto the bone of the abductor tubercle along the u
insertion is into the dorsal hood apparatus. The flexor digiti quinti
phalanx but does not insert into the dorsal hood apparatus. The p
metacarpophalangeal joint.

DORSAL HOOD APPARATUS

The dorsal hood apparatus, frequently referred to as the extensor
tendon insertions on the dorsal aspect of the finger (see Figure 10
muscles extend the metacarpophalangeal joint, the intrinsic muscl
and extrinsic muscles extend the proximal and distal interphalange

Extension of the metacarpophalangeal joint is achieved through th
sagittal band sling mechanism, which lifts up the proximal phalanx
by the tendinous insertion of the intrinsics on the proximal phalan

intrinsic mechanism blending into the hood, which flexes the meta
profundus and superficialis secondarily flex the metacarpophalang

Extension of the proximal interphalangeal joint is achieved througl
the extrinsic digital extensors on the middle phalanx. In addition, t
joint extension through medial slips from the lateral band, which r
middle phalanx as part of the central slip.

Distal interphalangeal joint extension is achieved through both intr
conjoined lateral bands, which merge to form the terminal tendon
band is through its insertion into the lateral band. The extrinsic co
through lateral slip fibers that diverge from the central slip over th
to form the conjoined lateral band. The conjoined lateral bands fro
tendon inserting on the distal phalanx.

DISRUPTION OF EXTENSOR MUSCLE INSERTIONS

Sagittal Band Disruption

Anatomy & Clinical Findings

The sagittal band fibers transmitting extrinsic extensor power may
attenuated because of underlying synovitis of the metacarpophalar
along either the radial or ulnar aspect of the dorsal hood become a
between the adjacent metacarpal heads. Because the subluxed ex
the metacarpophalangeal joint, full active extension of this joint m
may result from tearing of the sagittal band fibers with torquing a
baseball.

Treatment

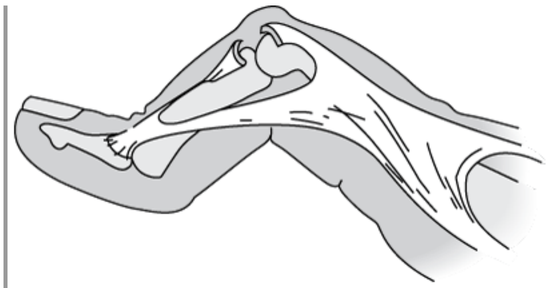
An acute tear of the radial sagittal band may be treated by splintir
Chronic injuries are treated by releasing the ulnar sagittal band ar
tendon around the radial collateral ligament.

Boutonnière Deformity

Anatomy & Clinical Findings

When the central slip is disrupted by laceration or closed rupture c
joint, the direct bony insertion of the extrinsic extensors on the m
from the lateral band is also lost, active proximal interphalangeal j
position of proximal interphalangeal joint flexion as the unopposed
the finger into flexion (Figure 10–10). The lateral bands migrate a
more palmar position, eventually coming to lie palmar to the axis c
bands become a deforming force contributing to the tendency of t

Figure 10–10.



Boutonnière deformity caused by loss of active proximal interphala insertion on the proximal dorsal middle phalanx.

(Reproduced, with permission, from Way LW, ed: *Current Surgical*

With central slip disruption, the force normally transmitted througl extensor and intrinsic muscles bypasses the proximal interphalang amplifying the force of extension of this joint and hyperextending resistant to active flexion, contraction of the flexor digitorum profu joint and is relatively ineffective in flexing the distal interphalange in maximal extension. The digit rapidly assumes the boutonnière d distal interphalangeal joint hyperextension.

Treatment

Because the proximal interphalangeal joint is at the center of the c restoration of proper balance and tension on the central slip may b lacerated, it should be directly repaired and the joint pinned in full repair. Closed ruptures of the central slip, if diagnosed acutely, sho interphalangeal joint in full extension. When diagnosis is delayed e interphalangeal joint is usual.

Surgical treatment of closed rupture of the central slip in a finger disappointing because the surgical procedure must both release th proximal interphalangeal joint extension on the dorsal aspect. A be extent of the fixed proximal interphalangeal joint flexion contractu Capener splint and the Joint Jack splint are particularly useful. Ser is changed every few days may also be helpful in bringing the prox of splinting, the patient should be instructed to carry out active fle phalanx supported in extension. Care should be taken to assure th Once full proximal interphalangeal joint extension is achieved, splir weeks. In many instances, this achieves sufficient tightening of the interphalangeal joint extension.

If active extension cannot be restored with prolonged splinting, se Fowler type of tenotomy, obliquely divides the dorsal hood apparat insertion. This diminishes distal interphalangeal joint hyperextensic extension by refocusing intrinsic and extrinsic forces at the more p

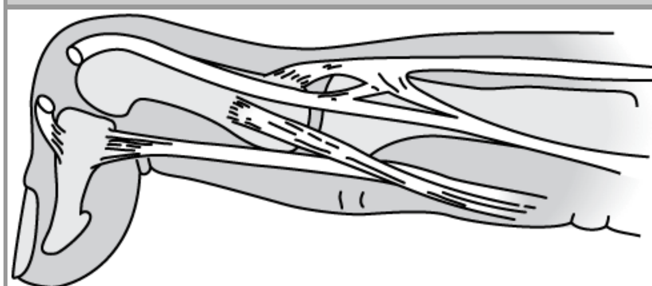
Alternatively, other surgical techniques attempt to more directly a
shortening the central slip or by mobilizing portions of one or both
extension of the joint, they often do so at the loss of full proximal

Mallet Finger

Anatomy & Clinical Findings

The mallet finger deformity is characterized by a loss of full active
evident. The mallet finger reflects the loss of normal extensor forc
distal phalanx. The unopposed flexor digitorum profundus pulls the
mechanism of injury involves sudden passive flexion of the actively
terminal tendon may be entirely confined to the tendon or may inv
distal phalanx proximal articular surface.

Figure 10–11.



Mallet finger deformity is secondary to loss of terminal tendon ins

(Reproduced, with permission, from Way LW, ed: *Current Surgical*

Because the avulsed fragment includes the terminal tendon inserti
fingers is similar. The distal joint rests in flexion, a posture that ca
interphalangeal joint is possible.

Treatment

A radiograph should be obtained to determine whether a fracture
distal phalanx is subluxed palmarward. If the joint is congruent, sp
fracture site gap persists. The distal interphalangeal joint should b
finger may then be tested. If residual drooping of the distal joint is

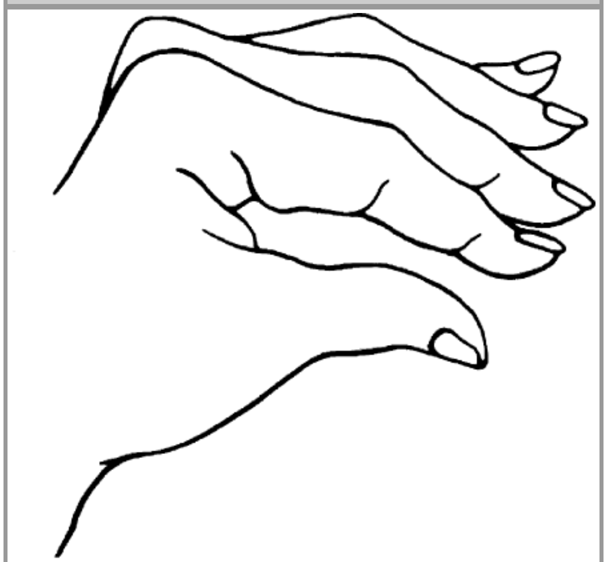
Kalainov DM et al: Non-surgical treatment of closed mallet finger f

INTRINSIC PLUS & INTRINSIC MINUS POSITIONS

Together, the interossei and lumbricals flex the metacarpophalange
joints. Hence, the posture of the hand in which the metacarpophal
interphalangeal joints are extended is known as the intrinsic plus p

the hand because the collateral ligaments of the metacarpophalan
ideal for immobilization of most hand injuries, it is termed the *pos*

Figure 10–12.



Intrinsic plus position.

The normal excursion of the intrinsic muscles is sufficient to allow
joints in extension while the proximal and distal interphalangeal jo
position, requires full excursion of the relaxed intrinsic muscles (se
are paralyzed, the hand tends to assume the intrinsic minus postu
extrinsic extensors have fibers that can provide proximal and dista
intrinsic muscles, in the intrinsic minus hand their excursion is exp
hyperextension. Thus, the hand devoid of intrinsic power is unable
interphalangeal joints, unless the metacarpophalangeal joint is flex

Figure 10–13.

Intrinsic minus position secondary to low median and ulnar nerve

Treatment

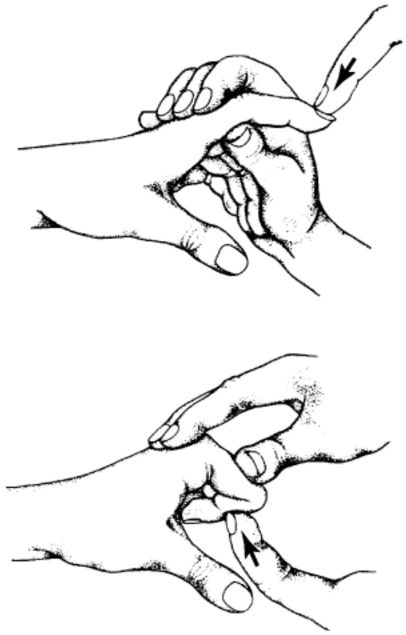
Surgical correction of the intrinsic minus hand must either prevent
restore active control of metacarpophalangeal joint flexion. This m
metacarpophalangeal joint or by an active tendon transfer. Once m
extrinsic extensors usually can effectively open the hand by exten
proximal interphalangeal joint extension is not possible through th
flexed, then tendon transfer for metacarpophalangeal joint flexion
augments proximal interphalangeal joint extension and provides m

INTRINSIC MUSCLE TIGHTNESS

Anatomy & Clinical Findings

When the lumbricals and interossei become contracted and overly
simultaneous metacarpophalangeal joint extension and interphalar
described by Finochietto and later by Bunnell (Figure 10–14). It is
metacarpophalangeal and interphalangeal joints each have a full ra
metacarpophalangeal joint is then passively held in an extended p
distal interphalangeal joints passively. If full passive flexion of the
this position, the intrinsic muscles are deemed tight.

Figure 10–14.



Intrinsic tightness test is performed by flexing the proximal interp
flexed. Tightness to proximal interphalangeal flexion occurs with t

(Reproduced, with permission, from Green DP, ed: *Operative Hand*

Causes of intrinsic muscle tightness include conditions as diverse a
and crush injury of the hand.

Treatment

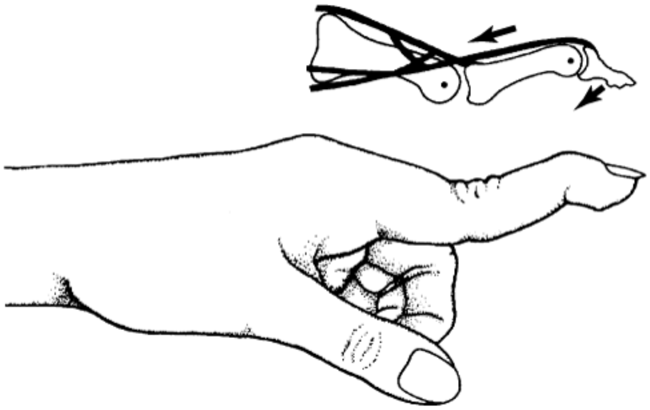
Surgical treatment of intrinsic tightness may be carried out as an i
metacarpophalangeal joint reconstruction. The intrinsic force is dir
of a triangular segment of one or both lateral bands. The intrinsic
adequacy of intrinsic muscle release.

SWAN-NECK DEFORMITY

Anatomy & Clinical Findings

Swan-neck deformity is characterized by hyperextension of the pro
interphalangeal joint (Figure 10–15). The pathophysiology of swan
stretching or disruption of the volar plate's restraint on proximal in
interphalangeal joint secondary in patients with RA may distend th
preventing proximal interphalangeal joint hyperextension. Overly f
intrinsic plus deformity) transmits an abnormally high force throug
interphalangeal joint. When the proximal interphalangeal joint is hy
ineffective in extending the distal interphalangeal joint, allowing th

Figure 10–15.



Swan-neck deformity.

(Reproduced, with permission, from American Society for Surgery
Churchill Livingstone, 1983.)

In some fingers, a fixed extension contracture or ankylosis of the
swan-neck deformity. In other fingers, the proximal interphalange
hyperextended posture.

Treatment

Surgical treatment of swan-neck deformity secondary to intrinsic t
through resection of a triangle of the proximal lateral band and do
extension is created, either through tenodesis of one slip of the fle
lateral bands is rerouted volar to the center of rotation of the prox
retinacular ligament.

Bruner S, Wittemann M, Jester A et al: Dynamic splinting after ex
2003B;28:224. [PMID: 12809652]

FLEXOR TENDON INJURY

Anatomy

The extrinsic flexors of the finger consist of the flexor digitorum p
digitorum profundus originates from the proximal ulna and the int
muscle groups: the most radial component supplying the index fin
little fingers. The flexor digitorum profundus and the flexor pollicis
forearm. As the flexor digitorum profundus and flexor pollicis long
floor of the carpal tunnel.

The tenosynovial sheath of the flexor pollicis longus is continuous
finger is continuous with the ulnar digital bursa. In some patients,

horseshoe abscess to spread between the thumb and little finger i
these digits.

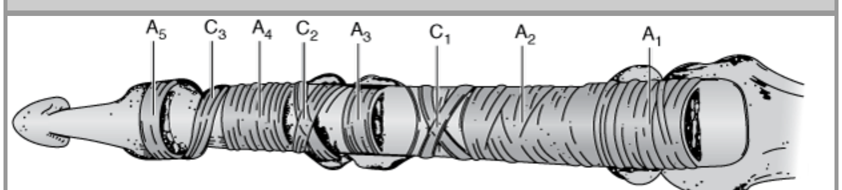
The lumbricals originate from the radial side of the index, middle,
passes through the bifurcation of the flexor digitorum superficialis
phalanx. The innervation of the flexor digitorum profundus of the i
branch of the median nerve, whereas the profundus of the ring an
digitorum profundus provides digital flexion at both the proximal a

The flexor digitorum superficialis has two heads: The radial head c
humeral ulnar head originates from the medial humeral epicondyle
corresponding independent superficialis muscle. As the superficialis
middle and ring fingers are more superficial and central than those
finger, the flexor digitorum superficialis tendon bifurcates around t
pulley. The flexor digitorum superficialis tendon slips then reunite
fibers staying on the ipsilateral side and half crossing to the contra
and ulnar slips into the proximal metaphysis of the middle phalanx
innervation from the median nerve. The primary function of the su
joint.

The flexor pollicis longus originates from two heads: The radial hea
membrane, and an accessory head originates from the coronoid pr
humerus. In the palm, the flexor pollicis longus tendon transverses
brevis. The flexor pollicis longus inserts into the proximal base of t
interosseous branch of the median nerve. The flexor pollicis longus
joints of the thumb.

As the flexor tendons pass distal to the metacarpal neck, they ente
fibroosseous tunnel extends distally to the proximal aspect of the
pulleys, which provide mechanical stability, and cruciate pulleys, w
fifth annular pulleys (A1, A3, and A5) are located over the metaca
interphalangeal joints, respectively, and the second and fourth pul
proximal and middle phalanges. The A2 and A4 pulleys are the mo
flexor tendons.

Figure 10–16.



Annular (A) and cruciate (C) pulley locations.

The tenosynovium that lines the fibroosseous tunnel supplies both tendons. Proximal to the sheath, the tendons are well vascularized supplied via the vincula system: the vinculum longus and brevis.

Following injury, the flexor tendon heals through both extrinsic an cells brought to the site of repair by ingrowth of capillaries and fib Intrinsic healing occurs from tenocyte within the tendon. The goal encourage both intrinsic and extrinsic healing without the formatio ultimately result in restricted motion of the finger.

Clinical Findings

The time since injury as well as the mechanism of injury (sharp op the history.

NORMAL CASCADE OF FINGERS

The resting posture of the fingers should be observed. Disruption fingers as one moves from the index finger to the little finger shou

Figure 10–17.

If the index finger remains extended when the hand is at rest, its

NORMAL TENODESIS PHENOMENON

Tendon integrity may also be evaluated by taking advantage of the the wrist is passively brought through a ROM. Normally, as the wr flexors become taut, passively flexing the fingers in the normal ca squeezed, the fingers normally flex involuntarily.

TESTING OF INDIVIDUAL TENDONS

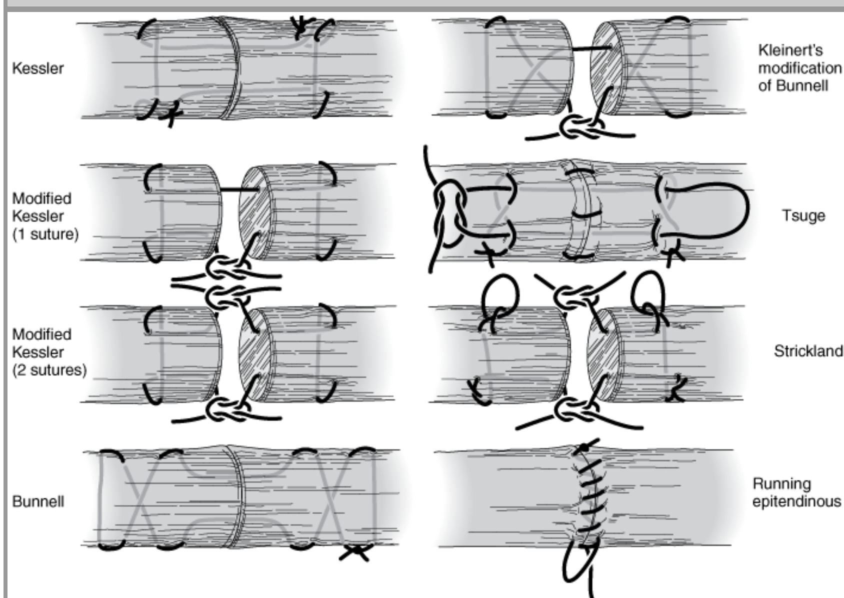
Isolated testing of the superficialis and profundus tendons is empl
10–2 and 10–3). Because the flexor digitorum superficialis of the l
individuals, either because of cross connections between the two t
may be impossible from clinical examination to detect injury to the
strength of flexion should be noted as each of the tendons is teste
with flexion and is unable to generate full power against resistance

Treatment

Functional outcomes are equivalent if the repair is done the day of
injury (delayed primary repair).

Because repair requires proper visualization of both ends of the te
tendon ends must be gently retrieved because trauma to the flexo
not be grasped along their tenosynovial surfaces. The A2 and A4 p
debrided from the tendon ends without compromising eventual dig
synthetic material is secured to coapt tendon ends (Figure 10–18)

Figure 10–18.



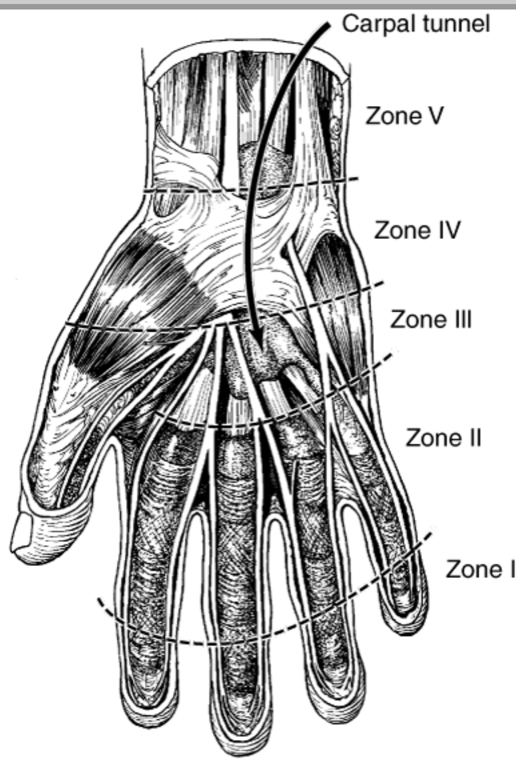
Kessler sutures and other types of sutures for flexor tendon repai
(Reproduced, with permission, from Green DP, ed: *Operative Hand*

The flexor tendon repair is strengthened by employing four strand
6-0 nylon epitendinous suture completes the tendon repair. The ro

Because the results and complications of flexor tendon repair vary
10–19). Zone I extends from the insertion of the profundus on the

superficialis on the middle phalanx. The tendon may be directly re
reinserted to bone. Care must be taken not to advance the tendor

Figure 10–19.



Flexor tendon injury zones.

(Modified and reproduced, with permission, from Way LW, ed: *Cur*
Appleton & Lange, 1994.)

Zone II, which extends from the proximal portion of the A1 pulley
problematic region of injury because it contains both the profundu
Care must be taken to preserve the vincular blood supply. When b
preferable to repair both tendons because greater digital independ
of tendon rupture during the rehabilitation period. Repair of the su
diminishes the likelihood of proximal interphalangeal joint hyperex

Zone III injuries are located between the proximal edge of the A1

In zone IV injuries, the area beneath the transverse carpal ligamer
ligament should be performed to prevent flexor tendon bowstringi

Zone I and II injuries of the thumb are handled similarly to those
difficult to access the flexor pollicis longus tendon as it passes thro

injuries at this level include either primary tendon grafting or step distal to the obscuring thenar muscles.

Improved results of flexor tendon surgery in recent years are subs programs. Immobilization of the finger after tendon repair is appro patients. Following flexor tendon injury, the wrist should be immob metacarpophalangeal joints at approximately 45 degrees of flexion program of passive ROM exercises should be initiated that decreas tendon repair. Passive motion may be achieved either through rub the patient move the finger passively. At 4–6 weeks following repa splinting is discontinued. At 6–8 weeks, passive extension exercise patient may begin flexion against resistance.

When a four-strand repair is performed, active assisted motion is extended and the fingers are passively flexed. The patient is then

With four-strand techniques for flexor tendon repair, active motion motivated and cooperative patients, an active hold program is beg hand into flexion and the patient is asked to maintain the position.

Flexor Tendon Avulsion Injuries

The flexor tendon may be avulsed from its bony insertion, usually simultaneously actively flexed. An estimated 75% of flexor digitoru injuries commonly occur in football or rugby, when the athlete gra as the opponent attempts to elude tackle.

Flexor digitorum profundus avulsion injuries may be classified acco injuries, the tendon retracts proximally from the sheath into the p days to avoid myostatic contracture, which will limit the ability to b tension. In type 2 injuries, the tendon retracts to the level of the p may be seen on a lateral radiograph of the finger in these injuries. 6 weeks after injury. Type 3 injuries involve an osseous distal phal of the flexor digitorum profundus proximal to the A4 pulley. These Missed or neglected profundus avulsion injuries, if symptomatic, m interphalangeal joint arthrodesis, or tenodesis.

Moiemen NS, Elliot D: Primary flexor tendon repair in zone 1. J Ha

Flexor Tendon Reconstruction

Direct repair of a disrupted flexor tendon is not possible if there is contracture, or unresolved soft-tissue defects. If the flexor digitoru proximal interphalangeal joint motion, arthrodesis or tenodesis of called superficialis finger. If the patient requires active motion at th Tendon grafting is usually indicated when neither flexor digitorum repaired.

Primary tendon grafting may be performed when there is satisfact
and interphalangeal joint motion, an intact annular pulley system,
and at least one intact digital nerve. Possible donor tendon source
tendons. The palmaris longus and plantaris tendons are absent in

SURGICAL PROCEDURE

The donor tendon graft is secured into the distal phalanx. The ten
pulleys. The proximal attachment of the donor tendon to the profu
end-to-end repair.

Establishing appropriate tension on the tendon graft is critical. If i
plus deformity occurs. With this condition, as the patient pulls the
lumbrical is placed under tension, and all of this tension is transmi
tendon graft. As a result, as the patient attempts to flex the finge
distal interphalangeal joints.

If the tendon graft tension is too tight, full extension is impossible
primary repair in similar circumstances.

Primary tendon repair is contraindicated if the fibroosseous sheath
Restoration of flexion in such situations requires a staged tendon r
from the sheath and joint contractures are released. At a minimun
tendon remnant, a tendon graft, or a strip of the wrist extensor re
tendon graft is secured to the distal phalanx and threaded through
of a pseudosheath surrounding the silicone tendon rod.

The second stage of the procedure occurs at least 3 months after
equilibrium must be achieved before the second stage is undertak
The donor tendon is secured to the distal phalanx and to the dono

COMPLICATIONS

Adhesions

The most common complication following flexor tendon surgery is
appropriate therapy program. Following flexor tendon repair or gra
restricted, despite a normal passive ROM, in a wound that has rea
repair or reconstruction), in a motivated patient.

Ideally, tenolysis should be performed under local anesthesia with
exposure of the sheath. Care is taken to preserve the annular pull
sheath and between the tendon and the phalanges. Evaluation of t
under local anesthesia to flex the finger actively. If regional or gen
a more proximal level and traction applied to the tendon at this le

Active ROM exercise is begun within the first 24 hours after surge
facilitate early motion.

Tendon Repair Rupture

The second major postoperative complication of flexor tendon repa
diagnosed, a second repair should be attempted because success
rupture is not promptly diagnosed, the ruptured tendon ends mus
tendon reconstruction is necessary to restore active flexion.

Failure of Staged Reconstruction

If staged reconstruction fails, arthrodesis or amputation of the dig
compromise occurs.

Beredjiklian PK: Biologic aspects of flexor tendon laceration and re

Beris AE et al: Two-stage flexor tendon reconstruction in zone II u
Surg Am 2003;28:652. [PMID: 12877856]

Slade JF et al: Zone II tendon repairs augmented with autogenous
Am 2001;26:813. [PMID: 11561232]

TENOSYNOVITIS

Tenosynovitis may develop about any of the extrinsic flexor or ext
commonly, at points of constraint by fibrous pulleys or retinacular

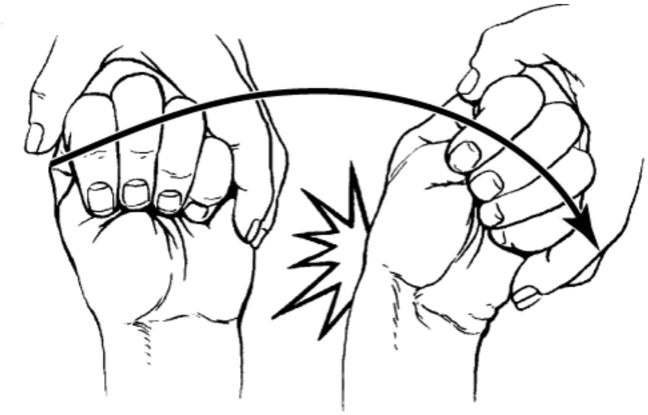
de Quervain Tenosynovitis

Clinical Findings

The abductor pollicis longus and extensor pollicis brevis tendons m
radial styloid region. Symptoms are provoked by lifting activity in
ulnarly deviated. Activities such as inflating a blood pressure cuff,
off the stove may provoke pain along the radial aspect of the wrist

Physical examination reveals tenderness directly over the first exte
test, is helpful in diagnosing this disorder (Figure 10–20).

Figure 10–20.



Finkelstein maneuver. The patient's thumb is enclosed in the palm
examiner. In a positive test, pain is produced on the radial border

(Reproduced, with permission, from Lister G: *The Hand: Diagnosis*

Treatment

Initial treatment includes either splinting or steroid injection. Imm
using a forearm-based thumb spica splint, which prevents both wr
metacarpophalangeal motion while allowing interphalangeal joint m
along the course of the extensor pollicis brevis may diminish swelli

If de Quervain tenosynovitis is unresponsive to conservative care,
Because most patients with symptomatic disease have more than
tendon must be identified and decompressed. In some cases, the
two separate tendon sheaths. In such cases, the more dorsal com
extensor pollicis brevis tendon gliding.

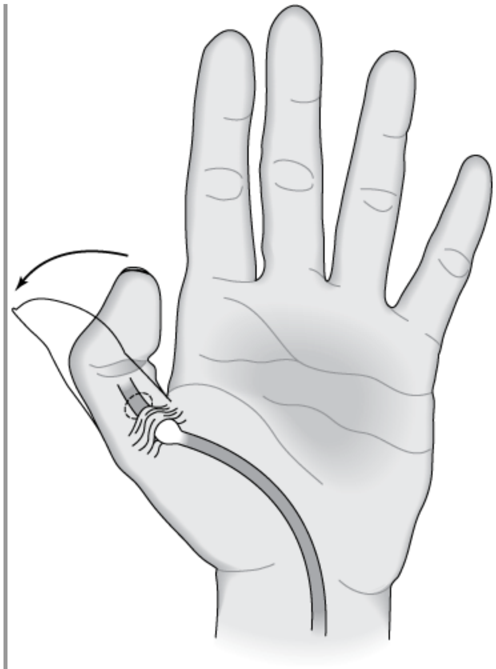
Extreme caution must be exercised in carrying out the skin incisio
the sensory branch of the radial nerve as it runs over the first com
overshadow any benefit from tendon decompression.

Flexor Tenosynovitis (Trigger Finger & Trigger Thumb

Clinical Findings

Flexor tenosynovitis or tenovaginitis is characterized by pain and t
pulley (Figure 10–21). Patients frequently note catching or trigger
more severe cases, the opposite hand must be used to force the f
cases, the finger becomes locked in a flexed position. Triggering is
Stenosing tenosynovitis is more common in diabetic patients than
possibility of diabetes should be considered.

Figure 10–21.



Trigger thumb.

(Reproduced, with permission, from American Society for Surgery
Churchill Livingstone, 1983.)

Treatment

Most triggering digits may be successfully treated by long-acting s
finger, the needle is inserted at the proximal palmar crease for the
ring, and small fingers. The needle enters the flexor tendon and p
out until the needle is between the tendon and the tendon sheath,
combination of a short-acting anesthetic and steroid are given. Th
initially positive response to injection.

Surgical release of the A1 pulley is curative in digits refractory to s
the pulley and incising its transversely oriented fibers longitudinall
effective digital flexion. Percutaneous release of the A1 pulley may
fingers, especially if they actively lock. In patients with RA, the en
further ulnar drift of the fingers. Triggering in these patients is tre
flexor digitorum superficialis.

Flexor Carpi Radialis Tenosynovitis

Clinical Findings

Flexor carpi radialis tenosynovitis is characterized by pain with wri
dorsiflexion. Marked tenderness is elicited on palpation of the skin

Treatment

Conservative care includes splinting the wrist in flexion and admin
measures are ineffective, a long-acting steroid may be injected ab

Surgical decompression of the flexor carpi radialis is considered if
unroofs the tendon sheath in the distal forearm and across the wr
resection of the palmar ulnar ridge of the trapezium overlying the

Finsen V, Hagen S: Surgery for trigger finger. Hand Surg 2003;8:2

Hwang M et al: Referred pain pattern of the abductor pollicis longu
16034228]

Ragoowansi R, Acornley A, Khoo CT: Percutaneous trigger finger r
[PMID: 15936736]

Wilhelmi BJ et al: Trigger finger release with hand surface landma
2001;108(4):908. [PMID: 11547146]

Zingas C et al: Injection accuracy and clinical relief of de Quervain

ANATOMY AND CLINICAL FINDINGS

Anatomy

The blood supply to the hand is predominantly through the ulnar a
artery and provides the primary arterial contribution to the hand.
palmar arch, which provides the principal blood supply to the com
hand by passing deep to the tendons of the first dorsal compartme
the bases of the first and second metacarpals, and forms the deep
embryologic vascular supply to the developing upper limb, contribu

The superficial palmar arch is located distal to the deep palmar arc
between the radial and ulnar arteries in 34% of hands and incomp
limited communication between the ulnar and radial arteries in var
motor branch of the ulnar nerve as it travels transversely just palr
artery is derived from the deep palmar arch in 98% of patients. Tl
arterial branches, which provide secondary blood flow to the digita

Clinical Findings

Patients with vascular insufficiency frequently complain of cold into
the fingers is more suggestive of loss of inflow, whereas redness c
Ulcerations of the tips of the fingers may denote ischemia.

The duration of vascular symptoms should be noted. If the abnorn
should be documented. The occupational history should record wh

repetitive blunt hand trauma during work. Occupations requiring o
environment indoors (butchering) are noted. A history of trauma r
activities that involve repeated trauma to the hand should be reco
particularly at risk of closed vascular injury. Exposure to vasoconst
Other evidence of vascular disease should be sought, as well as dis
Pulses are palpated, noting thrills or bruits.

ALLEN TEST

The Allen test allows assessment of the extent of connection betwe
The examiner compresses both the radial and ulnar arteries at the
fingers repetitively. After the hand blanches, pressure is released f
ulnar artery. The examiner observes how long it takes for each of
with both vessels compressed, and the ulnar artery occlusion is th
Again, examination of the reperfusion of the fingers reveals which
fashion, the extent of interconnections between the radial and ulna

DIAGNOSTIC STUDIES

Noninvasive vascular diagnostic studies include Doppler scans, whi
determines the pulse volume difference between brachial and digit
evaluates the effect of cold on arterial spasm. Invasive diagnostic
arteriography, and early-phase radionuclide scans.

ARTERIAL OCCLUSION

Arterial Trauma

Clinical Findings

Partial or complete division of an artery may occur as the result of
Hemorrhage from arterial disruption should initially be treated with
distal vascularity is inadequate. Partial arterial injuries may bleed p
one another and are unable to retract, constrict, and occlude furth
without reconstruction to prevent the formation of aneurysms or a
spasm or occlusion.

Treatment

The primary objective in treating arterial injuries is the restoration
remove distal clots with Fogarty catheters. If this is unsuccessful,
vasodilators, and stellate ganglion blocks may be employed to dim
multiple agents to ensure they do not interfere with one another. F
produce axillary artery hemorrhage, thereby compounding the pro

Thrombosis

Clinical Findings

The ulnar artery is the most common site of upper extremity arter
syndrome hypothenar hammer syndrome, is most often the result
Patients may complain of a tender pulsatile mass on the ulnar side
a low ulnar nerve palsy secondary to compression of the ulnar ner
vascular insufficiency may be evident in the ring and little fingers.

Treatment

If evaluation demonstrates that all the fingers are well perfused by
artery containing the aneurysm or thrombosed segment and ligati
may confer a modest sympathectomy effect to the residual ulnar a
artery are disrupted at the time of vessel division. If, however, dig
and the tourniquet deflated, a segmental vein graft is required to

Aneurysm

A distinction should be made between true and false aneurysms. I
These aneurysms are usually caused by blunt trauma but may also
are characterized by partial wall involvement, with periarterial tiss
aneurysms are most common following penetrating trauma, such a

Both true and false aneurysms should be treated with resection. A
necessity of vascular reconstruction is dictated by the adequacy of

VASOSPASTIC CONDITIONS

Clinical Findings

Raynaud phenomenon, Raynaud disease, and Raynaud syndrome a
which pallor of the digits occurs with or without cyanosis on expos
when Raynaud phenomenon occurs without another associated or
young (less than 40 years) women and is often bilateral, without c
patients may develop gangrene or atrophic changes limited to the
occurs when Raynaud phenomenon is associated with another dise
erythematosus), neurologic disorders, arterial occlusive disorders,

Treatment

All patients with Raynaud phenomenon experience cyclic episodes
hyperemia. Treatment includes protection of the hands from cold b
encouraged to cease all cigarette or cigar smoking. Drug treatmen
blocking agents, nitroglycerin ointment, nifedipine, and other calci
Digital artery sympathectomy, the surgical stripping of the periarte
at the distal palmar level, may improve circulation to ischemic digi

Balogh B et al: Adventitial stripping of the radial and ulnar arteries

Ruch DS et al: Arterial reconstruction for radial artery occlusion. J

Ruch DS et al: Periarterial sympathectomy in scleroderma patients
2002;27(2): 258. [PMID: 11901385]

PERIPHERAL NERVE INJURY

Anatomy

Peripheral nerves consist of a mixture of myelinated and unmyelin travel together in a single nerve. Axons are grouped in bundles te fine connective tissue between axons within a fascicle is called *end* epineurium. Nerves are considered monofascicular, oligofascicular, relationship between fascicles changes along the longitudinal cours distally. The mesoneurium, which is the connective tissue surrounc nerve.

After a nerve is injured, a number of changes occur. The somatose injured nerve diminishes. The cell body of the lacerated axon incre cytoskeleton is increased, and the production of neurotransmitters further proximal degeneration occurs based on the severity of the phagocytose the axon, allowing the surrounding myelin tube to col

Within 24 hours of injury, axonal sprouting occurs from the proxim unit. The number of axons in the unit decreases with time. Longitu ability of the axons to adhere to trophic factors in the basal lamina the nerve. At the motor endplate, the muscle fibers atrophy. The s their location expands from pits to the entire length of the muscle motor endplates become active. The recovery of strength is greate nerve grafting, and weakest after direct implantation of the nerve reaches the muscle within a year. In contrast, sensory receptors m

Nerve injures are classified into three types. (1) Neurapraxia is a c Recovery is usually complete within days to a few months. (2) Axc occurs, with the endoneurial tube remaining in continuity. The inta axons with a well-defined path to the end organs. Because axonal but slow. (3) Neurotmesis refers to transection of the nerve. Unles suitable path and recovery does not occur. The frustrated sproutin segment of the lacerated nerve.

Diagnostic Studies

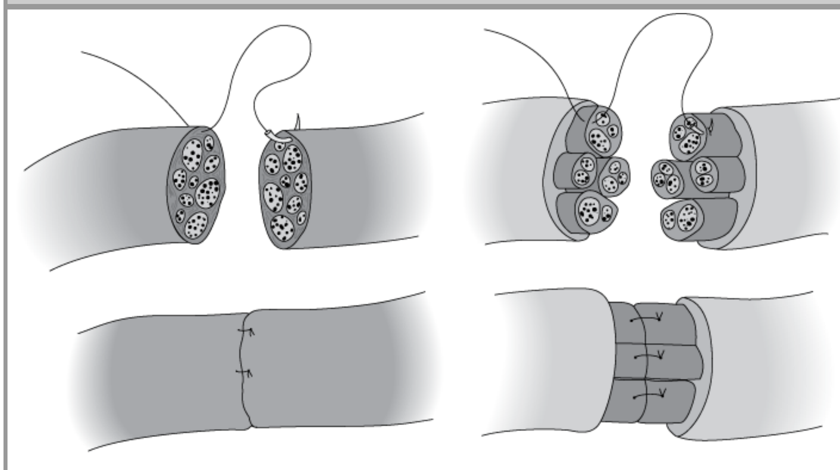
Preoperative and postoperative assessment of motor and sensory strength, static and moving two-point discrimination, and vibratior reflects innervation density, whereas vibration and pressure measu

Treatment

Nerve repair should be carried out with magnification and microsu
environment for nerve regeneration. Tension at the repair site may
transposition of the ulnar nerve for proximal forearm ulnar nerve l
repair is impossible, nerve grafting is necessary to bridge the defe
sural nerve, the anterior branch of the medial antebrachial cutane

Primary repair is preferred to nerve grafting because the latter pr
repair is usually performed under magnification, using 8-0 or 9-0 s
(eg, motor branch of the median nerve) is recognized as mediating
10–22B). Postoperative therapy may include motor and sensory re

Figure 10–22.



A: Schematic diagram of epineurial repair technique. **B:** Group fas

(Reproduced, with permission, from Mackinnon SE, Dellon AL: *Sur*

Primary nerve repair is indicated after a sharp nerve division occu
cannot be performed until the proximal and distal extent of injury
motor function is closely monitored. If no recovery is seen within 3
electrical evidence of recovery is documented, the nerve is explore
is accomplished.

COMPRESSIVE NEUROPATHIES

Compressive neuropathies are a group of nerve injuries that have
sites of normal anatomic constraint. Nerve dysfunction is the resul
may resolve after release of the anatomic structures producing pr
severe nor long standing.

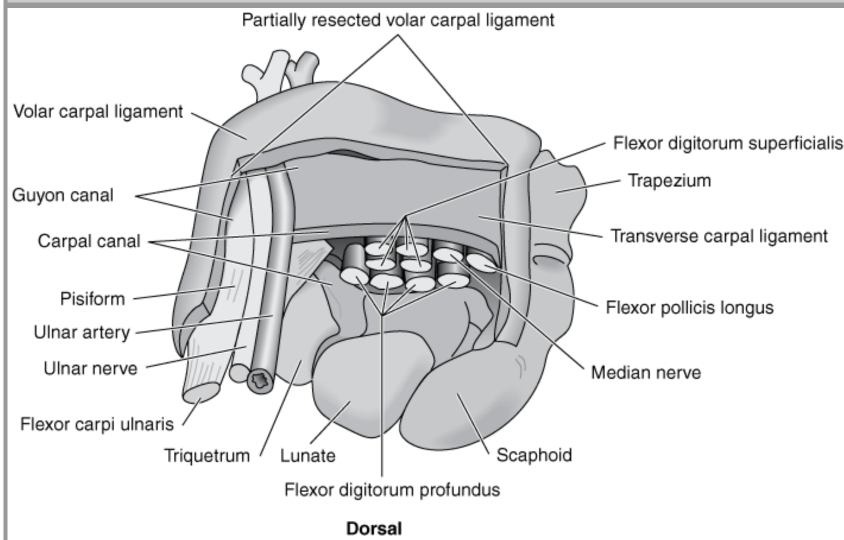
Median Neuropathy

Carpal Tunnel Syndrome

ANATOMY

Compression of the median nerve within the carpal tunnel is the m
carpal tunnel is that space along the palmar aspect of the wrist an
trapezium radially, the hook of the hamate and the pisiform ulnarl
palmarly (Figure 10–23).

Figure 10–23.



The Guyon canal and carpal tunnel and contents. (Cross section o
the relationship between the transverse carpal ligament and the v

(Reproduced, with permission, from Reckling FW, Reckling JB, Mol
Mosby-Year Book, 1990.)

CLINICAL FINDINGS

Carpal tunnel syndrome is often idiopathic. It is associated with pr
phenomenon, acute or chronic inflammatory conditions, traumatic
and hypothyroidism), and tumors within the carpal tunnel.

Differential diagnosis includes compression of the median nerve or
neuropathy may produce symptoms similar to those of carpal tunn
develop concomitant carpal tunnel syndrome.

Symptoms and Signs

Most patients complain of numbness in the thumb and index and r
numb. Pain rarely prevents the affected individual from falling asle
a number of hours. After a period of moving the fingers, most pat
finger stiffness upon arising in the morning.

Discomfort or numbness, or both, may be incited by activities in w
period of time (eg, holding a steering wheel, telephone receiver, b

the hand up the arm to the shoulder or neck. The patient may cor
unscrewing a jar top and may experience difficulty in holding on tc

Atrophy of muscles innervated by the median nerve is visible in se
recent onset. Weakness of the abductor pollicis brevis muscle may

Provocative Tests

Three provocative tests, the Phalen maneuver, the Tinel sign, and
diagnosis of carpal tunnel syndrome.

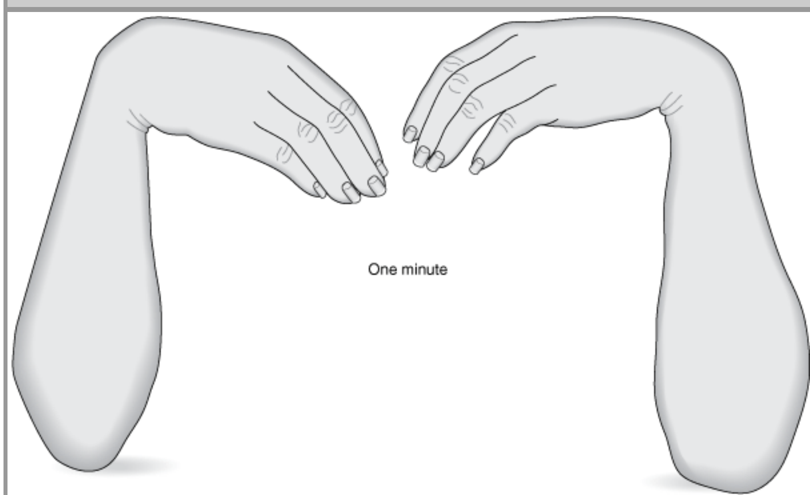
TINEL SIGN

The Tinel sign is elicited by percussing the skin over the median n
the patient complains of an electric or tingling sensation radiating

PHALEN MANEUVER

The Phalen wrist flexion sign, or Phalen maneuver, is usually positi
many to be even more diagnostic than the Tinel sign. When this m
extension while the wrist is passively flexed (Figure 10–24). The ti
of symptoms; onset within 60 seconds is considered supportive of
onset and the location of paresthesias should be recorded.

Figure 10–24.



Phalen maneuver.

(Reproduced, with permission, from American Society for Surgery
Churchill Livingstone, 1983.)

WRIST COMPRESSION TEST

pressure over the median nerve proximal to the wrist provoke syn
physical signs of median nerve compression.

Two-Point Discrimination Test

Two-point discrimination is often diminished in the finger pulps of
aspect of the palm should be normal, however, because the palma
through the carpal tunnel.

Imaging Studies

The diagnostic evaluation may include a radiograph of the wrist, ir

Electrodiagnostic Studies

Nerve conduction velocities and electromyography help localize ne
motor integrity. Nerve conduction velocity (NCV) and electromyog
conservative care and are considered candidates for surgery. A m
indicator of carpal tunnel syndrome.

TREATMENT

Conservative Measures

Because the pressure within the carpal tunnel increases if the wris
sustained extension, the initial treatment of carpal tunnel syndrom
position at night. Clinical improvement with this simple measure a
syndrome. Activities that provoke symptoms may be modified with
rotation of repetitive job activities.

Injection of steroids into the carpal tunnel often decreases the infl
symptoms. To inject the carpal tunnel, a 25-gauge 1.5-inch needle
palmaris longus tendon. If the palmaris longus is absent, a line alo
crease. Before placing the needle, patients are told they may expe
sensation occurs, the needle may be in the median nerve, and the
placed a few millimeters ulnar. When inserting the needle, first the
through the transverse carpal ligament. A mixture of a short-actin
symptoms after injection suggests a greater likelihood of a favora

Surgical Treatment

Patients unresponsive to conservative measures may benefit from
division may be accomplished through either direct open exposure
made in the palm over the transverse carpal ligament, staying uln
axis of the radial border of the ring finger. This incision avoids inju
incising the palmar fascia longitudinally, the transverse carpal liga
observation. Endoscopic division of the transverse carpal ligament
single wrist portal proximal to the palm or with a combined proxim
open incision. Although some studies noted an earlier return to wo
iatrogenic nerve and tendon injuries and late recurrence of sympto
endoscopic release than with open release. Both types of procedu
decision of which technique to use is based on the surgeon's expe
for treatment of recurrent carpal tunnel syndrome.

Patients are encouraged to actively move their fingers from the fir
week. Incisional tenderness often prevents patients from fully usin
4–8 weeks. If patients have difficulty with hand function 3–4 week
desensitization, ROM, and strengthening.

Pronator Syndrome

ANATOMY

The median nerve may be compressed in the proximal forearm by
Struthers, lacertus fibrosus, pronator teres muscle, or proximal fib
superficialis muscle.

CLINICAL FINDINGS

Patients with pronator syndrome complain of pain that is usually m
Pain usually increases with activity. Complaints of numbness in the
the possibility of carpal tunnel syndrome. Night symptoms, howev

Examination may reveal sensory and motor deficits similar to thos
may be detected on careful evaluation. Dysesthesia may include th
is positive at the forearm level rather than at the wrist. The Phaler
experience pain with resistance to contraction of the pronator tere
resistance to forearm pronation or to isolated flexion of the proxim

TREATMENT

Evaluation of symptomatic patients should include electrodiagnosti
improvement. Surgical treatment requires generous decompressio

Anterior Interosseous Syndrome

ANATOMY

The anterior interosseous nerve branch divides from the median n
innervates the flexor pollicis longus, flexor digitorum profundus of
muscles. The anterior interosseous nerve may be compressed by t
digitorum superficialis, a palmaris profundus, or the flexor carpi ra
digitorum superficialis to the flexor digitorum profundus proximally
longus) may impinge on the anterior interosseous nerve.

CLINICAL FINDINGS

Patients affected with anterior interosseous nerve syndrome comp
or the index-finger distal interphalangeal joint. In contrast to thos
numbness or pain.

TREATMENT

Surgical decompression of the anterior interosseous nerve may be
improve. All potentially compressing structures must be exposed a

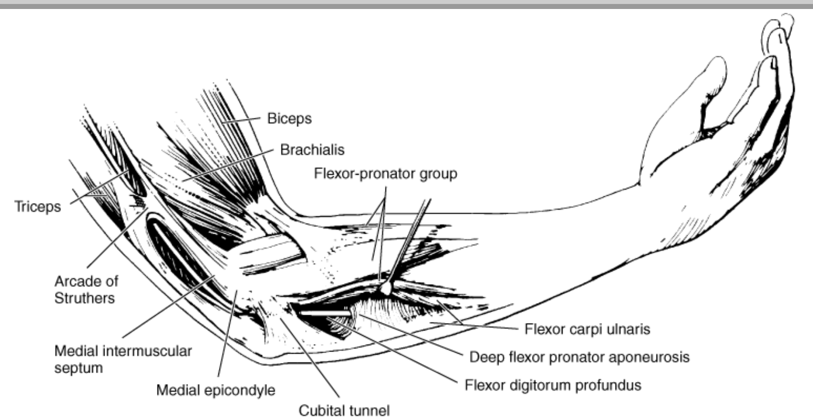
Ulnar Neuropathy

Cubital Tunnel Syndrome

ANATOMY

The ulnar nerve is most commonly compressed at the cubital tunn
occur between the ulnar and humeral origins of the flexor carpi ulı
the nerve is tethered anteriorly with elbow flexion (Figure 10–25).

Figure 10–25.



Points of constriction of the ulnar nerve at the elbow.

(From Amadio PC: Anatomic basis for a technique of ulnar nerve t
permission, from Mayo Foundation.)

CLINICAL FINDINGS

Patients affected with cubital tunnel syndrome most often complai
fingers. Because symptoms may be aggravated or provoked by su
symptoms while talking on the telephone. Many patients complain
when sleeping with the elbows flexed. Patients whose exam demoı
may note clumsiness and lack of dexterity.

Provocative Tests

TINEL SIGN

A positive Tinel sign is noted when percussion over the ulnar nerve
and hand. The nerve may be noted to sublux over the medial epic

MOTOR STRENGTH

Motor strength should be assessed both in intrinsic muscles innerv
and in extrinsic muscles innervated by the ulnar nerve (flexor digit

FROMENT SIGN

With weakness of the ulnar nerve innervated adductor pollicis mus
tries to hold a piece of paper placed between the thumb and the iı
attempt to substitute flexor pollicis longus activity for inadequate a

ELBOW FLEXION TEST

The ulnar nerve may be rendered symptomatic by fully flexing the
flexion test, a provocative maneuver, is considered positive if pare
seconds. The location of the paresthesia and the time between init
recorded.

TREATMENT

Conservative Treatment

Conservative treatment may include the use of an elbow pad to pr
approximately 45 degrees of flexion. The splint may be worn conti
intensity of symptoms.

Surgical Treatment

Electrodiagnostic studies should be obtained if conservative treatm
weakness is evident. The reliability of nerve conduction studies at
measure the length of the ulnar nerve accurately.

Numerous procedures are described to relieve ulnar nerve compre
the ulnar nerve within the cubital tunnel or decompression with an
intramuscularly, or submuscularly into the flexor pronator mass. W
excise the medial intermuscular septum proximally and to release
flexor carpi ulnaris distally, to avoid creating a new area of imping

An alternative surgical strategy involves decompression of the ner
prominence against which the ulnar nerve is tethered with elbow f
elbow ROM. Strengthening begins at 4–6 weeks, and the patient is

Ulnar Tunnel Syndrome

ANATOMY

The ulnar nerve passes from the forearm into the hand through th
the Guyon canal are the pisiform and pisohamate ligament ulnarly,
carpal ligament radially, and the volar carpal ligament forming the

CLINICAL FINDINGS

Examination should document ulnar nerve sensory and motor inte
the Tinel sign is positive at the wrist rather than at the elbow. Ext
should be delineated by electrodiagnostic studies. In some cases M
ganglion compressing the nerve within the Guyon canal.

TREATMENT

When splinting is ineffective, surgical decompression should be co
syndrome, release of the transverse carpal ligament favorably alte
is the same as following carpal tunnel release.

Radial Neuropathy

Radial Tunnel Syndrome

ANATOMY

The radial nerve may be rendered symptomatic if compressed in t
the radial tunnel, located at the level of the proximal radius, incluc
recurrent vessels, the extensor carpi radialis brevis, the tendinous
which the nerve emerges from beneath the distal edge of the supi

CLINICAL FINDINGS

Because radial tunnel syndrome often occurs in combination with l
confused. Patients with radial tunnel syndrome experience pain ov
carpi radialis longus, and extensor carpi radialis brevis muscles), w
epicondylitis is located at or just distal to the lateral epicondyle. Pa
simultaneously extending the wrist and fingers while the long finge
extension test). Patients with radial tunnel syndrome often also ex

TREATMENT

Conservative treatment of radial tunnel syndrome includes measu
wrist is splinted in dorsiflexion while the forearm is immobilized in
treated by surgical decompression of the radial nerve. Concomitan
time that the radial nerve is decompressed.

Posterior Interosseous Nerve Syndrome

ANATOMY

The radial nerve splits into the posterior interosseous nerve and th
anteriorly to the radiocapitellar joint. The posterior interosseous ne
radialis brevis, radial recurrent artery, and arcade of Frohse. The p
the proximal edge of the supinator, although entrapment may also
muscle.

CLINICAL FINDINGS

In contrast to radial tunnel syndrome, patients with posterior inter
weakness. Pain may be less than that of patients with radial tunne

Paralysis may be either partial or complete. Because the brachiora
extensor carpi radialis brevis are innervated by the radial nerve pr
muscles are spared. Digital extension at the metacarpophalangeal
communis, extensor indicis proprius, and extensor digit quinti func

The differential diagnosis in a patient with spontaneous loss of digi
ruptures in addition to possible radial neuropathy, particularly in p
extend as the wrist is passively flexed, is preserved in posterior in
tendons are ruptured.

TREATMENT

Treatment of posterior interosseous nerve syndrome requires thor
occur, tendon transfers restore digital extension.

Thoracic Outlet Syndrome

Anatomy

The brachial plexus exits the base of the neck and upper thorax th
are the scalenus anterior muscle anteriorly, the scalenus medius m
syndrome, usually resulting from irritation of the C8- and T1-deriv
from a rudimentary cervical rib, tendinous bands from the scalenu
fracture callus. Poor posture with slumping shoulders or prolonged
factor.

Clinical Findings

The symptoms of thoracic outlet syndrome are often vague. Symp
variable degree of intrinsic muscle weakness. Patients may experie
simultaneously being compressed in the thoracic outlet region.

PROVOCATIVE TESTS

Elevated Stress Test

Physical examination of the patient with suspected thoracic outlet
patient's shoulders are kept extended and the arm is externally ro
to open and close the hands with the arms elevated for 3 minutes
syndrome.

Other Tests

The Adson sign and the Wright test may be helpful in detecting va
is obliterated when the arm is dependent and the head is turned t
obliterated when the shoulder is abducted, externally rotated, and
addition, this maneuver should reproduce the patient's symptoms.
intrinsic muscle strength.

DIAGNOSTIC STUDIES

Workup of the symptomatic patient should include radiographs of t
studies to assess the function of the lower nerve roots, and Dopple
compression of the axillary artery.

Treatment

Initial treatment includes postural exercises. Patients who are unre
weakness may benefit from surgical resection of a cervical rib, res

Cervical Root Compression

Clinical Findings

Cervical spine root compression may result in complaints of hand p
or limitation of motion of the cervical spine. If the patient was invo
extension, this should be noted. Cervical root compression may oc
intervertebral foraminal osteophytes, or, rarely, a cervical cord tun

Patients with cervical root compression most often complain of pai
spite of symptoms involving the hand, most patients, when carefu
neck and radiates to the hand from pain that begins in the hand a
with neck motion (flexion and extension, lateral bending, or rotatic

SPURLING TEST

Physical examination of the patient with cervical radiculopathy frec
motion or pain with neck motion. Symptoms may be reproduced w
test). Detailed sensory and motor examination may reveal deficits

DOUBLE-CRUSH SYNDROME

The occasional simultaneous presentation of cervical radiculopathy
double-crush syndrome. Whether compression at one level render
level or whether such cases simply represent two common entities

Treatment

If a nerve is compressed at more than one location, the more sym
equally symptomatic, the simpler of the two operations is chosen.

Lindley SG, Kleinert JM: Prevalence of anatomic variations encount
2003;28:849. [PMID: 14507518]

Morgenlander JC et al: Surgical treatment of carpal tunnel syndror
1997;49:1159. [PMID: 9339710]

Naidu SH et al: Median nerve function in patients undergoing carp
Electromyogr Clin Neurophysiol 2003;43:393. [PMID: 14626718]

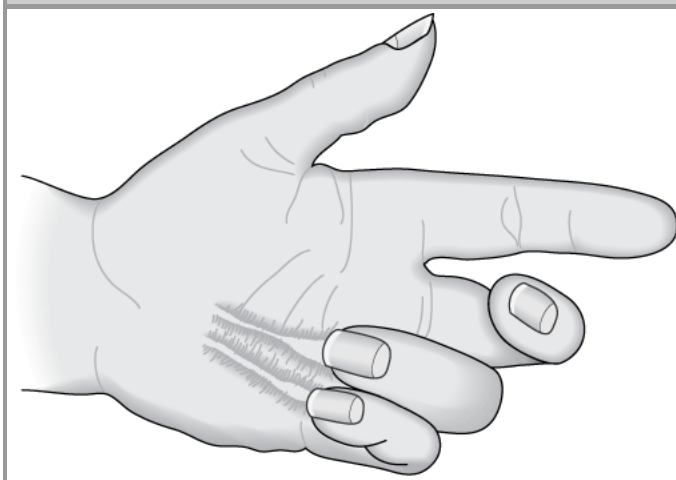
Trumble TE et al: Single-portal endoscopic carpal tunnel release cc
Bone Joint Surg Am 2002;84:1107. [PMID: 12107308]

Upton AR, McComas AJ: The double crush in nerve entrapment sy

DUPUYTREN DISEASE

Dupuytren disease is characterized by a nodular thickening on the
fascia (Figure 10–26). It is a progressive condition, resulting from
Dupuytren disease occurs most commonly in patients between 40
whom it appears earlier and is often more aggressive. Flexion cont
joints but may also tether the proximal interphalangeal joint and,
ring fingers and the thumb index web are the most commonly invo
proximal interphalangeal joint (knuckle pads), the dorsum of the p
(Ledderhose disease).

Figure 10–26.



Dupuytren contracture.

(Reproduced, with permission, from American Society for Surgery
Churchill Livingstone, 1983.)

Epidemiologic Factors

A number of predisposing factors are identified. The disease most
and is occasionally encountered in Asians; it is rarer in other racial
medications taken for seizure disorders and with alcoholism, smok
development of the disease remains controversial. The most aggre
disease and in those who have onset of disease prior to 40 years c
bilateral involvement and ectopic deposits on the dorsum of the ha
surgery at an early age, both extension and recurrence of the dise

Anatomy

Dupuytren contracture distorts the anatomy of the palmar fascia.
caused by pathologic contracture of pretendinous bands at a supe
web space contractures and scissoring of the fingers. The transver
except at the base of the thumb. In the fingers, the superficial vol
ligaments may contract alone or in combination to produce flexion
spiral band contracts, the digital nerve is often displaced palmarly
region of the proximal phalanx.

Treatment

Nonsurgical treatment is ineffective in reversing or halting Dupuyt
contracture of more than 30 degrees at the metacarpophalangeal
interphalangeal joint.

Surgical exposure may be achieved through either transverse or lo
distal palmar skin crease is useful when extensive palmar involvem
there is excessive tension, the wound may be left open to heal by
is needed, Brunner zigzag incisions are useful. An alternative is a l
Z-plasty flap transpositions.

The goal of surgical release is to achieve a regional fasciectomy or
joint motion. A local fasciotomy may occasionally be elected in olde

Severe or recurrent proximal interphalangeal joint disease may occ
proximal interphalangeal joint arthrodesis. Amputation may be con
compromise is present in patients with recurrent disease.

Complications

The most common postoperative complication is hematoma, which
for infection. To diminish the possibility of postoperative hematoma
hemostasis obtained prior to wound closure. Tight skin closure sho
regions should be treated by open dressing changes. If skin loss is
early wound closure.

Joint stiffness may occur, particularly after extensive surgical relea
Extensive therapy is often necessary, consisting of both active and

Mild sympathetically mediated pain (reflex sympathetic dystrophy)
form, hospitalization with elevation, sympathetic blocking agents, c

Prognosis

Contracture correction is usually maintained at the metacarpophala
interphalangeal joint, particularly when the extent of preoperative
degrees. Long-term postoperative night splinting may diminish the

Forsman M et al: Dupuytren's contracture; increased cellularity—P
[PMID: 15865122]

Godtfredsen NS et al: A prospective study linked both alcohol and
2004;57:858. [PMID: 15485739]

Ketchum LD, Donahue TK: The injection of nodules of Dupuytren's
2000;25:1157. [PMID: 11119679]

McFarlane RM: On the origin and spread of Dupuytren's disease. J

COMPARTMENT SYNDROMES

Compartment syndromes are a group of conditions that result fror
compromising the microcirculation and threatening the viability of

Recurrent or chronic compartment syndrome results from increase
most commonly in athletes during exercise. Symptoms of muscle v
in spite of the patient being asymptomatic between recurrences.

The Volkmann ischemic contracture is the result of an acute compa
muscle. Because nerve injury is not always associated with this co
normal distal to the involved compartment. Because there is often
motor function may be detected in the nerve domain distal to the

Etiologic Factors

The most common causes of compartment syndrome are fractures
localized hemorrhage or postischemic swelling, drug overdose with
cases, fractures are closed or, if open, are grade 1 injuries, with o
envelopes.

The pathophysiology of compartment syndrome is a consequence
increases the pressure on the walls of arterioles within the compar
resulting in venous hypertension within the compartment. The arte
becomes insufficient to allow tissue perfusion. Because the elevate
occlude major arteries completely as they pass through the compa
increasing tissue ischemia in the affected soft-tissue compartment

Clinical Findings

The diagnosis of compartment syndrome is established predomina
of suspicion whenever a closed compartment has the potential for
characterized by pain out of proportion to the initial injury. Pain is
immobilization. Pain may be accentuated by passive stretching of i
distribution of the nerve whose compartment is being compressed
ischemia. A third sign is weakness and paralysis of muscles within
compartment on palpation. Of the preceding signs and symptoms,
detecting compartment syndrome.

If the diagnosis of compartment syndrome is in question, the clinic
affected compartments. Various methods are available, including a
modification of a mercury manometer connected to tubing and a t
requiring fasciotomy is controversial, fasciotomy should be strongl
than 30 mm Hg in the forearm. Pressure measurements of the cor
to perform a fasciotomy of the hand or finger is based solely on cl

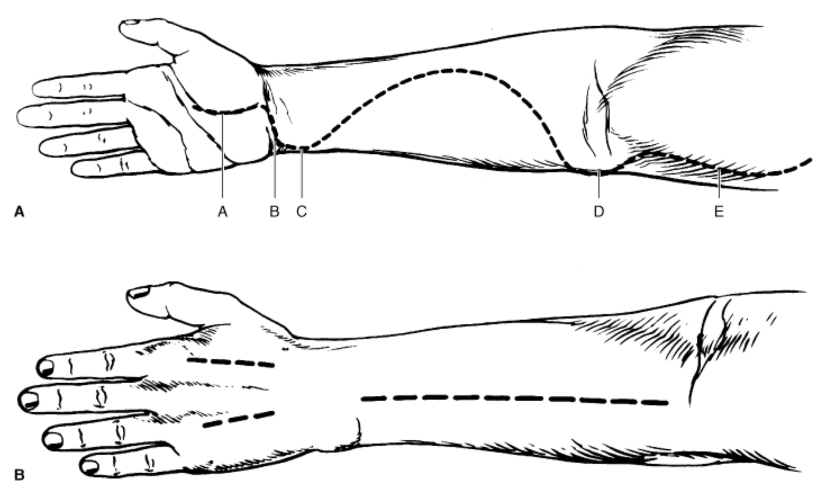
Treatment

Once the diagnosis of compartment syndrome is established, fasci
soon as possible because elevation of compartment pressure of m

irreversible tissue death. Prophylactic fasciotomy should also be co
than 4 hours. All patients undergoing forearm or arm replantation
surgical procedure.

The volar compartment of the forearm is the upper extremity com
skin incision should extend from the elbow to the carpal tunnel. Th
biceps and swings ulnarly toward the medial epicondyle. Care mus
The incision may be extended in a radial direction to allow decomp
the incision runs along the ulnar border. The flap is designed to all
the wounds are left open at the conclusion of the procedure. The i
exposure of the carpal tunnel in the proximal palm.

Figure 10–27.



A: Various skin incisions used for performing a volar arm fasciotor
compartments, straight incisions are preferred because fewer veir

(Reproduced, with permission, from Green DP, ed: *Operative Hand*

An epimysiotomy of the individual superficial and deep compartme
should be taken to ensure that the deep compartment musculatur
muscles) is completely decompressed. The skin incision should be
forearm. The proximal wound over muscle should be left open. Th
hours for reevaluation. At the second surgery, dressings are chang
muscle remains. In some instances, it is possible to close the wour
the residual skin defect is a safer alternative. Decompression of th
a dorsal longitudinal incision (Figure 10–27B).

In the hand, the connections between compartments are limited; t
This may be accomplished by two longitudinal dorsal incisions over

each of the interosseous compartments can be entered on both th
incisions are needed when decompression of the thenar and hypot

In the finger, fasciotomy may be required for treatment of either s
pressures in the finger are impossible to measure accurately, the i
swelling. Midaxial incisions along the ulnar side of the index, middl
thumb allow satisfactory digital decompression. Care is taken to re
between the neurovascular bundle and the flexor tendon sheath a
and wound closure is achieved either secondarily or with a split-th

Botte MJ, Keenan MA, Gelberman RH: Volkmann's ischemic contra
9742427]

Dente CJ et al: A review of upper extremity fasciotomies in a level

Hovius SE, Ultee J: Volkmann's ischemic contracture. Prevention a

Ultee J, Hovius SE: Functional results after treatment of Volkmann
Orthop 2005;431:42. [PMID: 15685054]

FRACTURES & DISLOCATIONS OF THE METACARPALS &

Fractures of the metacarpals and phalanges account for approxima
are work related. Fractures of the border digits, thumb, and little
is the distal phalanx, accounting for 45–50% of all hand fractures.

Clinical Findings

Description of a phalangeal or metacarpal fracture should include
(base, shaft, or neck), and whether the fracture is open or closed.
fracture is displaced or nondisplaced, if it has an intraarticular com
present.

Because rotational malalignment of a metacarpal or phalangeal fra
examination is essential. The patient is asked to flex actively the fi
orientation, and overlapping of the fingers is assessed. Associated
of soft-tissue coverage, also should be evaluated.

Treatment

Treatment of metacarpal and phalangeal fractures requires accura
the fracture reduction, with early motion of the uninvolved fingers
hand in an intrinsic plus, or safe, position to avoid secondary joint
exceed 3 weeks for phalangeal fractures or 4 weeks for metacarpa
clinical union in the hand, initiation of digital motion should not be
immobilization increases the likelihood of residual stiffness.

The fixation required to maintain fracture reduction depends on th
either buddy taping the affected finger to an adjacent finger and a
immobilization. Repeat radiographs at 7–10 days document mainte
fractures that require closed reduction to achieve proper alignmen

When external immobilization is impossible or unlikely to maintain
fixation techniques useful in the management of hand fractures in
band wiring, interfragmentary screw fixation, or fixation with plate
of other techniques. Additional stability may be achieved by combi
Interfragmentary screws provide ideal fixation for long oblique fra
times the diameter of the fractured bone. Plates and screws in the
with bone loss. When segmental bone loss occurs, initial treatment
maintenance of skeletal length with either internal or external fixa
reconstruction may be coupled with definitive internal fixation.

Physeal Fractures

Approximately a third of all fractures of the immature skeleton inv
into five types. Type 1 fractures, which shear through the growth
be effectively treated with simple immobilization. Type 2 fractures,
epiphysis, can usually be reduced in a closed fashion and immobili
the so-called extraoctave fracture at the base of the proximal phal
the finger. Reduction may be accomplished by metacarpophalange
fractures are intraarticular injuries. When displaced, these fracture
articular surface and physis. Type 5 fractures are uncommon in th
as a result of axial compression. Type 5 crush injuries to the grow
physis and thereby result in late angular deformity or digital short

Distal Phalanx Fractures

Distal phalangeal fractures occur most often in the middle finger a
injury, such as occurs with a misdirected hammer striking a thumb
caught in a closing door.

Precise reduction of distal phalangeal fracture fragments is not rec
involved. Treatment consists of splinting the bone and distal interp
interphalangeal joint is splinted, motion should be encouraged at t
Splint protection may be discontinued at 3 weeks.

Nail matrix injuries are often associated with open distal phalanx f
removal of the nail, irrigation of the fracture and nail bed, and nai
is usually accomplished by nail matrix repair and replacement of th
phalanx fractures may be required. After nail bed repair, either the
package, or a piece of gauze should be interposed between the na
formation.

Displaced open distal phalangeal epiphyseal injuries are most ofte dorsal physis. The nail is often avulsed dorsal to the eponychia. Tr fracture, and nail bed repair. Failure to appreciate the open nature result in osteomyelitis with growth arrest of the distal phalanx.

Proximal & Middle Phalanx Fractures

Angulation of fractures of the proximal and middle phalanges refle phalanx has an extensor force transmitted to it by the central slip tendon inserts dorsally and distally into the terminal phalanx, prov superficialis inserts volarly over the middle three fifths of the midc proximal to the flexor digitorum superficialis insertion angulate wit superficialis insertion angulate with the apex palmarly. Proximal ph because of the force of lateral bands that pass palmarward to the axis of the proximal interphalangeal joint.

Adhesions involving the flexor or extensor tendons are a major co Fracture displacement increases the likelihood of tendon adherenc the fractures may require secondary correction.

Early appropriate treatment of these fractures attempts to preven fracture, only temporary splint protection is required, followed by Radiographic follow-up is needed to document maintenance of the immobilization should have the forearm, wrist, and injured digits a gutter splint.

Metacarpal Fractures

Metacarpal Head Fractures

Intraarticular fractures of the metacarpal head require open reduc surface is involved. Realigned articular fracture fragments may be with marked comminution of the metacarpal head distal to the liga and may be treated with early mobilization with distraction tractio

Metacarpal Neck Fractures

Metacarpal neck fractures are most frequent in the little finger, alt fractures result from a direct blow, either delivered to the hand or Comminution of the volar cortex results in collapse deformity with fracture angulation may be accepted in the ring and little fingers b joints allows greater compensatory motion. The flexion and extens and 30 degrees in the little finger.

Figure 10–28.

Boxer's fracture. If the angulation in a metacarpal neck fracture is
extend the finger. This is a good clinical test to supplement the ev
radiographically.

(Reproduced, with permission, from Rockwood CA Jr et al, ed: *Fra*

Fracture site angulation of more than 10 degrees should not be ac
and little fingers with initial angulation of less than 15 degrees sho
angulation is 15–40 degrees, reduction should be accomplished be
weeks. With angulation of more than 40 degrees, extensor lag ma
patient may complain of a "marble" in the palm when making a fis
may be employed.

Metacarpal Shaft Fractures

Metacarpal shaft fractures result from a direct blow or crushing in
to the interosseous muscle forces. The closer the fracture is to the
hence, the less angulation can be tolerated. Less shortening occur
than in the index or little fingers because the deep intermetacarpa
metacarpal distally. Isolated metacarpal fractures may be treated
metacarpal shaft fractures may be fixed percutaneously with a lon
metacarpal to an adjacent metacarpal. Skeletal fixation is essentia
closed means because modest metacarpal malrotation results in su
degrees in index and middle metacarpals and more than 20 degre
mm, or multiple displaced metacarpal fractures should be treated
effectively fixed with multiple screws, and transverse fractures are
When two or more metacarpals are simultaneously fractured, the s
Secure fixation with screws or plates should be employed in at leas

Joint Injuries

Distal Interphalangeal Joint

The most common intraarticular fracture of the distal interphalang
articular surface is avulsed by the extensor tendon. Most bony ma
weeks. Indications for fixation of these fractures are controversial.
include articular surface loss greater than 30% and subluxation of

Dislocation of the distal interphalangeal joint is uncommon without
splint protection allows early mobilization to begin within 7–10 day

Condylar Fractures

Condylar fractures may occur in either the proximal or middle pha
Anteroposterior, lateral, and oblique radiographs are necessary to
appreciated, angulation of the finger and joint incongruity may lea
Displaced fracture should be openly reduced and internally fixed if
both condyles are fractured, they must be precisely secured toget
ligament insertion to the condyle must be preserved because it is
may be anticipated in complex condylar fractures.

Proximal Interphalangeal Joint Dislocation & Fracture

Dorsal dislocations of the proximal interphalangeal joint are more
dislocations may be separated into three types (Figure 10–29). In
plate from the base of the middle phalanx, and the collateral ligam
surface remain intact. Type 2 dislocations are dorsal dislocations si
collateral ligament is torn. In type 3 injuries, dorsal dislocation occ
of the middle phalangeal palmar base may be sheared away. Stabl
less than 40% of the middle phalanx base is fractured. Unstable fr
involvement and are associated with complete loss of collateral lig

Figure 10–29.

Various dorsal dislocations of the proximal interphalangeal joint. **A**
incomplete longitudinal split occurs in the collateral ligaments. The
(dorsal dislocation). There is complete rupture of the volar plate a
middle phalanx resting on the dorsum of the proximal phalanx. Th
alignment. **C:** Type 3 (fracture-dislocation). The insertion of the v
phalanx, is disrupted. The major portion of the collateral ligament
articular defect may be present.

Treatment of proximal interphalangeal joint dislocations depends o
treated by closed reduction and immobilization in a dorsal splint in
splinting, a radiograph should document the reduction. While in th
interphalangeal joint actively. After 2–3 weeks, the splint is remov
during sports for the next month.

Unstable fracture-dislocations should be treated with closed reduct
necessary to achieve reduction. Again, radiographs must documen

active proximal interphalangeal joint flexion while constraining ext
each week until approximately 6 weeks after reduction, when splir
achieved, open reduction is required. When a single large palmar a
attempted. If the fracture is comminuted, however, either volar pl
early controlled passive joint motion is necessary.

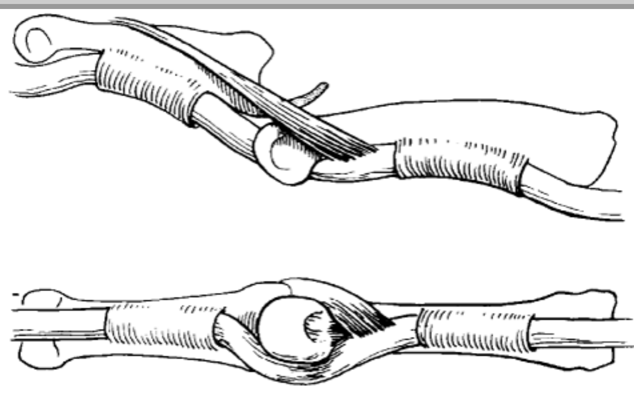
Radial lateral proximal interphalangeal dislocation is six times more
These dislocations are associated with avulsion of the volar plate,
After the joint is reduced, the residual joint stability should be ass
dislocations are immobilized at 5–10 degrees of flexion for 3 week

Palmar proximal interphalangeal dislocations are unusual. The con
central slip and the lateral bands. Closed reduction may be attemp
metacarpophalangeal and proximal interphalangeal joints. If closed
extension for 3–6 weeks to allow healing of the extensor rent. If c
to free the condyle from the rent in the extensor mechanism.

Metacarpophalangeal Joint

Dorsal metacarpophalangeal dislocations most commonly involve e
proximally from the metacarpal by hyperextension injury. If the jo
interposed in the joint, closed reduction may be achieved by flexio
metacarpophalangeal joint can transform a reducible joint into an
volar plate becomes interposed between the dislocated articular su
open reduction to extract the volar plate from between the articula
accomplished through either a palmar or dorsal approach. If the p
to the radial digital nerve of the index finger or the ulnar digital ne
tension of the flexor tendons on the volar plate. If the dorsal appr
facilitate reduction.

Figure 10–30.



Complex dislocation of the metacarpophalangeal joint. In the uppe
head of the metacarpal and the base of the proximal phalanx. In t

metacarpal can be seen trapped between the flexor digitorum pro
(Reproduced, with permission, from Lister G: *The Hand: Diagnosis*

Postoperatively, the metacarpophalangeal joint is immobilized in ap
that allows active motion is maintained for 3 weeks.

Although lateral dislocations of the metacarpophalangeal joint are
These injuries should also be immobilized in approximately 30 deg
from ulnar stress for an additional 3 weeks. Unstable index- and m
repaired.

Finger Carpometacarpal Joints

Sprains and fracture-dislocations may involve any of the carpomet
carpometacarpal joints may occur with palmar flexion and torsion.
careful radiographs fail to demonstrate fracture, a sprain may be d

Treatment of acute sprain injuries consists of 3–6 weeks of immob
considered. Chronic pain at the index middle trapezoid capitate joi
arthrodesis of the carponmetacarpal joint. Carpometacarpal fractu
secondary to direct or longitudinal blows. Dorsal dislocations are m
partial pronation and supination may be required to visualize the c
achieved with longitudinal distraction. The reduction may be maint
dislocation of the little-finger metacarpal articular surface shears o
shaft is likely. Because of forces of the extensor carpi ulnaris and t
displace proximally and angulate palmarly. Longitudinal traction ar
metacarpals stabilize these fractures. Open reduction is necessary
dislocations. If the patient develops degenerative arthritis of the h
finger carpometacarpal joint (or both) is well tolerated.

Thumb Metacarpophalangeal Joint

The most common injury to the metacarpophalangeal joint is sprai
thumb, skier's thumb). This injury occurs when the thumb is force
When the ulnar collateral ligament tears from its phalangeal insert
between the retracted ligament, preventing healing of the ligamen
lesion). Evaluation of the integrity of the ligament may be made by
under local anesthesia. Radial deviation that is more than 30 degre
disrupted, incompetent ligament.

Closed treatment of a partial ligament tear may be accomplished w
of the ligament requires surgical exploration and reattachment to t
occur with a bony fragment. If the fragment is greater than 15% o
more than 5 mm, open repair of the ligament is recommended.

Chronic symptomatic ulnar collateral ligament injuries may be repa
Supplementation of the repair with either tendon transfer or tendo

arthritis or if ligament reconstruction is not deemed feasible, arthr

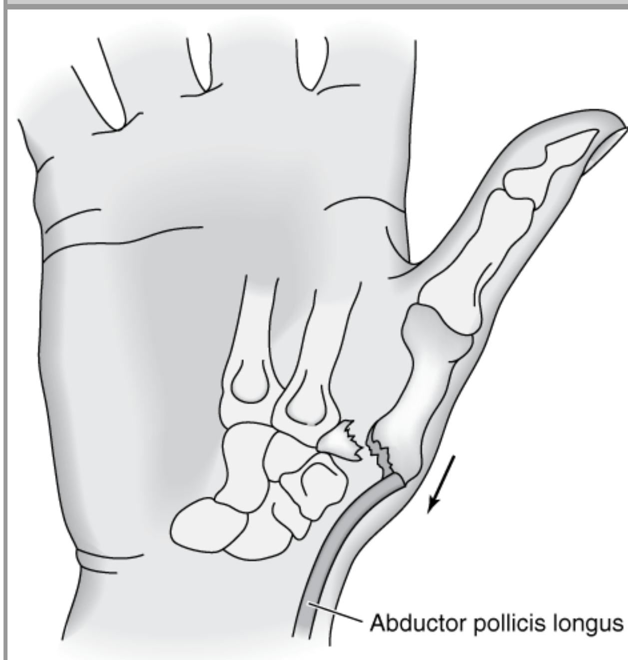
Thumb Carpometacarpal Joint

Four patterns of thumb metacarpal fracture are most commonly e

BENNETT FRACTURE

Bennett fracture is an intraarticular fracture in which the small vol attached to the anterior oblique ligament, and the remainder of th proximally, radially, and into adduction in response to the force of insertion on the metacarpal (Figure 10–31). Acute Bennett fractur proximal metacarpal, with slight pronation. The reduction may the metacarpal shaft into either the fragment or the trapezium. If sati reduction and internal fixation is required.

Figure 10–31.



Bennett fracture. The first metacarpal shaft is displaced by the pu

(Reproduced, with permission, from American Society for Surgery Churchill Livingstone, 1983.)

ROLANDO FRACTURE

The Rolando fracture is a comminuted T or Y intraarticular fracture are present, open reduction and internal fixation is possible. When or limited open reduction and internal fixation with cast immobiliza

EXTRAARTICULAR FRACTURE

Extraarticular fractures are less likely to develop traumatic arthriti
carpometacarpal joint of the thumb, up to 30 degrees of angulatio

EPIPHYSEAL FRACTURE

Epiphyseal fractures of the thumb metacarpal are treated in a fash

Freeland AE, Lineaweaver WC, Lindley SG: Fracture fixation in the

Kiefhaber TR, Stern PJ: Fractures dislocations of the proximal inte

Page SM, Stern PJ: Complications and range of motion following pl
Surg Am 1998;23:827.

WRIST INJURIES

Scaphoid Injuries

The scaphoid is the most commonly fractured bone in the carpus.
middle, and distal thirds. The middle third is termed the *waist.* Th
the scaphoid articulates with four carpal bones and the radius, mo
little room for vascular perforation. Therefore, the vascular supply
in the waist. Most of the blood supply to the scaphoid enters dista
there is diminished flow to the proximal pole, which may result in
100% of proximal pole fractures develop ischemic or aseptic necro

Middle third fractures account for approximately 70% of scaphoid
fractures for the rest.

Cast immobilization is recommended in the treatment of all nondis
2 mm of displacement and no fracture site angulation. On average
fractures in 4–8 weeks, and proximal third fractures in 12–20 wee
displacement, open reduction and internal fixation is required to p
smooth K-wires or a buried compression screw. Because of the tim
primary fixation of these fractures even when nondisplaced. Newe
nondisplaced waist fractures decreases or eliminates the period of

Delayed union may be treated with either prolonged casting or op
ununited fractures may be treated by percutaneous screw fixation
cancellous volar graft is employed to correct the deformity. The gr
or K-wires. If the proximal pole is avascular and no radiocarpal art
vascularized bone graft from the dorsal radius should be performe

Once degenerative arthritis is evident at the radiocarpal joint, salv
excision and midcarpal arthrodesis, or total wrist arthrodesis.

Lunate & Perilunate Dislocations

Lunate and perilunate dislocations are the result of a powerful forc
lunate. The mechanism of these injuries is usually dorsiflexion, uln
stages of disruption. Stage 1 injuries demonstrate disruptions of tl
of the ligaments dorsal to the lunate. In stage 3 injuries, the arc o
4 injuries have total disruption of the entire lunate ligamentous su
of clinical entities from scapholunate dissociation to perilunate disl

When the entire carpus except the lunate dislocates and the lunat
the abnormality is termed *perilunate dislocation* (Figure 10–32). W
maintained but the lunate is dislocated palmarward into the carpal
lunate and perilunate dislocations imply disruption of ligamentous
the capitate and the lunate, and between the lunate and the triqu
scapholunate ligament and to the triquetrum through the lunotriqu
capitate, known as the space of Poirier, lacks direct ligamentous co

Figure 10–32.

Perilunate dislocation: Anteroposterior view (**A**); lateral view (**B**).

A variant of perilunate dislocation is transscaphoid perilunate dislo
the scaphoid rather than the scapholunate ligament. The disruptio
capitate, between the capitate and the lunate, and between the lu

Intercarpal ligamentous disruptions heal if the normally connected
dislocations should be reduced initially in a closed fashion. Reducti
pressure on the dislocated carpal bone or bones. Occasionally, ana
maintained with closed reduction and cast application. In most inst
ligamentous repair is necessary to secure anatomic reduction. Sur

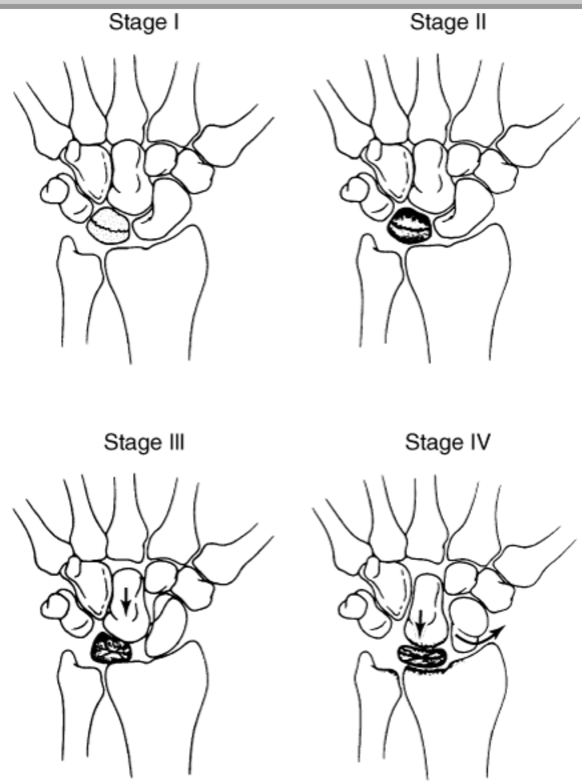
requires both palmar and dorsal approaches. Through the dorsal a
stabilized. The palmar approach is employed to release the mediar
space of Poirier.

Kienböck Disease

Kienböck disease results from ischemic necrosis of the lunate. The
The condition is more common in patients with a negative ulnar va
unclear whether the relatively shorter ulna alters and increases th
the radius or whether the altered stress causes the lunate to be sh
configuration.

Kienböck disease may be classified based on the extent of collapse
compression fracture but an otherwise normal-appearing architect
lunate in stage I (Figure 10–34). In stage II disease, the density is
present. Stage III disease is subdivided into stage IIIA, in which th
stage IIIB, in which the lunate is collapsed and carpal height is als
changes are present.

Figure 10–33.

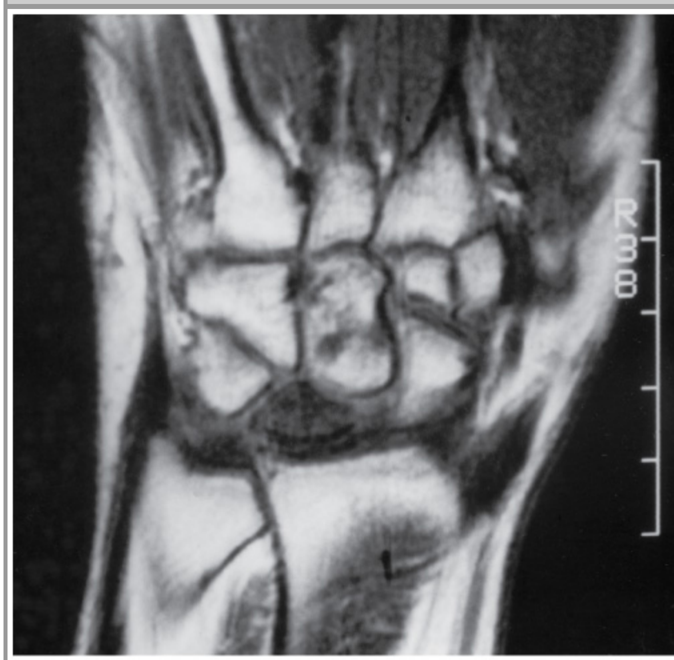


Staging of Kienböck disease (after Lichtman). Stage I: Routine rad
tomography may show a linear fracture, usually transverse throug
Stage II: Bone density increase (sclerosis) and a fracture line are

Posteroanterior and lateral tomograms demonstrate sclerosis, cyst
deformity. Stage III: Advanced bone density changes are present,
diagnosis is evident from posteroanterior radiograph. Tomograms
infractionation and amount of fracture displacement. Proximal mig
moderate rotary alignment of the scaphoid. Stage IV: Perilunate a
fragmentation of the lunate. Carpal instability is evident, with sca
space.

(Reproduced, with permission, from Rockwood CA Jr et al, eds: *Fr*

Figure 10–34.



MRI showing Kienböck disease.

The current recommendations for the treatment of Kienböck disea
neutral variance when no carpal collapse is present. If the patient
recommendations include either a capitate shortening osteotomy c
trapezoid. A new technique restores the anatomic height of the lur
bone. In stage IIIB and IV wrists, consideration is given to either p
replacement of the lunate is no longer advised for Kienböck diseas

Carpal Instability

To evaluate the orientation of the carpus properly, true anteropost
anteroposterior view should be obtained with the forearm position
evaluation of the relationship between the distal radius and the dis

negative ulnar variance is used, and when the ulna extends furthe
used.

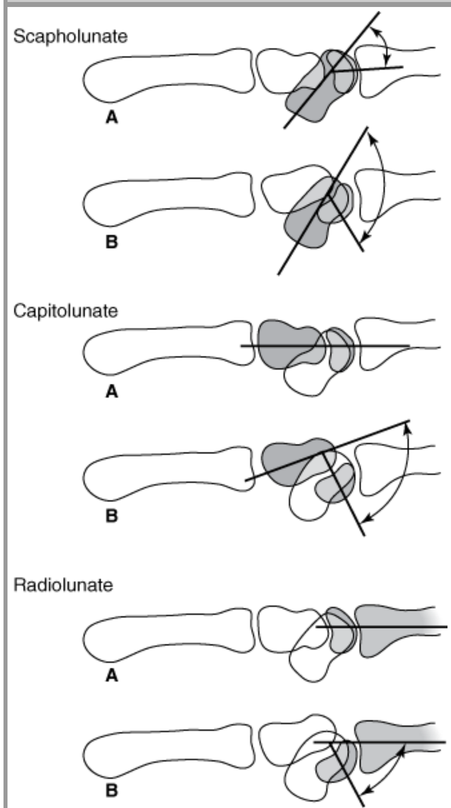
The anteroposterior radiograph should demonstrate the close relat
portions of these two bones are separated by their abutting respe
3 mm or less. In an adult a gap of more than 3 mm is considered
secondary to ligamentous disruption. When the scapholunate gap
is referred to as static scapholunate dissociation (Figure 10–35). W
an anteroposterior radiograph taken with the fingers squeezing tig
referred to as dynamic scapholunate dissociation.

Figure 10–35.

Anteroposterior view of static scapholunate dissociation.

The lateral radiograph should be obtained with the wrist in a neutr
radiograph is often overlooked because of the projected superimp
measurement of a number of angles between bones. Normally, the
The long axis of the radius is readily defined. Establishing the relat
drawn along the most palmar portions of the distal and proximal p
intersect, forming the radioscaphoid angle (Figure 10–36). This an
greater than 60 degrees, the scaphoid is abnormally flexed.

Figure 10–36.



Carpal angle measurements are of considerable aid in identifying c
angle seen in dorsiflexion instability. The capitolunate angle shoulc
but the range of normal probably extends to as much as 15 degre
angle of greater than 80 degrees is definite evidence of dorsiflexic
15 degrees.

(Reproduced, with permission, from Green DP, ed: *Operative Hanc*

The orientation of the lunate viewed on the lateral radiograph is de
palmar and dorsal lips of the lunate. A second line is then drawn p
lunate. The angle between the radial and lunate axes (radiolunate

The orientation of the lunate seen on the lateral radiograph norma
adjacent scaphoid and triquetrum. The scaphoid tends to tether th
whereas the triquetrum tends to tether the lunate into extension (
scapholunate ligament is disrupted, the scaphoid tends to flex exce
the triquetrum, dorsiflexes (dorsal intercalated segment instability
disrupted, the lunate, under the unopposed influence of the scaph
The optimal treatment for DISI is currently an area of intense inte

direct ligamentous reapproximation and repair. When ligamentous
degenerative change, ligamentous reconstruction, dorsal capsular

Figure 10–37.

Lateral radiograph of dorsal intercalated segment instability.

Degenerative arthritis occurs in wrists subjected over time to load
scapholunate advanced collapse (SLAC) wrist pattern describes the
of the scapholunate ligament (Figure 10–38). The earliest evidence
and, with time, degenerative change progresses to include the cap
present but the articular surface of the capitate retains its normal
scaphoid, lunate, and triquetrum) allows preservation of wrist mot
the lunate fossa of the distal radius. When degenerative change is
in addition to radioscaphoid change, the scaphoid may be excised
hamate is accomplished. This selective intercarpal fusion procedur
articulation. The ultimate salvage procedure, complete wrist fusion
wrist motion.

Figure 10–38.

Scapholunate advanced collapse pattern.

Distal Radioulnar Joint

The distal radioulnar joint (DRUJ) is composed of two joints. The p
forearm rotation. The ulna also articulates with the ulnar carpus th
Approximately 20% of the load from the hand to the forearm pass
related to one or both of these joints.

When the ulnar variance is positive, the patient may develop an ul
on the ulnar side of the wrist, particularly with ulnar deviation. Ra
distal ulna and ulnar lunate. Treatment consists of shortening the
(wafer procedure) either by open method, by arthroscope, or by a
ulna, and fixed with a plate and screws. After the wafer procedure
month) period. Approximately 50% of patients who have an ulnar
healing.

Another source of ulnar-sided wrist pain is a tear of the TFCC. Tea
Degenerative tears are usually related to ulnocarpal impaction. Tra
Central tears and tears near the attachment of the TFCC to the ra
Tears in the well-vascularized periphery of the TFCC are treated w
are maintained in a long arm cast for 6 weeks to allow fibrocartila

Arthritis between the distal radius and ulna can be caused by trau
consists of hemiresection or complete excision of the ulnar head (D
Kapandji procedure, fuses the DRUJ and creates a pseudarthrosis
ulnar translocation of the carpus.

Instability of the DRUJ is difficult to treat. Instability is usually the
ulna resection. Treatment requires detection and correction of any
tissue operations are designed to stabilize the distal ulna, all with v

Adams BD, Berger RA: An anatomic reconstruction of the distal ra
instability. J Hand Surg [Am] 2002;27(2):243. [PMID: 11901383]

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fractured hook of the hamate. Orthopedics 2003;26:717. [PMID: 1

Berger RA: The anatomy of the ligaments of the wrist and distal ra
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arthrodesis. J Hand Surg [Am] 2001;26:94. [PMID: 11172374]

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and ligament repair. J Bone Joint Surg Br 2001;83(7):1023. [PMID

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approach. J Bone Joint Surg Am 2003:85:20. [PMID: 14652390]

Steinmann SP et al: Use of the 1,2 intercompartmental supraretin
scaphoid nonunion. J Hand Surg [Am] 2002;27(3):391. [PMID: 12

Szabo RM et al: Dorsal intercarpal ligament capsulodesis for chron
Surg Am 2002;27A:978. [PMID: 12457347]

SOFT-TISSUE INJURIES

Because of the importance of the fingertip in providing a contact s
result in troublesome disability. The pulp of the fingertip is normal
phalanx by fibrous septa. The dorsum of the fingertip is composed

Treatment

The goals in treatment of fingertip injuries are to provide adequate
and full joint motion. Preservation of length should be balanced wi

The choice of treatment depends on the size and location of the de
the presence of exposed bone, and the angle of soft-tissue loss ar

OPEN WOUND CARE

The simplest treatment is open wound care, which is indicated in r
adults. The wound is thoroughly cleansed. Bone is shortened so it
same as the length of the nail bed. Dressings are changed until th
are the possibility of stump tenderness and prolonged healing time
immediately and to thus preserve full digital motion.

COMPOSITE GRAFTING

Replacement of the amputated part as a composite graft (skin and
adults with sharp distal amputations. When successful, this treatm
unpredictable viability of the part, may result in recovery delayed

MICROVASCULAR REPLANTATION

Microvascular replantation is possible in selected sharp amputation
include the expense of complex surgery and the time lost from wo

PRIMARY SHORTENING AND CLOSURE

Primary bone shortening and closure is indicated when more than
irreparably damaged. This one-stage procedure allows for immedia
distal phalanx bone should be trimmed to provide a tension-free s
proximal as the bone. If the nail bed is pulled over the end of the
digital nerves under traction allows the nerve ends to retract into

SKIN GRAFTING

Skin grafting may also be employed to obtain closure if no bone is
vascularized bed. Split-thickness grafts contract more than full-thi
also shrinks. The appearance and durability of scar tissue may be

Full-thickness skin grafts provide more durable coverage and bette
pigmentation of the skin at the donor and recipient sites. The ulna
thickness grafts require a better vascularized bed to assure surviv

SKIN FLAPS

Local advancement skin flaps are useful in the treatment of fingert

V-Y Advancement Skin Flaps

V-Y advancement skin flaps may advance palmar tissue or unite tw management of transverse or dorsal oblique amputations in which shortening deemed undesirable. Complete separation of the vertic mobilize skin flaps for advancement. The septa between the flap a flap helps differentiate the septa from vessels and nerves.

Moberg Palmar Advancement Flap

Defects of up to 1.5 cm on the thumb may be covered by a palma midlateral incisions dorsal to the neurovascular bundles of the thu sheath. The flap may be maximally advanced by flexion of the thu required, the skin of the flap may be transversely divided at the m are preserved, the distal portion of the flap may be advanced furt and the proximal flap. Disadvantages of this flap include the possi potential for dorsal tip necrosis if dorsal vascular branches to the c

Regional Skin Flaps

Regional skin flaps are considered when fingertip skin is lost but n

CROSS-FINGER FLAP

The cross-finger flap is the most commonly used distant flap. Skin taken not to incise the extensor paratenon. The skin is then rotate finger. The donor region on the donor finger is skin grafted. The tr Joint stiffness is a potential complication in both the donor and rec another disadvantage.

THENAR FLAP

The thenar flap may be used in children and young (less than 25 y More subcutaneous fat is transferred with a thenar flap than with matching of color and texture with the pulp.

NAIL BED INJURIES

Clinical Findings

Nail bed injuries, often neglected, should be carefully attended to fine manipulation of the finger, and gives the finger a normal appe hematoma, nail matrix laceration, avulsion of the nail matrix from

Treatment

When a subungual hematoma involves more than 50% of the subu laceration repaired with fine absorbable suture. Either the nail is re synechia formation with resultant splitting of the nail. Nail bed def from either an adjacent uninjured fingernail or a toenail.

When nail bed injuries occur with an open distal phalangeal fractur
stabilizes the nail bed repair.

Caution is required in the treatment of nail bed injuries in children
door. The nail often lies dorsal to the nail fold, and a small subung
physeal fracture of the distal phalanx is observed. Because the na
injury represents an open fracture and must be treated appropriat
irrigated. An interposed portion of the nail bed often must be extr
the fracture is unstable, pin fixation facilitates nail bed repair. Failu
result in osteomyelitis and physeal arrest of the distal phalanx.

Heistein JB, Cook PA: Factors affecting composite graft survival in
12800909]

ACUTE BURN INJURY

Degree of Injury

FIRST-DEGREE BURNS

Burns are characterized by the depth of skin injury. First-degree b
swollen red areas, and care is symptomatic.

SECOND-DEGREE BURNS

Second-degree burns involve both the epidermis and the superfici
skin blistering and blanching of the skin when pressure is applied.
burns. Superficial second-degree burns are treated with topical an
and the hand splinted in the intrinsic plus position. With the wrist
flexed and the interphalangeal joints are extended. The thumb sho
contracture of the first web space. The patient should begin a vigo
is tolerated. Compression garments may deduce swelling and scar

In deep second-degree burns, excision of the remaining portion of
long-term results superior to those achieved with spontaneous hea
should be similar to that of superficial second-degree burns.

THIRD-DEGREE BURNS

Third-degree burns involve the entire epidermis, dermis, and a po
dry regions often having a nontender central area, caused by burn
treated with excision within the first 3–7 days and a split-thicknes

FOURTH-DEGREE BURNS

In addition to involvement of the skin, fourth-degree burns involve
the only effective treatment for these burns is amputation of the i
residual stump.

Complications

NEUROVASCULAR COMPLICATIONS

The neurovascular status of the burned hand should be carefully m
compartments of the hand and forearm. Digital releases are best p
the index, middle, and ring fingers and along the radial border of t
hand allow decompression of interosseous muscle compartments. I
arm and forearm.

LATE COMPLICATIONS

Joint Contractures

Joint contractures are the most common complications of upper ex
contractures. Treatment consists of soft-tissue release and either s
Elbow motion may also be limited by the development of heterotop
if delayed until the area of ossification has matured, often 1.5–2 y
heterotopic ossification is posteromedially, care must be taken to c
surgery.

Wrist and Hand Contractures

Wrist contracture may tether the hand into either a flexed or exte
fingers, burns usually involve the thin skin on the dorsum of the fi
middle phalanx. The loss of active proximal interphalangeal joint e
development of a clawlike deformity, with flexion contractures of t
contracture at the metacarpophalangeal joint.

Treatment of metacarpophalangeal joint extension contracture usu
skin graft, and dorsal metatarsophalangeal joint capsular release.
secondary to scarred volar skin. In such cases, soft tissue release
or by palmar scar excision and full-thickness skin graft application
interphalangeal joint contracture in the burn patient is arthrodesis

Adduction contracture, the most common thumb deformity in the
release required depends on the degree of contracture. A modest
plasty of the thenar skin to regain adequate abduction in the first
adductor pollicis from its origin or at its insertion and release of th
metacarpal may be required. If web space skin coverage is inadeq
or distant skin flaps may be needed.

Ideally, first web space contracture should be avoided by carefully
burn treatment. When the extent of web space burn is severe and
an external fixator should be placed, spanning the thumb and inde

ELECTRICAL BURNS

The extent of injury in electrical burns is proportional to the amou
body. The Ohm law states that the amount of current is equal to t
voltage, those structures that have a lower resistance conduct a g
structures in the arm from least resistance to greatest resistance i
bone. Alternating current is more injurious than direct current. Be

tetany in the finger flexors, which may prevent the patient from re
plays a direct role in the severity of injury because a longer contac
body.

Clinical Findings

The greatest current density occurs at the entrance and exit woun
surrounded by a gray-white zone, an area of tissue necrosis in wh
surrounded by a red zone, in which there is a variable extent of ve

High-voltage, or arc, burns produce a greater thermal than electri
the hand to the wrist or from the forearm to the arm. Arc burns a
5000°C.

It is difficult to assess precisely the extent of tissue necrosis in bu
should be examined for fractures, particularly cervical spine fractu
distance by the current. The possibility of either compartment syn
considered. Patients should be admitted to an intensive care unit a
secondary hemorrhage, and neurologic complications to the brain,

Treatment

Treatment for upper extremity burns consists of initially debriding
and nerve decompression should be guided by examination. A sec
the gray-white zones. Debridement should be continued every 48-
necrosis often appears to increase with each successive debridem
extent of initial injury and progressive vascular thrombosis. After a
with either local or distant skin flaps or amputation.

CHEMICAL BURNS

The severity of chemical burns is directly proportional to the conce
duration of skin exposure, and the mechanism of contact. Tissue d
tissue or the agent is neutralized by an applied secondary agent o
chemical burns of the skin is irrigation with water.

Two notable exceptions are burns resulting from hydrofluoric acid
cannot be removed with water, calcium gluconate 10%, either app
required to neutralize the acid. Patients with hydrofluoride burns e
injury. White phosphorus burns, also refractory to water irrigation,

Iatrogenic chemical burns may occur with extravasation of chemot
Chemotherapeutic agents are classified as vesicants, which include
causing skin necrosis, and nonvesicants, which include cyclophospl
surgical debridement of the region of extravasation. Secondary wo
grafting or skin flap coverage.

COLD INJURY (FROSTBITE)

Clinical Findings

Frostbite occurs as the result of cellular injury when the cell memb
space. With the formation of ice crystals, osmotic gradients develo
Patients may develop severe vasoconstriction as a result of increas
thrombosis. With capillary endothelial damage, leakage occurs into
sludging within the capillary system.

Frostbite injuries may be classified as either superficial or deep. Su
spontaneously, whereas deep frostbite damages both the skin and
injuries, the depth of the area of necrosis is difficult to determine

Figure 10–39.

Radiograph of deformities of the fingers of the left hand in a 12-y
Note destruction of epiphyses of middle and distal phalanges of al
little finger. Osseous changes in right hand were similar.

Treatment

The initial treatment of frostbite consists of rewarming the part an
restored and the frozen extremity rapidly rewarmed in a water ba
pain, it should be delayed until adequate analgesia can be adminis

the hand, local wound care, and dressing changes. Frequent whirl
instituted. The role of anticoagulants and sympathectomy in increa

Long-Term Sequelae

Long-term sequelae depend on the extent of initial injury. Adult pa
joints. Skeletally immature patients may develop epiphyseal destru
destruction. Severe injuries may produce intrinsic muscle atrophy
tone. Vasospasm may lead to severe pain, coldness, or edema of t
growth; or Raynaud phenomenon. In severe injuries, mummificati
Amputation or surgical debridement of these mummified parts sho
develops. This delay allows maximal reepithelialization beneath the

Woo SH, Seul JH: Optimizing the correction of severe postburn ha
fasciocutaneous free-tissue transfers. Plast Reconstr Surg 2001;1

HIGH-PRESSURE INJECTION INJURY

Injection machinery used in industry may create pressures of 300
design of the nozzle aperture and the distance between the nozzle
pressures of over 7000 psi require amputation.

Clinical Findings

Injection injuries usually puncture the palmar digital pulp, track to
injected material. These injuries have a poor prognosis. Injections
site of the material is unconfined by fascial planes. Prognostic fact
as the amount and type of material injected. Whereas paint injecti
more often leads to fibrosis of the finger. The amputation rate for
grease injection injuries is 20%.

The examiner must be wary of an innocuous-appearing entrance w
but increases with time as more distal swelling and early necrosis

Treatment

The effectiveness of corticosteroids administered every 6 hours re
Patients should be operatively treated soon after the injury occurs
the injected material is pigmented. Nonpigmented materials such
remove thoroughly. The hand should be splinted in the safe positic
Repeat debridement should be done if there is doubt about the ad

Although injection injuries may appear simple, these severe injurie
seriousness of these injuries should be recognized at the time of p

Christodoulou L et al: Functional outcome of high-pressure injectic
11303170]

Gutowski KA et al: High-pressure hand injuries caused by dry clea
treatment guidelines. Plast Reconstr Surg 2003;111:174. [PMID: 1

Luber KT, Rehm JP, Freeland AE: High-pressure injection injuries o

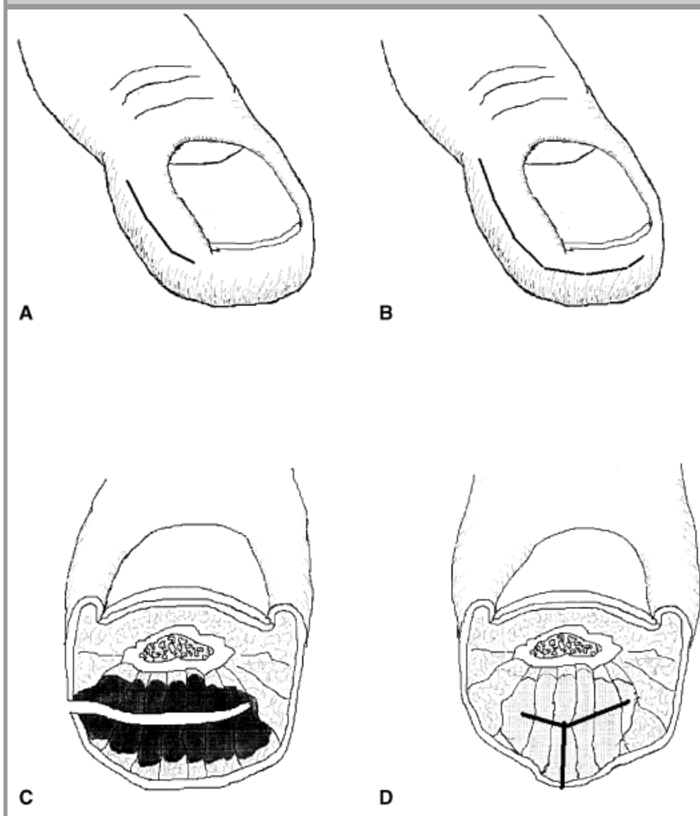
INFECTIONS OF THE HAND

Felon

A felon is an abscess of the pulp space of the distal phalanx. Vertic
compartments within the pulp space. Infection in this region produ

Treatment of these infections requires incision and drainage, with
completely (Figure 10–40). A drain is placed in the wound, the har

Figure 10–40.



Incisions for drainage of felons. **A:** Unilateral longitudinal approach
the ulnar side of the finger, unless it is the little finger, to preserve
reserved for extensive or severe abscess or felon. **C:** The incision
through and through. **D:** The felon that points volarly may be dec

preferable because of less risk to sensory nerves. A transverse inc
digital nerves.

(Courtesy of HB Skinner, ©copyright 2002.)

Paronychia

Paronychia is the most common digital infection. The paronychia is
fingernail. The eponychium is the roof of the nail over the nail lunu
chronic.

ACUTE INFECTION

Acute infections are most often caused by *Staphylococcus aureus.*
around the nail. Untreated, this cellulitis may progress to an absce

Treatment of early infection includes warm soaks and oral antibioti
To debride the region adequately, either an incision is made in the
nail is removed and the abscess decompressed.

CHRONIC INFECTION

Chronic paronychial infections are most often caused by *Candida* s
their hands in water, such as bartenders or dishwashers. Patients
chronic infection.

Treatment of chronic infection may be accomplished by eponychial
without incision of the nail roof. Simultaneous nail removal may inc

Web Space Abscess

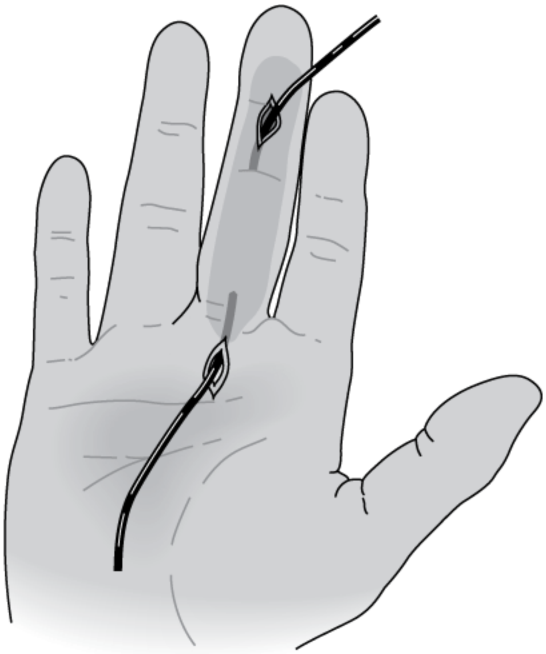
Web space abscesses most often occur after palmar puncture wou
least resistance to the dorsal web space. Treatment requires dorsa
appropriate antibiotic coverage.

Flexor Suppurative Tenosynovitis

Kanavel described four cardinal signs of acute suppurative tenosyr
position of the digit; (3) symmetric swelling of the digit, which ma
the flexor tendon sheath. Acute suppurative tenosynovitis of the fl
Likewise, infections in the flexor sheath of the little finger may ext
between the radial and ulnar bursas may allow infection to track ir
finger.

Treatment of acute suppurative tenosynovitis requires incision, irri
incision may be used, limited incisions are preferred. Short incisior
distal (distal interphalangeal region) margins of the flexor tendon s
sheath is opened distally and a small tube (16-gauge catheter or r
in the flexor sheath through the proximal wound. Irrigation of the
hours. Intravenous antibiotics are administered, and the hand is e

Figure 10–41.



Drainage and closed irrigation for flexor sheath infection. The anti
out through the proximal one.

(Reproduced, with permission, from Way LW, ed: *Current Surgical*
1994.)

Two days after surgery the dressing is changed. Swelling should b
patient is encouraged to begin active ROM exercises.

Bite Injuries

Although bite wounds may initially appear harmless, a bite may in

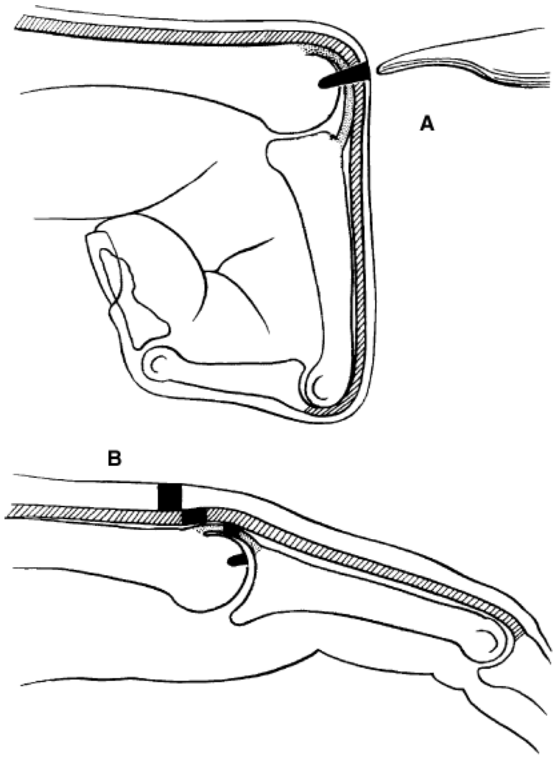
CAT AND DOG BITES

Because the small puncture wounds of cat bites are more likely to
late sequelae are more common after cat bites. Cat and dog bites
treated with ampicillin, penicillin, or a first-generation cephalospor
drainage and an initial course of intravenous antibiotics in the eme

HUMAN BITES

Most human bite wounds result from a fist striking a tooth, which
tendon, and capsule of the metacarpophalangeal joint (Figure 10–
organism best treated with penicillin or ampicillin. Human bite wou
therapy instituted. Arthrotomy of the metacarpophalangeal joint a

Figure 10–42.



Human bite wound of metacarpophalangeal joint. **A:** The tooth pie
tendon, joint capsule, and metacarpal head. **B:** When the finger is
wounds do not correspond.

(Reproduced, with permission, from Lister G: *The Hand: Diagnosis*

SPIDER BITES

Although most spider bites are innocuous, the bite of a brown recl
injected toxin.

Infection Caused by Unusual Organisms

ATYPICAL MYCOBACTERIAL INFECTION

Mycobacterium marinum infection may present as a chronically inf
saltwater fish. Successful culture of the organism is difficult but is
therapy is effective in treating and eradicating these infections.

GRAM-NEGATIVE INFECTION

Because of the risk of a gram-negative infection following mutilatir
these patients should be treated with broad-spectrum antibiotics.

ANAEROBIC INFECTION

When *Clostridium perfringens* infection occurs after hand injury, in
instituted. Hyperbaric oxygen therapy may be helpful. If infection
necessary to avoid death.

The possibility of *Clostridium tetani* contamination must be remem
patients with penetrating wounds must include questioning about t
should be administered.

GONORRHEA

A patient who presents with an isolated septic joint or tenosynovit
hematogenous gonorrheal infection. Treatment consists of culturin
treatment with penicillin or tetracycline.

NECROTIZING FASCIITIS

The causative agent in necrotizing fasciitis is most commonly hem
debridement to the fascia and appropriate antibiotics.

HERPETIC WHITLOW

Herpes simplex infections may involve the fingertips. They are mo
oral tracheal area and are also seen in small children. It may be di
infections of the fingers. Close examination reveals the presence o
Aspiration of a vesicle yields clear fluid. Serial viral titers confirm t
should not be incised but simply treated with splinting and elevatio

Connor RW, Kimbrough RC, Dabezies MJ: Hand Infections in patie
11727802]

Huish SB et al: Pyoderma gangrenosum of the hand: A case series
[PMID: 11466644]

Karanas YL, Bogdan MA, Chang J: Community acquired methicillin
reports and clinical implications. J Hand Surg Am 2000;25:760. [P

Perron AD, Miller MD, Brady WJ: Orthopedic pitfalls in the ED: Fig

OSTEOARTHRITIS

Osteoarthritis is a slowly progressive polyarticular disorder of unkn
weight-bearing joints. Clinically, osteoarthritis is characterized by p
articular cartilage space loss, subchondral sclerosis, cyst formation
radiographic examination.

Epidemiologic Factors

The disease occurs commonly in older individuals, with approximat
radiographic evidence of osteoarthritis. The strongest predictors o
increasing age, and positive family history.

The most frequently involved joints in the hand are the distal inter
10–43), and proximal interphalangeal joints. The bony enlargemen

joint are referred to as Heberden nodes, whereas osteoarthritic en
as Bouchard nodes.

Figure 10–43.

Osteoarthritis of the carpometacarpal joint of the thumb.

Secondary osteoarthritis may develop in the hand as the result of
metabolic disorders.

Clinical Findings

Patients with osteoarthritis of the hand often complain of activity-i
periods of exacerbation and remission. Functional limitations result
Tenderness and enlargement of the distal and proximal interphalar
the thumb trapeziometacarpal with a circumduction motion (grind
subluxation of the thumb metacarpal on the trapezium may develo

Treatment

Nonoperative treatment includes oral nonsteroidal antiinflammator
injection, and splint immobilization.

The primary indication for surgery is pain unresponsive to oral me
relieves pain, corrects deformity, and resolves joint instability. Bec
stiff, the additional loss of motion occasioned by arthrodesis is usu
10–15 degrees of flexion, a position in which the fingernail is paral

At the proximal interphalangeal joint, pain is the primary indicatior
pain and retaining motion in the ring and little fingers. The motion
interphalangeal joints than in the metacarpophalangeal joints. Imp
finger proximal interphalangeal joint because of residual instability

Arthrodesis effectively relieves pain at the proximal interphalange
arthrodesis varies from the radial to the ulnar digits. The index-fin
degrees of flexion, the middle finger at 45 degrees, the ring finger

At the trapeziometacarpal joint, conservative treatment includes a
left free, cortisone injections, and NSAIDs. Many patients with adv
relief with conservative therapy.

The primary indication for surgery is persistent pain. Trapezium re
joint and allows retention of full metacarpal base motion. Either th
resected. A tendon interposition is created using either the flexor
tendon may be threaded through a drill hole in the articular surfac
remaining tendon is rolled into a so-called anchovy and placed in t
prevents impingement of the metacarpal on the scaphoid. After su
weeks.

Arthrodesis of the thumb carpometacarpal joint is an alternative to
lay their hand flat on a table. However, pain relief is excellent, and

RHEUMATOID ARTHRITIS

RA is a chronic inflammatory disease of unknown cause. The comb
periarticular tissues results in progressive joint destruction and de
two to three times more commonly affected than men.

Clinical Findings

Evaluation of the hand affected by RA requires care. The goal is to
weakness, or mechanical dysfunction—is most problematic. Evalua
as nerve compression symptoms. The most common nerve compre
the wrist and compression of the radial nerve at the elbow. The ap
the metacarpophalangeal joint may be disturbing aesthetically. Rh
are not treated unless associated with erosion, pain, or infection.

Treatment

The shoulder, elbow, forearm, wrist, and hand should be examined
of a functional upper extremity, not just a functional hand. Indicat
the progression of disease, improving function, and improving app

Surgical treatment may be classified as either preventive or correc
synovectomy. Corrective procedures include tendon transfers, nerv

Synovectomy is considered in patients who have pauciarticular per
Contraindications to synovectomy include rapidly progressive disea

destruction.

ELBOW RECONSTRUCTION

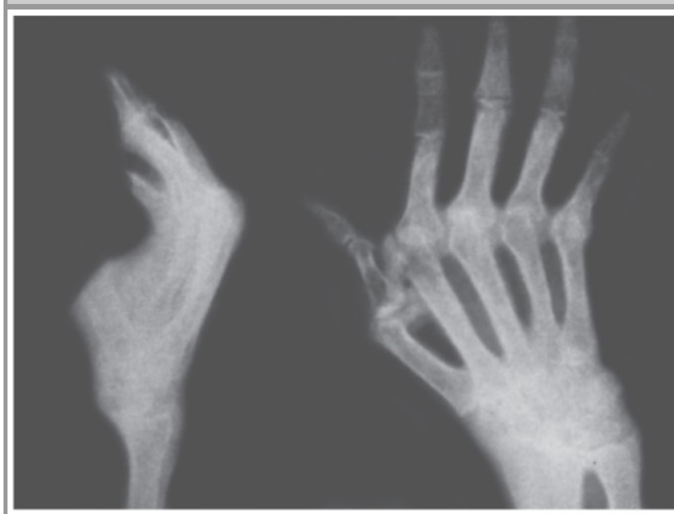
Synovitis of the elbow joint may cause pain, joint destruction, and
over the olecranon. Surgical treatment of the rheumatoid elbow in
progresses, consideration may be given to total elbow arthroplasty

WRIST RECONSTRUCTION

RA frequently involves the wrist and occurs in a predictable patter
the radiolunototriquetral ligaments are attenuated, permitting rota
is followed by radiocarpal collapse.

On the ulnar side of the wrist, the ulnar carpal ligaments become a
translates ulnarward. Attenuation of the distal radioulnar joint allo
ulnae syndrome. The extensor carpi ulnaris tendon displaces volar
radius, ulnar translocation of the carpus, and a concomitant radial
carpus may also dislocate volarly beneath the radius.

Figure 10–44.



Radialward displacement of the metacarpals in rheumatoid arthriti

Surgical treatment consists of extensor tenosynovectomy, with tra
reinforce the capsule, and wrist synovectomy. The extensor carpi u
position.

If pain is present over the distal ulna or if rupture of the little- or r
of the distal ulna, then resection of the distal ulna is performed. Fu
increase function. Either a total wrist arthrodesis or a radiolunate a
midcarpal joint involvement.

HAND RECONSTRUCTION

Triggering of the digits is a common problem caused by flexor ten
treatment of rheumatoid trigger digits. Loss of the A1 pulley increa
tenosynovectomy and excision of the ulnar slip of the sublimis ten

If flexor tendon rupture occurs, treatment may include tendon tra
most commonly ruptures is the flexor pollicis longus because it rub
scaphotrapezial joint (Mannerfelt lesion). Extensor tendon ruptures
the ring and little fingers over the distal ulna (Vaughn-Johnson syn

Treatment of the arthritic hand depends on the joints involved. Th
arthrodesis. At the proximal interphalangeal joint, synovectomy m
interphalangeal joint without multiple joint involvement. Alternativ

At the metacarpophalangeal joint, inflammation of the synovium m
of attenuation of the radial sagittal band. The mechanism may be
without significant destruction, synovectomy may be performed. W
arthroplasty is required (Figure 10–45). Subluxation and ulnar drif
satisfactory function of the hand remains. Arthroplasty does not in
its arc. Because most patients have severe flexion and ulnar devia
ROM, especially for grasping large objects. Because the implants f
only in the low-demand hand and is therefore better suited to rheu

Figure 10–45.

A B

A: Preoperative view of metacarpophalangeal joint in rheumatoid

BoutonnièRe Deformity

In addition to arthritis, various finger deformities occur related to
the most common is boutonnière deformity. Because of proximal i

elongated or ruptured, which allows the proximal interphalangeal j
lateral bands migrate below the proximal interphalangeal joint axis
than extensors. In addition to increasing the proximal interphalang
mechanism leads to distal interphalangeal joint hyperextension. Tr
correctable, consists of synovectomy and splinting. Lateral band re
to the axis of rotation. Alternatively, tenotomy of the terminal slip
and prevent hyperextension of the distal interphalangeal joint. On
occurs (30- to 40-degree flexion deformity, with a flexible joint an
to reconstruction of the central slip as well as lateral band reconst
boutonnière deformity, the joint deformity becomes fixed, and the

Swan-Neck Deformity

Swan-neck deformities consist of hyperextension at the proximal i
joint. The mechanism of swan-neck deformity is terminal tendon r
proximal interphalangeal joint resulting from overpulling of the cer
caused by laxity of the volar plate, rupture of the flexor digitorum
these mechanisms is intrinsic tightness secondary to metacarpoph

Swan-neck deformities are divided into four stages. In stage 1, th
splinting, distal interphalangeal joint fusion, or soft-tissue reconstr
In stage 2, proximal interphalangeal flexion is limited because of i
reconstruction of the metacarpophalangeal joint may be of benefit
in all positions, yet the joint is still preserved. Mobilization of the l
4, the proximal interphalangeal joint is arthritic. Either proximal in
considered for stage 4 joint destruction.

Synovitic Metacarpophalangeal Joint Deformity

The metacarpophalangeal joints subluxes volarly and ulnarly in RA
collateral ligaments with secondary laxity, volar and ulnar forces th
forces by radial deviation of the wrist, attenuation of the radial sa
tendon), and contracture of the intrinsic muscles. Treatment of th
management and splinting. When the joint space is preserved, su
moderate joint destruction or volar subluxation and ulnar deviatio
of the hand. When the patient is still able to use the hand for activ
provided. Once loss of function is noted, metacarpophalangeal art
arthroplasty, the wrist deformity should first be corrected, and all
should be performed. The radial collateral ligament of the index fi
be relocated. Postoperatively, extensive splinting and therapy are
an outrigger splint holding the wrist in dorsiflexion and the metap
alignment. The splint is worn full time for 6 weeks and part time f
for 1 year.

THUMB RECONSTRUCTION

Three patterns of rheumatoid thumb deformities are defined. In ty
the interphalangeal joint is hyperextended and the thumb metacar
carpometacarpal subluxation leads to metacarpal adduction. In typ
develops with metacarpophalangeal flexion, and in type 3 deformit
interphalangeal joint is flexed. Type 2 deformities are unusual. Typ
metacarpophalangeal joint, leading to attenuation of the extensor
and volar displacement of the extensor pollicis longus.

Treatment is based on the degree of progression. In type 1 deform
are passively correctable, synovectomy and extensor reconstructic
flexion deformity is fixed, arthrodesis or arthroplasty of the joint is
interphalangeal extension deformities are present simultaneously,
metacarpophalangeal joint is replaced with an arthroplasty or also

Type 3 deformities are analogous to swan-neck deformities of the
radial subluxation of the joint, with secondary adduction contractic
metacarpophalangeal joint. Treatment with minimal metacarpopha
metacarpophalangeal deformity (stage 2) consists of splinting and
metacarpophalangeal deformity becomes fixed (stage 3), first web

SURGICAL PRIORITIES

When multilevel deformity is present, consideration should be give
deformities are both present, the wrist should be fused prior to or
reconstruction. When both metacarpophalangeal and proximal inte
procedures such as arthroplasty should be carried out at the meta
interphalangeal joint involvement depends on the stage of deformi
deformities can either be ignored or treated by closed manipulatio
proximal interphalangeal joint should be performed.

In all cases, attempts should be made to perform multiple procedu
numerous operations for multiple joints of the upper and lower ext
judiciously.

Other Inflammatory Arthritides

Other inflammatory conditions related to RA may affect the hand,

JUVENILE RHEUMATOID ARTHRITIS

In juvenile rheumatoid arthritis (JRA), early epiphyseal closure occ
flow. Narrowing of phalangeal and metacarpal medullary canals ma
joints may deviate radially rather than ulnarly.

ARTHRITIS MUTILANS

In arthritis mutilans, axial shortening because of marked bone loss
joint fusion is required to avoid progressive bone loss.

SYSTEMIC LUPUS ERYTHEMATOSUS

Systemic lupus erythematosus (SLE) affects periarticular soft tissu
Synovitis is minimal in lupus, and therefore the articular cartilage
joint fusions are preferable to restore stability and function. The e
implant arthroplasty may be appropriate, even though normal arti

PSORIATIC ARTHRITIS

Psoriatic arthritis presents deformities similar to that of RA. The h
arthritis, the metacarpophalangeal joints become stiff in extension

Davis TR, Brady O, Dias JJ: Excision of the trapezium for osteoartl
of ligament reconstruction or tendon interposition. J Hand Surg An

Day CS et al: Basal joint osteoarthritis of the thumb: A prospectiv
2004;29:247. [PMID: 15043897]

Fulton DB, Stern PJ: Trapeziometacarpal arthrodesis in primary os
Surg Am 2001;26:109. [PMID: 11172376]

Jain A et al: Influence of steroids and methotrexate on wound com
Hand Surg Am 2002;27:449. [PMID: 12015719]

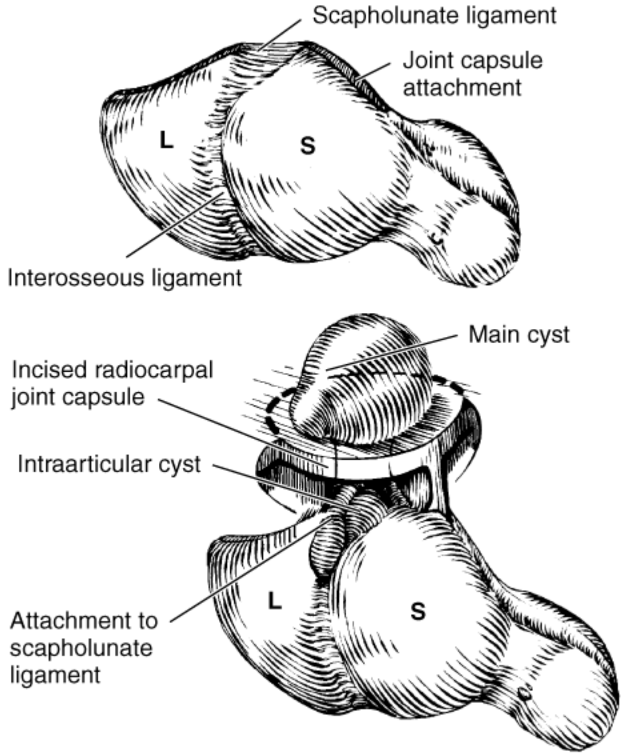
HAND TUMORS

Nearly all mass lesions in the hand or wrist are benign conditions.
neuromas are usually related to prior trauma. Ganglions and fibro

Ganglion

Ganglions are the most common soft-tissue tumors of the hand an
but without a synovial or epithelial lining. In most cases, a stalk ca
adjacent joint or tendon sheath. The most common locations for g
interphalangeal joint (Figure 10–46).

Figure 10–46.



The ganglion and scapholunate attachments are isolated from the
(Reproduced, with permission, from Green DP, ed: *Operative Hanc*

DORSAL WRIST GANGLION

Dorsal wrist ganglions arise from the dorsal capsule of the scaphol
palpable but highly symptomatic, whereas large ganglions are ofte
injection may provide transient symptomatic relief, but recurrence
with expectation of cure if care is taken to excise the stalk of the l
these lesions arise from the dorsal portion of the scapholunate liga
integrity to avoid an iatrogenic scapholunate dissociation.

PALMAR WRIST GANGLION

Palmar wrist ganglions present as swellings on the palmar radial a
arise from either the palmar radioscaphoid or palmar scaphotrape
requires mobilization and protection of the adjacent radial artery.

FLEXOR SHEATH GANGLION

Flexor sheath ganglions present as firm mass lesions over the palr
3 and 8 mm in diameter and often so firm that it is presumed to b
accomplished with aspiration or excision.

MUCOUS CYST

Mucous cysts are ganglions arising from the distal interphalangeal
ulnar side of the extensor terminal tendon. Surgical excision requi

thinned, a local rotation flap is required for soft-tissue coverage af

FIBROXANTHOMA

Fibroxanthomas are also known as giant cell tumors of tendon she firm lesions are usually painless, often arising from an interphalan often on the palmar aspect of the hand or finger. Surgical resectio displaced, compressed, or encircled by a fibroxanthoma.

EPIDERMOID INCLUSION CYST

Epidermoid inclusion cysts are usually the result of previous traum Epidermal cells become embedded in the subcutaneous tissue, gra becomes noticeable, particularly when it is located over the palmar mass without rupture.

FOREIGN BODIES

Foreign bodies may act as a nidus, inciting the development of a s a local inflammatory reaction or frank infection. Treatment consist

NEUROMAS

Neuromas, the bulbous enlargement of the distal end of a severed Neuromas are inevitable in all amputations of the hand. If the neu of the transected nerve is in an area of palmar pulp contact, the le include neuroma revision or transposition of the neuroma to a loca

CONGENITAL DIFFERENCES

Congenital hand differences occur in approximately 1 in 1500 live terms *abnormality, anomaly,* or *malformation.* Many congenital ha syndrome. The abnormality may suggest that other regions of the with bilateral total absence of the radius and normal or very mildly absent radius (TAR) syndrome should be considered and a platelet the VATER association, children with abnormalities that may includ

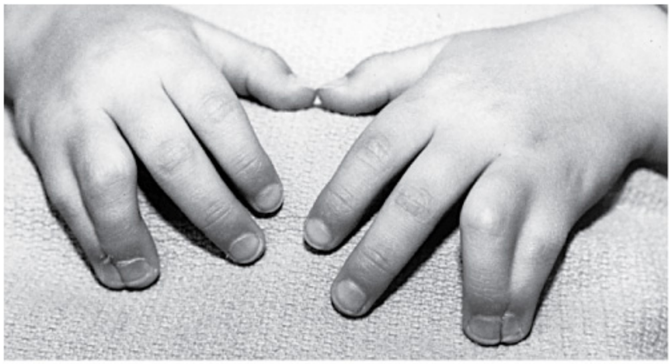
A number of frequently encountered conditions such as cleft hand an experienced geneticist is invaluable in providing counsel to fam know the likelihood that their offspring would be affected by the d

The two most commonly encountered conditions are syndactyly an common, and in African American populations, polydactyly is the m

Syndactyly

Syndactyly, the webbing together of digits, is simple if soft tissue (Figure 10–47). Surgical release of syndactyly requires the use of to partially surface the adjacent sides of the separated digits. Resi covered with full-thickness skin grafts. Surgery is indicated when t the fingers and the webbing prohibits full use of the fingers. Surge

Figure 10–47.



Bilateral complex syndactyly of the ring and little fingers.

Polydactyly

Radial polydactyly is usually manifest as thumb duplication. When
both normal in size, alignment, and mobility (Figure 10–48). The r
the more radial thumb component. The level of bifurcation varies f
possessing a metacarpal and a proximal and distal phalanx. In the
metacarpal supports two proximal phalanges, each of which suppo
of elements of both component digits. Usually the ulnar thumb is r
metacarpophalangeal joint, the radial collateral ligament is preserv
of the ulnar thumb. Surgery is usually performed at 6–12 months
usually be treated by simple excision.

Figure 10–48.

Thumb polydactyly.

Partial or Absent Structures

Absence or partial deficiency of the radius results in inadequate su angulates radially. Stretching of contracted radial soft-tissue struct splinting, or distraction lengthening. The hand is then surgically re procedure.

Mild hypoplasia of the thumb is treated by release of the first web and opponensplasty tendon transfer. More severe hypoplasia or ab index finger. This procedure shifts the index finger to the thumb p tendons as well as the dorsal and palmar interosseous tendons to

McCarroll HR: Congenital anomalies: A 25-year overview. J Hand S

Giele H et al: The incidence and epidemiology of congenital upper 2001;26:628. [PMID: 11466636]

PEDIATRIC ORTHOPEDIC SURGERY: INTRODUCTION

The scope of pediatric orthopedics ranges from congenital anomali
the more independent relationship the physician may form with ar

Guidelines for Pediatric Orthopedics

The following rules may be helpful when applying general orthope

1. A growing bone normally tends to remodel itself toward the adult configuration.
2. Skeletal deformities worsen as abnormal growth continues (eg, following perman
3. Children tolerate long-term immobilization better than adults and tend to recove
4. Fracture healing is usually more rapid and predictable in the actively growing ske
5. Joint surfaces in children are generally more tolerant of irregularity than those o
6. Many so-called deformities, such as metatarsus adductus, internal tibial torsion,

GROWTH DISORDERS

General skeletal growth is discussed in detail in Chapter 1.

Limb-Length Inequality

Limb-length inequality may reflect either a congenital deficiency or
function and require treatment. Lesser discrepancies can be mana

Table 11–1. Causes of Limb-Length Inequality.

Infectious causes	Osteomyelitis	Septic arthritis	Neoplastic causes

Treatment

CALCULATION OF LIMB LENGTH AT MATURITY

Clinical management of limb-length inequality in pediatric patients
10–12 mm/year and 5–6 mm/year, respectively, with growth conti

SURGICAL TREATMENT

Epiphysiodesis

The simplest surgical procedure to treat pediatric bone-length disc
they are rapidly growing and easily accessible surgically. The rema
still be growing and that accurate data be collected on this growth

Femoral Shortening

If a child reaches the age when bone growth is insufficient to mak
introduced through a buttock incision for fixation. A cylindrical seg

Other Techniques

Leg-length inequalities projected to be 6 cm or more generally do
children (see Chapter 1).

Anderson M et al: Growth and predictions of growth in the lower e

Birch JG, Samchukov ML: Use of the Ilizarov method to correct lo

Little DG et al: A simple calculation for the timing of epiphysiodesi

Moseley CF: Assessment and prediction in leg-length discrepancy.

Surdam JW, Morris CD, DeWeese JD et al: Leg length inequality ar

Dwarfism & Other Disorders of Growth

Orthopedic disorders (achondroplasia, multiple epiphyseal dysplasi
some of these conditions and the major orthopedic problems asso

Table 11–2. Orthopedic Involvement in Selected Synd

Achondroplasia	Short limbs; genu varum; exaggerated lumbar lordosis; spinal stenosis; ligamentous laxity	Apert syndrome	Foot deformities; hand and foot polydactyly	Arthrogyposis	jo st co ar di re cl

INFECTIOUS PROCESSES

Hematogenous Osteomyelitis

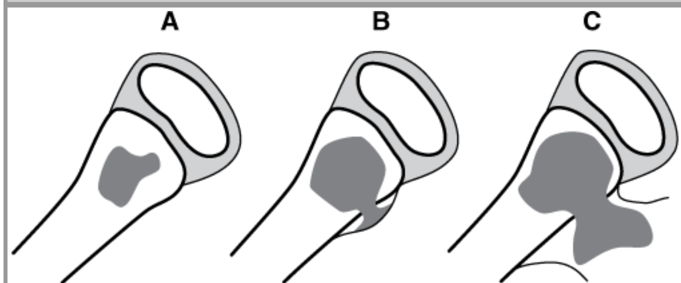
Osteomyelitis, an infection of bone tissue, usually occurs in the ma
may resemble other serious bacterial infections in children (Table 1

Table 11–3. Common Pathogens in Pediatric Bone and			
Osteomyelitis	Group A *Streptococcus*	*Salmonella* (with sickle cell)	*Staphylococ aureus*

Clinical Findings

Acute bacterial hematogenous osteomyelitis usually occurs in the r
extreme vascularity. The pressure of the pus beneath the richly in

Figure 11–1.



Hematogenous osteomyelitis in children. Cellulitic phase (**A**) can e

The accumulated purulence in the marrow cavity and under the pe

The elevated periosteum responds to infection by producing a shel

Pain and tenderness at the infection site are universal signs, limpi
occasionally bone scans or MRI may be required to help localize le

Treatment

EARLY TREATMENT

Treatment depends on the duration of symptoms and findings on r
of cultures may be negative despite other clear evidence of bacter

TREATMENT FOR ADVANCED INFECTION

In advanced cases, lytic defects or osteoporosis may be present, a
month prolonged regimen of oral antibiotics minimizes the possibil

Hamdy RC et al: Subacute hematogenous osteomyelitis: Are biops

Scott RJ et al: Acute osteomyelitis in children: A review of 116 cas

Septic Joint

Septic arthritis in children, like osteomyelitis, usually is hematoger

Clinical Findings

The classic septic joint in a child presents a dramatic picture: The

Although white blood cell counts and the ESR are usually elevated,

Synovial white blood cell counts range from 50,000/µL (in nonpyog can initially be based on results of Gram staining. In addition, imm

Treatment

Treatment always includes drainage of the joint. In easily accessib

Antibiotics easily cross the synovial membrane and are continued u

Darville T, Jacobs RF: Management of acute hematogenous osteon

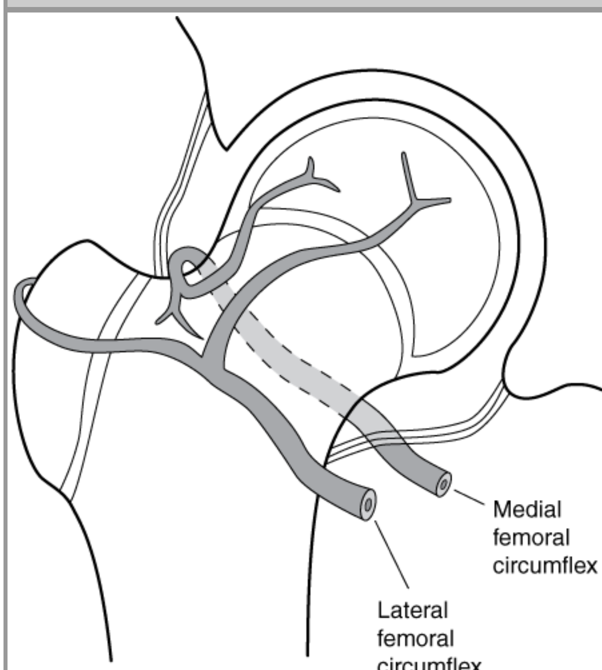
Kim HKW et al: A shortened course of parenteral antibiotic therap

Septic Hip

Septic hip is one of the true surgical emergencies in pediatric orth

Because of the unique structure and blood supply of this joint (Fig always requires surgical drainage. Delay of even 4–6 hours may co

Figure 11–2.



The blood supply of the proximal femur is unusual because the ca

Septic hip in a growing child is also a special orthopedic case becau

A common clinical problem is the differentiation between septic an

Table 11–4. Clinical Differential Diagnosis of Inflamm

	Septic Hip	Transient Synovitis of Hip	Juvenile Arthritis of Hip	
Pain	Severe	Moderate–severe	Moderate	Ga

WBC = white blood cells.

Kocher MS, Mandiga R, Zurakowski D et al: Validation of a clinical

Puncture Wounds of the Foot

Sneakers and tennis shoes offer little protection from nail puncture

The symptoms of infection include redness, swelling, and pain that deep infection.

Eidelman M et al: Plantar puncture wounds in children: Analysis of

Skeletal Tuberculosis

As in the adult, *Mycobacteria* organisms may invade the pediatric the child is immunosuppressed.

Clinical Findings

Hip involvement is characterized by a chronic limp associated with

Spine involvement may include paraspinal abscess (best visualized

Treatment

Treatment of skeletal tuberculosis consists of combination chemoth

Teo HE, Peh WC: Skeletal tuberculosis in children. Pediatr Radiol 2

Diskitis in Children

Diskitis is a low-grade inflammatory process involving the interver walk; pain is not a prominent symptom in this age group. Older ch

Clinical Findings

Small children may have limitation of passive hyperextension of th to 40% of patients. Radiographs at first are normal but eventually

Treatment

Management depends on the severity of clinical findings because a
required for symptom relief. Long-term outcome is universally fav

Early SD, Kay RM, Tolo VT: Childhood diskitis. J Am Acad Orthop S

METABOLIC DISORDERS

Rickets & Rickets-Like Conditions

Nutritional rickets is a dietary deficiency of vitamin D that interfer

Renal Osteodystrophy

Renal osteodystrophy, a disorder of calcium, phosphorus, vitamin

Osteoporosis, leading to compression fractures of the spine, is a c
only after transplantation or other improvement in renal status. O

Hypophosphatemic Rickets

Hypophosphatemic rickets (vitamin D–resistant rickets) is an domi

The medical history usually discloses a parent or sibling with short

Figure 11–3.

Hypophosphatemic rickets. Radiographs demonstrate bowing of lo

Medical treatment with megadoses of vitamin D and phosphorus s
possible.

Saland JM: Osseous complications of pediatric transplantation. Pec

Santos F et al: Alterations of the growth plate in chronic renal failu

HIP DISORDERS

Transient Synovitis of the Hip

Transient synovitis of the hip is a benign, nontraumatic, self-limite

Although the cause of transient synovitis is unclear, evidence sugg

Clinical Findings

As with septic hip, upper respiratory tract infections often precede
passive movement.

Radiographs reveal only capsular swelling, and effusion may be de

Although experienced physicians frequently suspect transient sync

Treatment

Treatment of transient synovitis includes simple analgesics and spl

The early stages of Legg-Calvé-Perthes disease (see section on Le
synovitis, the children are a bit older (older than 4–5 years), and t

Luhmann SJ et al: Differentiation between septic arthritis and tran

Developmental Dysplasia of the Hip

Developmental dysplasia of the hip is one of the most serious prob
may cause excess stretching of the posterior hip capsule, which re

This relative instability may lead to asymptomatic subluxation (par
superior acetabular rim and medial femoral head (*dysplasia* is the

In the completely dislocated hip, dysplasia also occurs because nor

Developmental dysplasia of the hip (DDH) occurs in approximately
cesarean delivery), female gender, large fetal size, and first-born s

Clinical Findings

Reversal of dysplasia and subsequent normal hip development dep

Radiographs are usually not useful in newborn infants because the
at each well-infant check until the child is walking normally. A high

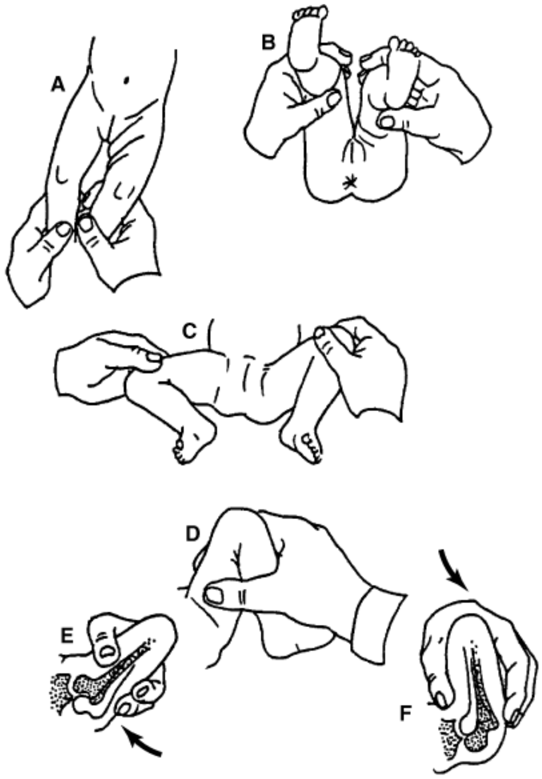
TESTS FOR DYSPLASIA

Several examination maneuvers require a quiet, relaxed infant anc

Asymmetric Skin Folds

A dislocated hip displaces proximally, causing the leg to be margin

Figure 11–4.



Clinical examination of developmental dislocation of the hip. In all

Galeazzi Test

With the child lying on a flat surface, flex the hips and knees so th
bilateral.

Passive Hip Abduction

The flexed hips are gently abducted as far as possible (Figure 11–
dislocated), the abduction test is normal despite the presence of s

Barlow Test

A provocative test that picks up an unstable but located hip, the B
11–4D, F). Detection of so-called pistoning, or the sensation of the

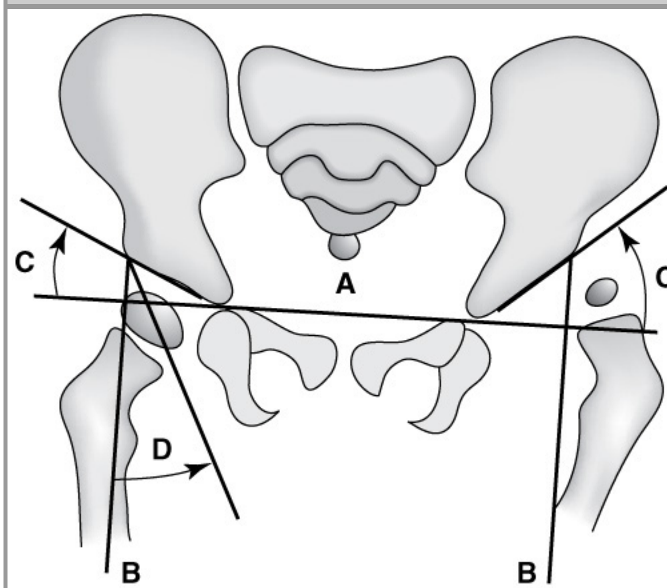
Ortolani Test

This test detects hips that are already dislocated. The flexed limb
The Ortolani test may be negative at 2–3 months of age, even wh

IMAGING STUDIES

In the infant, diagnosis is made by physical examination alone, an
prior to 6–10 weeks of age. Radiographs may be used at any age,
estimates of geometric parameters (Figure 11–5). These may sug

Figure 11–5.



Lines drawn for measurement in developmental dysplasia of the h
line) drawn down from the lateral edge of the acetabulum. The fe
depth and should be below 30 degrees by 1 year of age and belov

Increased femoral anteversion (external rotation of the femoral he

DETECTION OF DYSPLASIA IN THE OLDER CHILD

As the infant grows older, many diagnostic maneuvers that are po
signs of developmental dysplasia may then not be recognized until

Treatment

Treatment of DDH should be initiated as soon as the diagnosis is s
treatment plan. The current recommendations described next.

AGE 0–6 MONTHS

A dislocated hip at this age may spontaneously reduce over 2–3 w
spontaneous reduction and stabilization of the hip. The Pavlik harn

Figure 11–6.

The Pavlik harness, a device used for treatment of hip dislocation,

AGE 6–15 MONTHS (BEFORE WALKING)

Gentle manipulative reduction of the dislocation under a general a
adequate hip flexion and limited abduction in the spica cast is the

AGE 15 MONTHS TO 2 YEARS

In toddlers or young children in whom closed reduction failed, ope
acetabulum must be removed. Femoral shortening osteotomy may
that accompanies untreated dysplasia in this group of children.

AGE OLDER THAN 2 YEARS

Significant residual dysplasia is present in children with DDH who a
femoral head.

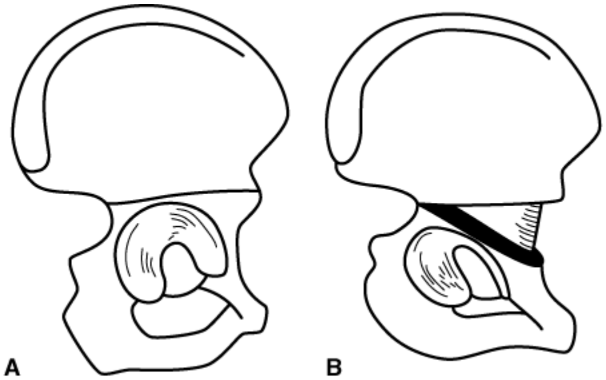
Surgical correction of dysplasia creates a stable mechanical enviro
stability of the joint.

Femoral osteotomy corrects the anteversion and femoral neck valg
correct the dysplasia. In general, the osteotomy should address th
more stable, thus allowing the normal mechanisms of growth to ta

Salter Osteotomy

Salter osteotomy is a surgical procedure to redirect the acetabulur

Figure 11–7.



Salter innominate osteotomy, used for managing acetabular dyspl

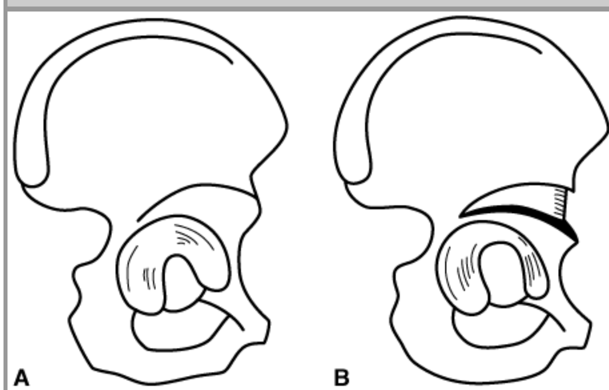
The procedure is indicated in children 18 months to 10 years of ag made, using a wire saw, from the sciatic notch to the anteroinferic weeks to protect the graft during healing.

Salter osteotomy requires a second operation to remove the fixati

Pemberton Osteotomy

Indications for the Pemberton osteotomy (Figure 11–8) are similar is done by cutting above the acetabular roof, down to the flexible children, this quickly remodels, but it is the major reason many su

Figure 11–8.



Pemberton pericapsular iliac osteotomy. An osteotomy cut is made

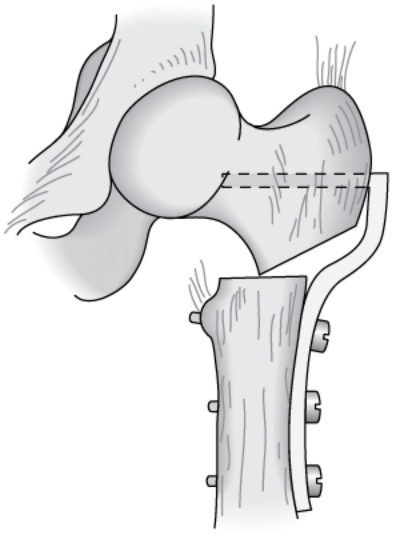
Like the Salter procedure, Pemberton osteotomy requires concentr allows the fragment to be hinged down over the femoral head, pro

Rarely, early extrusion or graft collapse occurs, and transient stiffr

Femoral Osteotomy

Femoral osteotomy (Figure 11–9) may be used to correct severe i

Figure 11–9.



Femoral osteotomy is performed at the intertrochanteric level and

The procedure is particularly indicated when radiographs taken wit

Femoral osteotomy is performed using a lateral approach, with the
The femoral neck fragment is rotated into a more horizontal positi
screws. A spica cast is usually used to supplement fixation.

After healing (6 weeks), the patient may resume walking. A Trend

Avascular Necrosis of the Hip

If a reduction maneuver for DDH was forceful or if there is tension
A well-recognized cause of avascular necrosis is exaggerated force
growth at the proximal physis. As it revascularizes, a dead femora

Lehmann HP, Hinton R, Morello P et al: Developmental dysplasia o

Weinstein SL, Mubarak SJ, Wenger DR: Developmental hip dysplas

Legg-Calvé-Perthes Disease

Legg-Calvé-Perthes disease (LCP, Perthes disease) is a serious but
The disease is generally unilateral. If it is bilateral, other condition
considered a causative factor in LCP.

Although early radiographs may be negative, they eventually show
corresponding to areas of necrosis, and MRI is typical of avascular
dead trabeculae (a process known as creeping substitution). Durin

Figure 11–10.

Legg-Calvé-Perthes disease. **A:** Central necrotic fragment with col

At this point, continued growth may allow gradual remodeling and

Clinical Findings and Classification

SYMPTOMS AND SIGNS

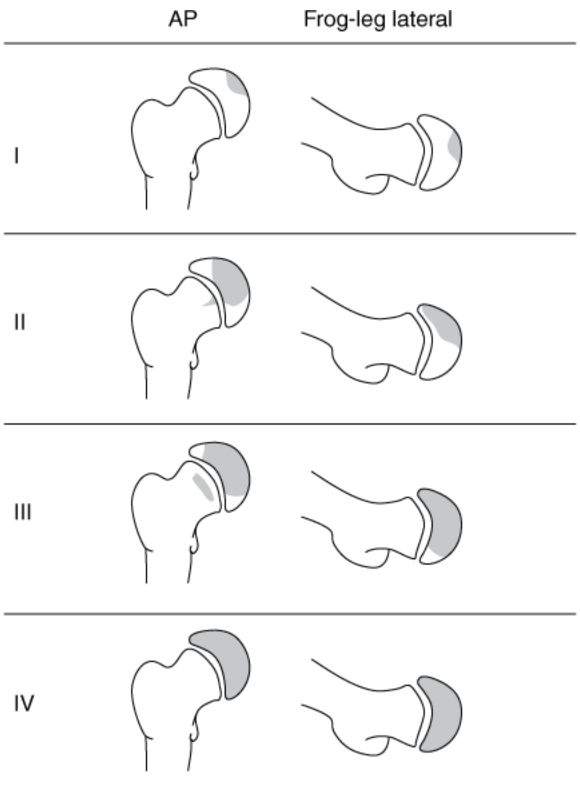
The clinical presentation of LCP in a child 4–10 years of age is usu severe cases, no abduction beyond 0 degrees), and loss of interna

IMAGING STUDIES

Radiographs may be negative at first, probably because the initial

The exact extent of necrosis, which is usually estimated in fourths

Figure 11–11.



The Catterall classification is used to determine probable course a

An alternative radiograph classification uses the lateral third of the
and the need to delay until the collapse phase before the exact ex

There is little value in bone scans or MRI in the clinical manageme

Treatment Options

NO TREATMENT

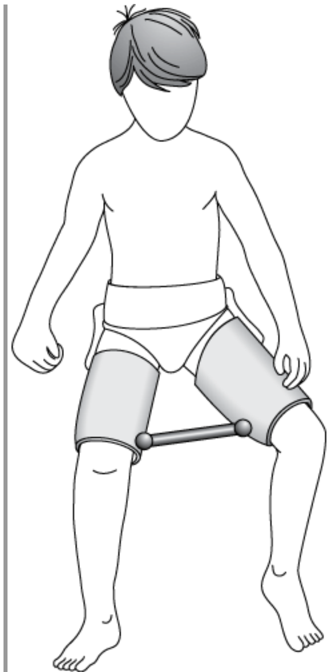
Children with bone age less than 5 years and children who exhibit
and minor collapse can be outgrown before maturity. Older childre

NONOPERATIVE AND OPERATIVE TREATMENT

The issues surrounding selection of patients with LCP who need tre
loss of abduction, treatment is frequently recommended.

No evidence indicates that use of crutches or relief of weight beari
acetabular shape is thought to help improve the contour of the col

Figure 11–12.



Abduction bracing is one method used for ambulatory treatment c

Operative procedures are advocated by some and include varus fe

Despite many studies, there is still no consensus for the best meth

Table 11–5. Factors in Long-Term Prognosis for Patie

Relative Prognosis	Good	Poor		
Age at diagnosis	< 5 years	> 8–9 years	Hip motion[a]	Maintained

[a]During first year of treatment.

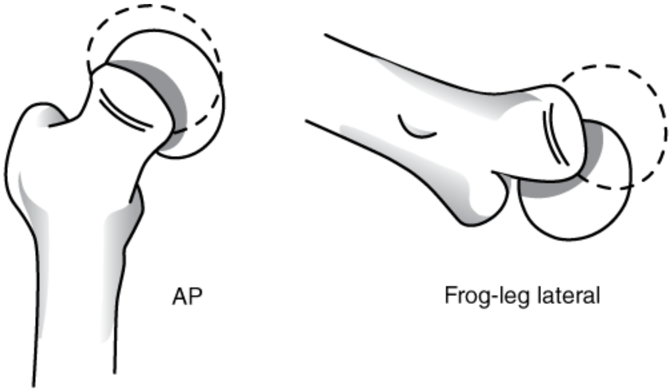
Balasa VV, Gruppo RA, Glueck CJ et al: Legg-Calve-Perthes diseas

Herring JA, Kim HT, Browne R: Legg-Calve-Perthes disease. Part I

Slipped Capital Femoral Epiphysis

Slipped capital femoral epiphysis is an adolescent hip disorder cha

Figure 11–13.



Anteroposterior (AP) and frog-leg views of a slipped epiphysis. Th

Slipped capital femoral epiphysis usually affects both male and fen

This disorder occurs at a time when the cartilage physis of the pro
and subject to shear), lack of sexual maturity (which would stabiliz

The direction of the slip is always posterior and often medial, and
condition that can be superimposed on chronic changes. Displacem

Because slipped capital femoral epiphysis is a progressive disorder

Clinical Findings

SYMPTOMS AND SIGNS

The onset of chronic slipped capital femoral epiphysis is usually ins
examination and radiographs. A high index of suspicion is required
characteristic obligatory external rotation of the hip when it is flex

Acute slipped capital femoral epiphysis is accompanied by severe p
high rate of avascular necrosis. In its stable form, the sudden incr

IMAGING STUDIES

Slipped capital femoral epiphysis can be difficult to detect on stand

Figure 11–14.

A

B

Radiograph diagnosis of left slipped capital femoral epiphysis. **A:** A
displacement.

Establishing the severity of slippage is important in determining tr

Treatment

Slipped capital femoral epiphysis is usually a progressive disease t
across the growth plate, regardless of the severity of the slip (pinr

Following surgery, aching rapidly resolves, and during the remainir

Acute slips, if unstable, may be gently reduced before fixation, but

In some cases, high-grade slipped capital femoral epiphysis does r
osteotomy can be performed at the trochanteric level; this is a saf

Complications

CHONDROLYSIS

In addition to the problems of impingement of the anterior metapł

During chondrolysis, cartilage is replaced by fibrous tissue, the joi

Chondrolysis can result from iatrogenic malposition (permanent pe
detected in patients before treatment begins.

Chondrolysis is treated by nonsteroidal antiinflammatory medicatic

AVASCULAR NECROSIS

Patients with an acutely slipped capital femoral epiphysis can deve
may be treatable by intertrochanteric osteotomy to reorient the ar

PROGNOSIS

A slipped epiphysis is a major cause of early osteoarthritis. In gen
recognized.

Loder RT, Greenfield ML: Clinical characteristics of children with at

Perron AD, Miller MD, Brady WJ: Orthopedic pitfalls in the ED: Slip

Tokmakova KP, Stanton RP, Mason DE: Factors influencing the dev

FOOT DISORDERS

Metatarsus Adductus

Metatarsus adductus (metatarsus varus) is the most common foot
packing.

Clinical Findings

The hallmark of metatarsus adductus is medial deviation of the for
is fairly rigid. When the examining physician places a hand on the

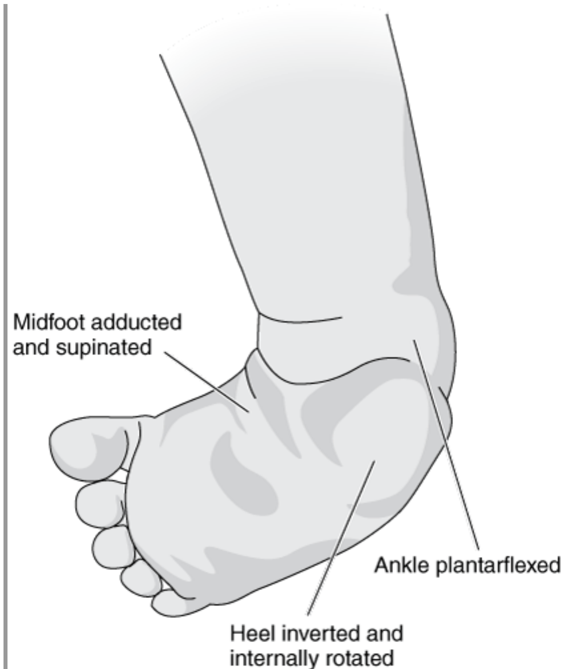
Treatment

Metatarsus adductus tends to be self-correcting. Even severe case
casting is frequent in young children, however, and treatment for

Congenital Clubfoot

Congenital clubfoot (equinovarus foot; talipes equinovarus) is a se
medial and plantar midfoot crease. Whether unilateral or bilateral,

Figure 11–15.



Clinical appearance of congenital right clubfoot.

The incidence in the newborn population is 1 in 1000, with increas
may frequently be present in association with a wide variety of syı

Clinical Findings

SYMPTOMS AND SIGNS

Clinical diagnosis of clubfoot is uncomplicated. Because it is a rigid
palpate. Clubfoot is always associated with a permanent decrease

Special attention should be paid to the presence of spine deformity

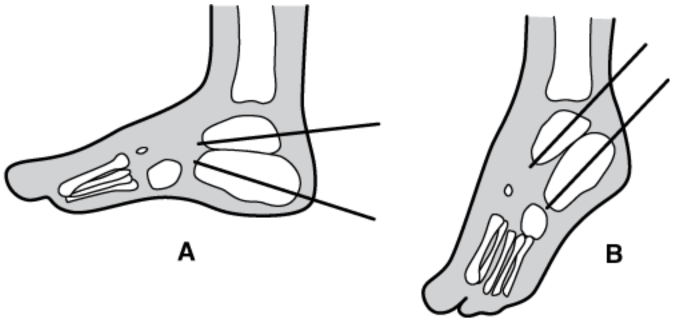
IMAGING STUDIES

Increasingly, clubfoot is suspected from prenatal ultrasound exami
correction achieved by casting or surgery.

The typical radiographic findings of incompletely treated clubfoot iı

1. presence of hindfoot plantar flexion;
2. lack of the normal angular relationship between the talus and calcaneus (so-calle
3. residual medial subluxation or displacement of the navicular on the talus and the

Figure 11–16.



Diagrammatic appearance of radiograph in clubfoot. **A:** Normal fo

Treatment

CONSERVATIVE TREATMENT

Clubfoot always requires treatment, which should begin at birth. T
adhesive tape) or splinting with a variety of braces are popular me
lengthening needs to be done at 4 weeks or later to facilitate cast

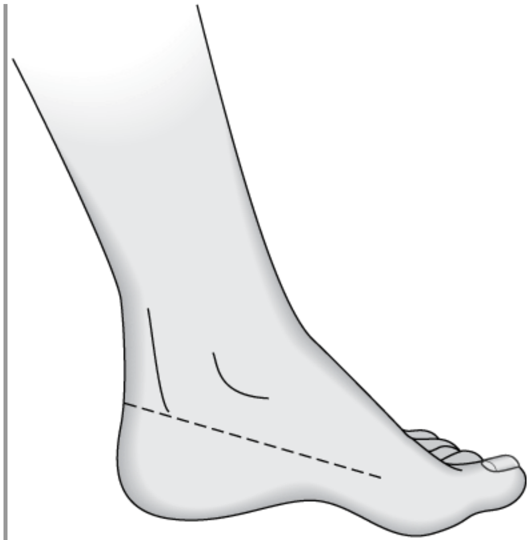
The combination of careful casting and limited release allows most
the joints are carefully held in a corrected position during growth,
damaging compressive forces on delicate cartilaginous anlages of t
particularly in girls (where the deformity is often more severe) and

SURGICAL TREATMENT

Surgical correction of all clubfoot deformities is generally performe
approach.

One common approach uses the so-called Cincinnati incision, which
and Achilles tendon are Z-lengthened. The capsules of the talonav

Figure 11–17.



Cincinnati incision used for surgical correction of clubfoot.

The navicular is usually subluxated medially on the head of the tal
wires, which are removed after 4–6 weeks.

The ankle is repositioned by dorsiflexion to neutral prior to repair (

COMPLICATIONS

Early complications of clubfoot surgery are rare, but the rate of re
expectations about the outcome.

If surgical release is too aggressive, overcorrection with late heel v

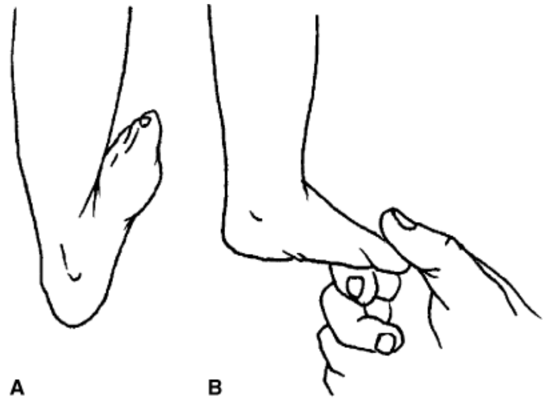
Dobbs MB, Morcuende JA, Gurnett CA et al: Treatment of idiopath

Herzenberg JE, Radler C, Bor N: Ponseti versus traditional method

Calcaneovalgus Foot

Calcaneovalgus foot is generally considered a uterine-packing prob
not allow ankle plantar flexion beyond a right angle.

Figure 11–18.



Calcaneovalgus foot as it appears in relaxed position (**A**) and max

Despite its dramatic appearance, calcaneovalgus foot corrects spo

Congenital Vertical Talus

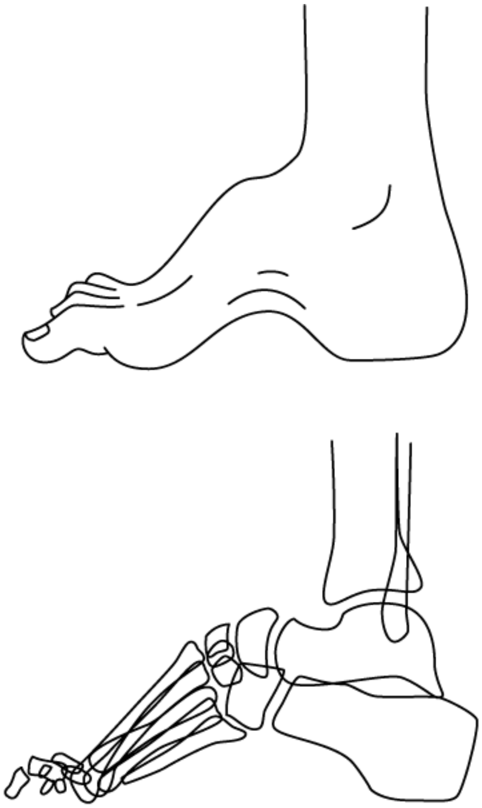
Calcaneovalgus foot must be differentiated from a much rarer con
hindfoot and dorsiflexion of the forefoot, the midfoot joints (talona

Congenital vertical talus often accompanies genetic disorders, syn

Cavus Foot

Cavus foot is a foot with an abnormally high arch. Although it is di

Figure 11–19.



Cavus foot: clinical appearance and radiographic appearance.

Cavus foot frequently accompanies hindfoot varus deformity (cavo

Clinical Findings

One of the most common symptoms of cavus foot is anterior ankle
leading to anterior ankle impingement and pain. The inability to do

The cause of cavus foot is usually muscle imbalance in a growing f
condition.

Cavus foot is a marker for neuromuscular disease. Diagnosis requi

Table 11–6. Common Neuromuscular Causes of Cavus		
Cerebral palsy	Charcot-Marie-Tooth disease	Compartment syndrom

Treatment

Conservative treatment of cavus foot includes accommodation by s

Schwend RM, Drennan JC: Cavus foot deformity in children. J Am

Pes Planus (Flatfoot)

Flatfoot refers to loss of the normal longitudinal arch of the medial
the deformity is often overemphasized.

Clinical Findings

Physical determination of the flexibility of the flatfoot requires care
alternative diagnoses such as tarsal coalition (see section on tarsa

Standing radiographs disclose loss of the normal medial longitudin

Treatment

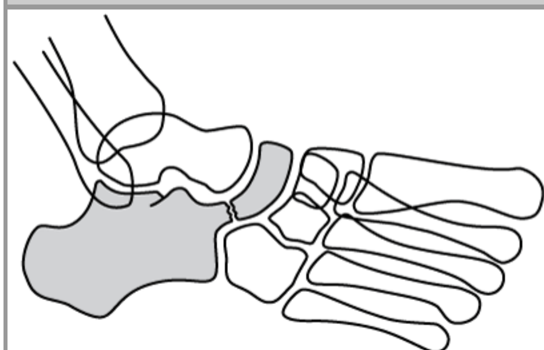
Symptomatic treatment (shoe modifications, arch supports, and pl

Tarsal Coalition

Tarsal coalition is a congenital connection between two or more tar

The most common sites for tarsal coalition are between the calcan

Figure 11–20.



Calcaneonavicular tarsal coalition is best seen on oblique radiogra

Clinical Findings

Symptoms of tarsal coalition may include foot pain and stiffness as
protectively overactive. As the lesion matures, pain may diminish l

This diagnosis should be suspected in adolescents with foot pain, v

Treatment

Not all coalitions require treatment. The decision to initiate treatm
or deformity, hindfoot fusion by triple arthrodesis is effective treat

Harris EJ, Vanore JV, Thomas JL et al: Clinical Practice Guideline Pe

Toe Deformities

Toe deformities occur as isolated conditions, in association with sin

Simple Syndactyly

Simple syndactyly, a connection of two or more toes, is the most c

Acrosyndactyly

Acrosyndactyly is joining of the tip of two or more toes distally wit

In the hand, acrosyndactyly interferes with independent finger fun

Polydactyly

Polydactyly is the presence of more than five digits on either the h
often accompany genetic syndromes and should prompt the physic

Constriction Bands (Amniotic Bands)

During gestation, protein-laden amniotic material can condense ar
simple syndactyly in that the distal, rather than proximal, web is c

Constriction bands may be very deep and circumferential and occa
suggest that the remaining blood supply is probably subfascial and

Adolescent Bunions (Hallux Valgus)

Although bunion (prominence of the medial metatarsophalangeal jo
wide forefoot allows severe lateral deviation of the great toe (hallu

Figure 11–21.

Adolescent bunion (hallux valgus) is generally accompanied by a w

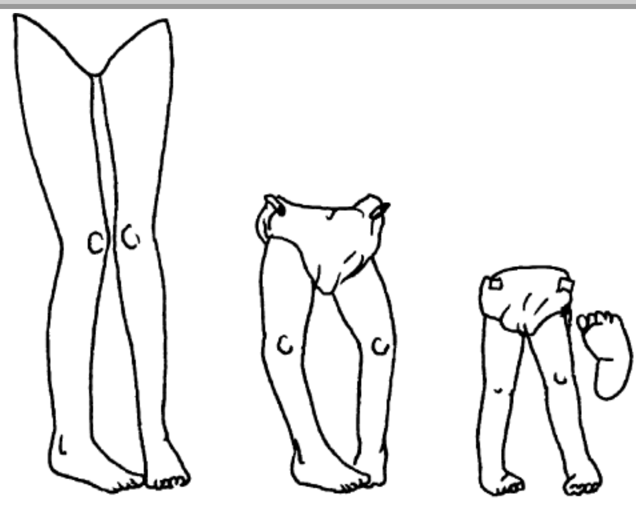
Although conservative measures may relieve discomfort, many ado
There is a fairly high incidence of recurrence of the deformity follo

Johnson AE et al: Treatment of adolescent hallux valgus with the f

TORSIONAL & ANGULAR DEFORMITIES OF THE KNEE &

Torsional (rotational) and angular deformities are a major source c

Figure 11–22.



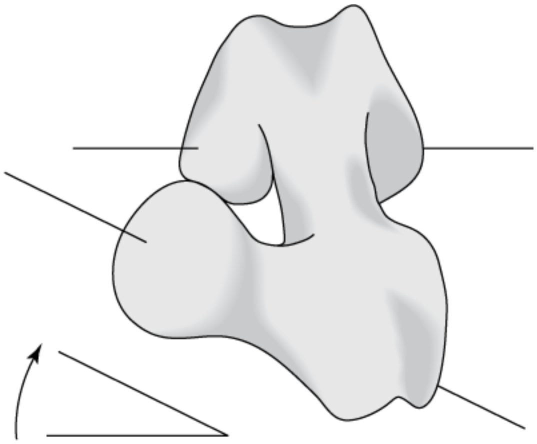
The major causes of clinical in-toeing include increased femoral an

The internal rotation, which can occur at the level of the thigh, leg radiograph or other imaging modalities, occasionally disclose condi

Increased Femoral Anteversion

The normal femoral neck does not lie exactly in the frontal (corona is slow or incomplete, causing the child to have excessive antevers

Figure 11–23.



The angle of anteversion describes the inclination of the femoral n

Observation of the walking child discloses internal rotation of the e

Increased femoral anteversion gradually decreases, with improven

Internal Tibial Torsion

Some infants are born with a relatively dramatic internal twisting (

Internal tibial torsion can be clinically measured by comparing the

Torsion of 30–40 degrees is not uncommon in the newborn. When

With growth, internal tibial torsion spontaneously resolves, and no

Metatarsus Adductus

Metatarsus adductus may cause apparent in-toeing in the young c

Table 11–7. In-Toeing Summary.

	Metatarsus Adductus	Internal Tibial Torsion
Age at resolution	12 months	3–4 years

Staheli LT et al: Lower extremity rotational problems in children. N

Bowlegs, Knock-Knee, & Genu Varum

Many infants have bilateral symmetric bowing of the legs, which m
remodels spontaneously to the adult average value of 5–7 degrees

Bowing of the legs in infants and excessive valgus of the knees in

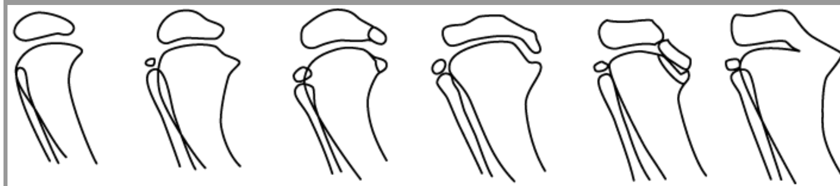
INTERNAL TIBIAL TORSION

Internal tibial torsion may masquerade as bowing when the child w
disappear.

BLOUNT DISEASE

Also known as tibia vara, Blount disease is a poorly understood los
walking in heavy children with physiologic bowing of the legs may

Figure 11–24.



The Langenskiöld diagrammatic classification of radiographic chan

Diagnosis of Blount disease is based on radiographic evidence of d

Mild cases of Blount disease may improve spontaneously. Althougl

Severe or progressive cases of Blount disease require surgical corr

Surgical treatment early in life is now popular, and many orthoped
until growth ceases at maturity. Controlled studies of the issues in

Rickets

Metabolic disorders of calcium intake can decrease the rate of calc
disease.

Accadbled F, Laville JM, Harper L: One-step treatment for evolved

Ferrick MR, Birch JG, Albright M: Correction of non-Blount's angul

Fraser RK et al: Medial physeal stapling for primary and secondary

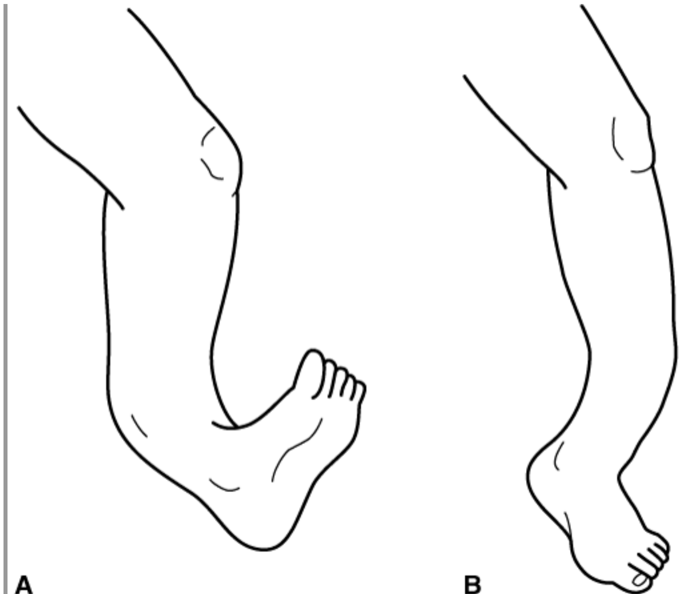
Heath CH, Staheli LT: Normal limits of knee angle in white childrer

Langenskild A, Riska EB: Tibia vara (osteochondrosis deformans ti

Tibial Bowing & Pseudarthrosis

The tibia has a propensity to exhibit congenital angular deformitie

Figure 11–25.



The major types of tibial bowing. **A:** Posteromedial bowing. The ar

CONGENITAL POSTEROMEDIAL BOWING OF TIBIA

Congenital posteromedial bowing of the tibia is a unilateral birth de the ankle joint, however, not the foot itself, is responsible for the c

Despite its dramatic appearance, posteromedial tibial bowing corre

The tibial curvature remodels enough by 3 years of age that the lii deformity needs no treatment, long-term follow-up and treatment

Pseudarthrosis of Tibia

CONGENITAL ANTEROLATERAL BOWING OF TIBIA AND CON

Congenital anterolateral bowing of the tibia and congenital pseudo spontaneous fracture, which does not heal as readily as most fract

All children with variations of this disorder require treatment. Beca or surgical bone grafting (with or without internal fixation).

Bone grafting in children whose fracture occurs before 3 years of a

The dismal results with conventional treatment of congenital pseuc functional result, however, that many patients eventually undergo

Johnston CE: Congenital pseudarthrosis of the tibia: Results of tec

Kim HW, Weinstein SL: Intramedullary fixation and bone grafting f

Morrissey RT: Congenital pseudarthrosis of the tibia: Factors that a

Ohnishi I et al: Treatment of congenital pseudarthrosis of the tibia

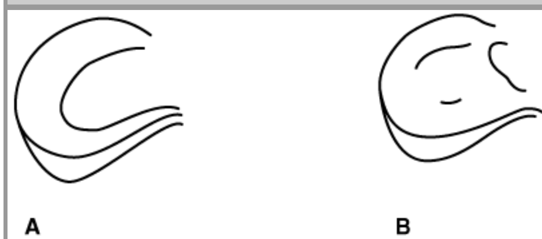
Tudisco C et al: Functional results at the end of skeletal growth in

KNEE DISORDERS

Discoid Meniscus

The normal menisci of the knee are semilunar in shape and wedge
Rarely, the lateral meniscus remains congenitally round (or discoid

Figure 11–26.



A: Normal lateral meniscus. **B:** Discoid lateral meniscus, which ma

Clinical Findings

The classic physical finding of discoid meniscus is loud clicking ove
subchondral sclerosis laterally, and convexity of the lateral tibial ar

Treatment

In the past, symptomatic discoid menisci were treated by total late
shape, thus sculpting the lateral meniscus into a roughly semiluna

Ahn JH et al: Discoid lateral meniscus in children: Clinical manifest

Kelly BT, Green DW: Discoid lateral meniscus in children. Current (

Washington ER III et al: Discoid lateral meniscus in children. Long-

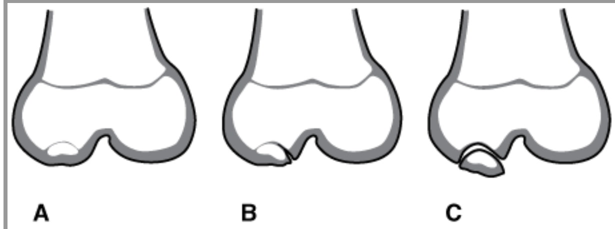
Chondromalacia and Internal Derangements of the Kn

Patellar chondromalacia and patellar subluxation are common in ac
A somewhat more conservative approach to suspect internal knee
These disorders are described in Chapter 3, Musculoskeletal Traum

Osteochondritis Dissecans

Osteochondritis dissecans is a poorly understood disorder usually c
is an infrequent problem in the adult.

Figure 11–27.



Various forms of the osteochondritis dissecans lesion found in chilc

The disease appears to be caused by a combination of two factors
whereas in younger children, ossification defects render the femor

Clinical Findings

SYMPTOMS AND SIGNS

Symptoms and physical findings can be highly variable. Younger cl

IMAGING STUDIES

Plain radiographs show an irregular fragment of the surface that is
ossification defects that mimic osteochondritis dissecans may be n

In children older than 11–12 years, MRI or arthrography is used tc

Treatment

Young children with asymptomatic osteochondritis dissecans need

Sometimes immobilization is not effective, though. If the lesion is
presence of open physes may necessitate modifications of standar

Hefti F et al: Osteochondritis dissecans: A multicenter study of the

Letts M, Davidson D, Ahmer A: Osteochondritis of the talus in chilc

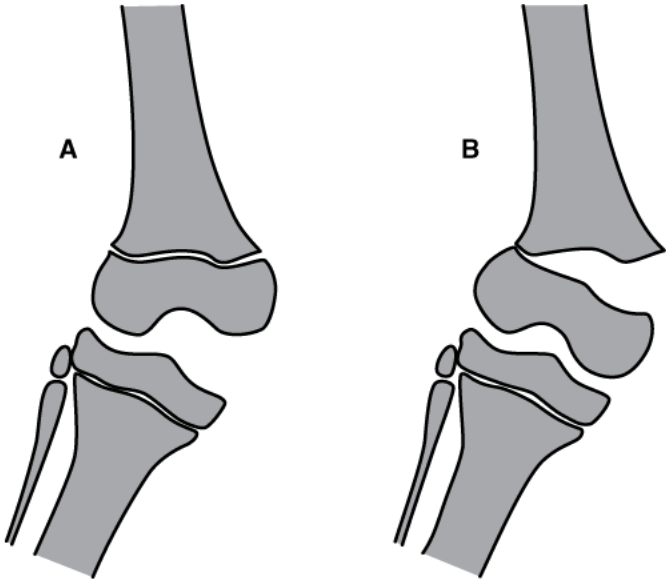
Wright RW et al: Osteochondritis of the knee: Long-term results o

Ligament & Epiphyseal Injury

Children who have not reached skeletal maturity have far fewer m
immature skeleton compared with bone or cartilaginous physes. Tl

Residual instability may occur in the child's knee after varus or val
that fracture is present, although stress radiographs may help in c

Figure 11–28.



Stress radiograph of the unstable knee in an immature patient ma

Major intraarticular disruptions of the knee joint (meniscal tear or
blood supply in children. Anterior cruciate rupture can be difficult t
necessary in children younger than 15 years. A review of the majc

Not all effusions in the knee are traumatic, particularly in younger

Beasley LS, Chudik SC: Anterior cruciate ligament injury in childre

Luhmann SJ: Acute traumatic knee effusions in children and adole

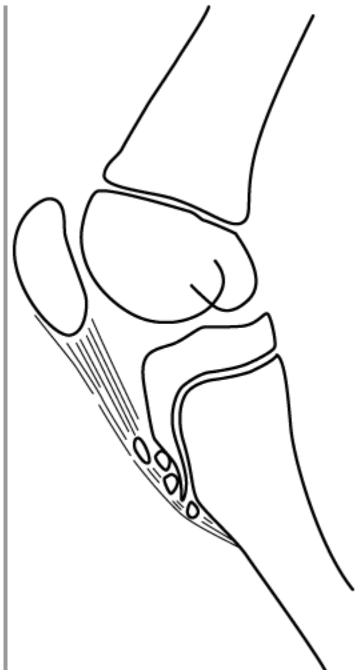
OSGOOD-SCHLATTER DISEASE

The proximal tibial physis contains a transverse component that co
is known as Osgood-Schlatter disease. As the tibial tubercle becom

Clinical Findings

Symptoms vary from mild aching at the tubercle to severe pain wi

Figure 11–29.



Osgood-Schlatter disease. The radiographs would show characteri

Treatment

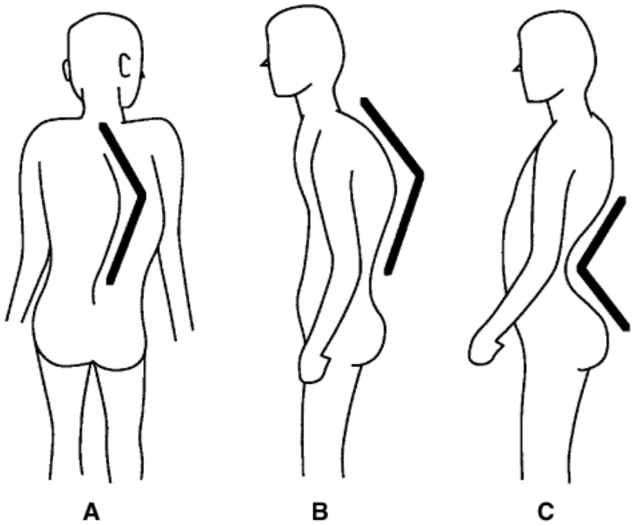
Treatment is symptomatic, including analgesics, knee pads to aver
disease.

Krause BL et al: Natural history of Osgood-Schlatter disease. J Pe

SPINAL CURVATURE

Spinal curvature may occur in any age group and present with var
Figure 11–30 shows the different types of spinal deformities.

Figure 11–30.



Definitions of spinal deformities. **A:** Scoliosis. **B:** Kyphosis. **C:** Lord

Types of Curvatures

SCOLIOSIS

Scoliosis is a lateral spinal curvature in the frontal plane, best appr
opposite direction, above and below the primary curvature. True s
that allows clinical detection.

KYPHOSIS

Kyphosis is a forward (flexed) curvature of the spine in the sagitta

LORDOSIS

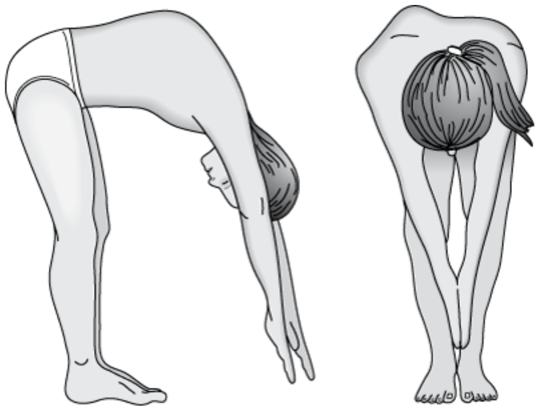
Lordosis is a hyperextension deformity of the spine, most common

Detection of Curvature

Although spinal curvatures may be detected first during routine ra

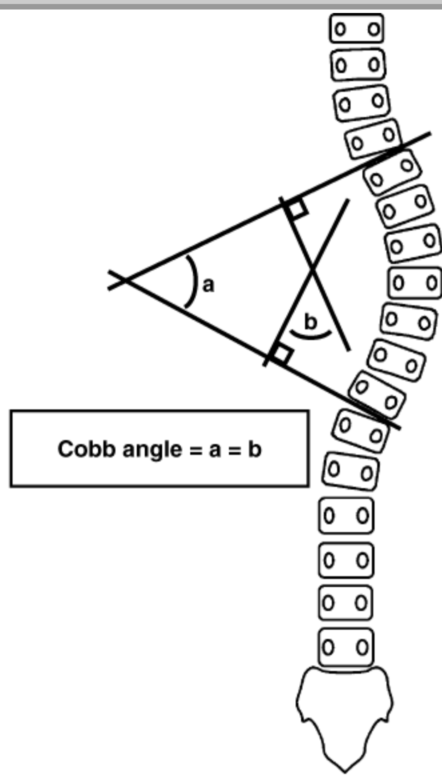
1. Place the patient in the standing position (Figure 11–31).
2. Check the level of the pelvis and look for obvious asymmetry of the rib, scapula,
3. Level the pelvis by seating the child on a firm surface if the pelvis cannot be leve
4. Have the child bend forward, carefully noting any asymmetric prominence of the
5. From the side, check for prominence of the spine that might indicate kyphosis, b
6. Perform a careful neurological exam, including upper extremity reflexes and abd
7. Use radiographs to assess type, severity, and location of the curvature and to loc
magnitude.

Figure 11–31.



Examination of the spine for deformity is best carried out by obse

Figure 11–32.



The Cobb method of measurement is commonly used to assess sp

Scoliosis

IDIOPATHIC SCOLIOSIS

Idiopathic scoliosis has no apparent underlying cause. It is most co
children may require more extensive testing (eg, EMG, MRI) befor

Many idiopathic curvatures progress in magnitude with growth anc
ossification pattern begins laterally at puberty and spreads medial

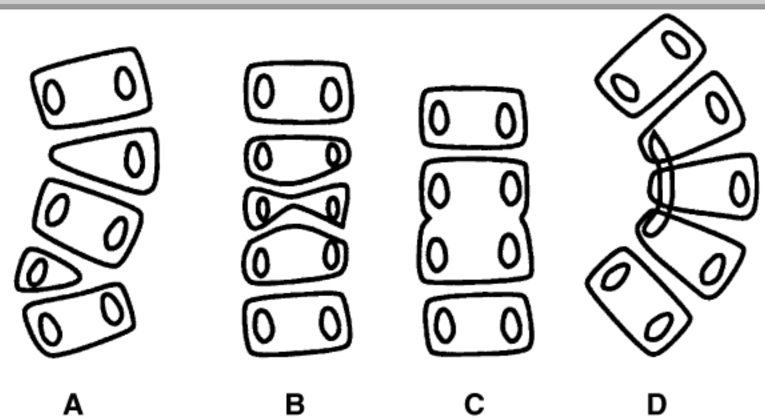
Growing children with progressive curvatures should be treated. A
are too rigid to brace effectively and can only be observed if they

Surgery for scoliosis corrects the deformity using metal rods that (
anterior fusion through the thorax or retroperitoneal space.

CONGENITAL SCOLIOSIS

Congenital scoliosis is caused by malformations of vertebral shape
originate from primitive mesenchymal condensations of embryonic

Figure 11–33.



Vertebral anomalies of congenital scoliosis. **A:** Hemivertebra. **B:** B

Curvatures can originate when vertebral parts fail to form (eg, hei
systems that form during the same embryonic period (eg, cardiac

Diagnosis of congenital scoliosis must be followed by a careful carc

Congenital scoliosis may encompass one or many deformed verteb
usually the first treatment, although surgery is indicated if progre:

NEUROMUSCULAR SCOLIOSIS

Neuromuscular scoliosis includes a diverse group of curvature patt
progressive muscle weakness that eliminates the paraspinous stab

Patients with neuromuscular scoliosis often develop curvatures at a
bracing may slow progression enough to allow additional skeletal g

OTHER SCOLIOSES

Childhood scoliosis can be associated with benign tumors of the sp

Neurofibromatosis is associated with both scoliosis and kyphosis ar

Dobbs MB et al: Prevalence of neural axis abnormalities in patient

Kyphosis

Kyphosis may be congenital, traumatic, or acquired. Some patient

POSTURAL KYPHOSIS (POSTURAL ROUNDBACK)

Postural kyphosis, a variation of normal posture, is a cosmetic pro

SCHEUERMANN KYPHOSIS

Scheuermann kyphosis is a disorder of growth of the vertebral enc irregularity of the endplates with radiographic lucent pits known a

Figure 11–34.

Scheuermann kyphosis is characterized by vertebral wedging, end

Lumbar Scheuermann kyphosis responds to symptomatic treatmen sometimes be used at night only so it will not have to be worn dur

Scheuermann disease is the exception to the general rule that spi

CONGENITAL KYPHOSIS

Congenital kyphosis is a rare but important group of diseases, whi spinal cord over the kyphotic prominence and eventually cause pa

TRAUMATIC KYPHOSIS

Traumatic kyphosis is a traumatic compression of vertebrae that m

INFECTIOUS KYPHOSIS

Infectious kyphosis refers to septic destruction of vertebral bodies

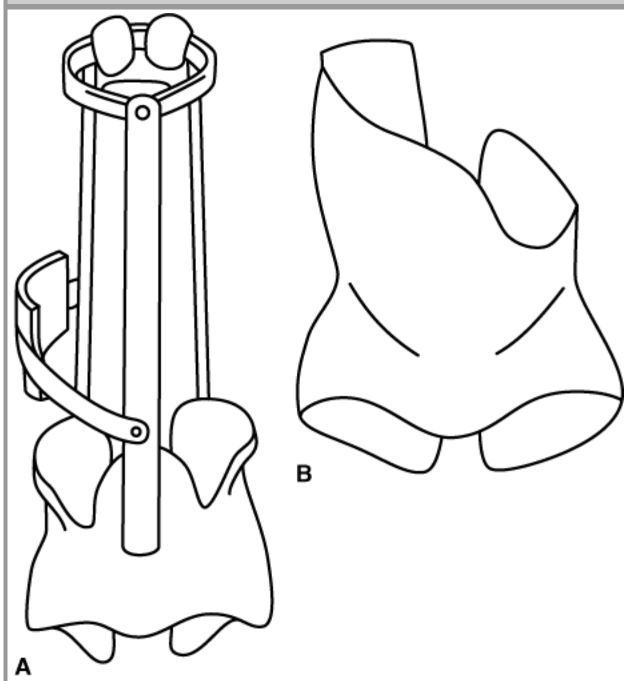
Treatment includes chemotherapy, surgical debridement and drain

Treatment

BRACING

Bracing can be used to slow progression of spinal curvatures, prev so-called clamshell brace, may suffice for waking or sitting hours.

Figure 11–35.



Two popular brace styles used for the treatment of spinal deformi

Long-term braces designed to arrest progression must be custom

All braces must be modified or replaced to accommodate growth.

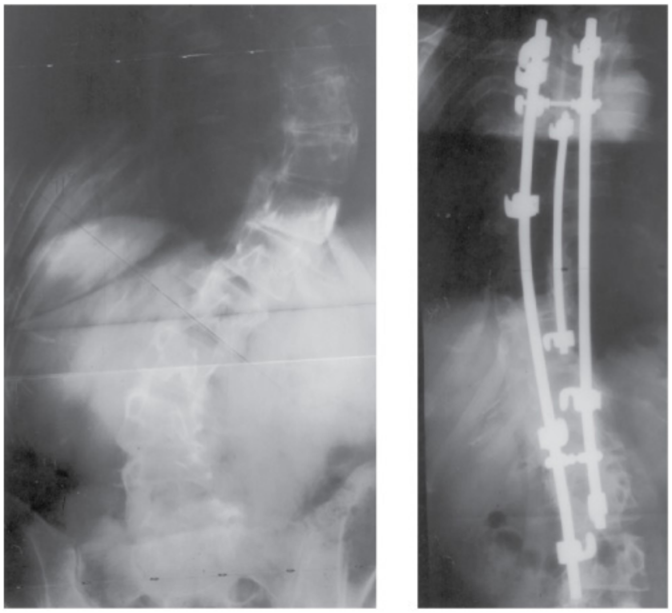
SURGICAL TREATMENT

Surgical intervention is indicated for curvatures that progress desp

Surgical Stages

Surgery involves two separate stages: correction and stabilization. limit the force that can be applied. Once correction is obtained, the

Figure 11–36.



A

B

Treatment of a scoliotic curve by instrumentation and fusion. Preo

Treatment of Severe Curvatures

For small curvatures, posterior instrumentation and fusion are suff
of a previously corrected curvature. In this case, fusion must be re

Lonstein JE: Adolescent idiopathic scoliosis: Screening and diagnos

Danielsson AJ, Nachemson AL: Radiologic findings and curve progr

Weinstein SL, Ponseti IV: Curve progression in idiopathic scoliosis.

NEUROMUSCULAR DISORDERS

Because muscle weakness or imbalance changes the underlying st

Many childhood neuromuscular diseases require coordinating the s

Cerebral Palsy

Cerebral palsy is a static encephalopathy in a growing child. Althou

The challenges to physicians evaluating cerebral palsy are making

Types of Cerebral Palsy

The hallmark of most cases of cerebral palsy is alteration in motor
of joints, joint dislocations, and scoliosis). Dystonia can be confuse

HEMIPLEGIA

Hemiplegia is spasticity involving only one side of the body. Most h
insufficiency, trauma, or porencephalic cysts.

Many patients with hemiplegia have normal development and intel
associated with abnormalities of sensation and proprioception in th

DIPLEGIA

Diplegia, or diplegic cerebral palsy, is an encephalopathy usually as
trigone. This involvement of the pyramidal tract and associated ba

Most diplegic children exhibit mixed patterns of spasticity with a va
patients develop high tone (dystonic rigidity) and spasticity by 12-

Diplegia, usually more severe in the lower extremities, is relatively

QUADRIPLEGIA

Quadriplegia (total body involvement) often occurs in children who
(because of hip muscle imbalance) and high-grade scoliosis. Both c

MIXED NEUROLOGIC INVOLVEMENT

Mixed neurologic involvement of extrapyramidal portions of the bra

Treatment

Before treating cerebral palsy, specific goals should be set for the
treatment may improve sitting position in the wheelchair or improv

Many children benefit from physical or occupational therapy during

Bracing or surgery may be required to control effects of spasticity
portion of the posterior roots of the lumbar spinal cord, may reduc
spasticity. Intrathecal baclofen, delivered by a subcutaneous pump

Hip subluxation is common in quadriplegia, and pelvic radiographs
adductors. In older children, bony reconstruction by varus-derotat

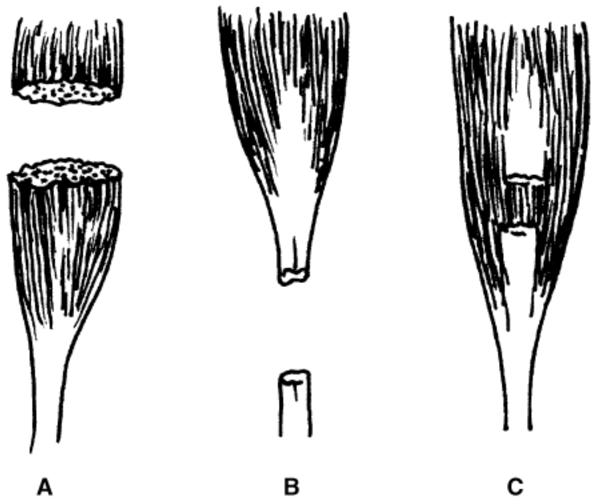
ADDUCTOR RELEASE

Adductor release may be done as an open procedure (usually by m
done for hip subluxation, adductor release is most effective before
supplies the released adductor longus muscle, so the muscle rema

Obturator neurectomy must be used carefully because it can cause

Dynamic spasticity or joint contracture (the result of chronic spast
lengthening of the aponeurosis of a muscle, which is often done fo

Figure 11–37.



Schematic representation of surgical options for muscle release or

It is convenient to combine multiple procedures for children with c
operation. The exact timing and extent of surgery are controversia

MUSCLE RELEASE FOR DYNAMIC DEFORMITY

Muscle releases for dynamic deformity may be done in several way

Achilles Tendon Lengthening

Achilles tendon lengthening is usually done by Z-lengthening of the
group hinders walking and can actually encourage a deeper crouch

Gastrocnemius Lengthening

Gastrocnemius lengthening is required in patients whose gastrocne
calf and sectioning the aponeurosis or by release of the insertion c

Hamstring Lengthening

Hamstring lengthening is indicated when the hamstrings are tight
tenotomized (transversely released). The semimembranosus is len
leg is splinted or casted in extension for 3–4 weeks to allow soft-ti

Iliopsoas Lengthening

The hip flexors (psoas and iliacus) may be released at the insertion
muscle for strength.

DeLuca PA: The musculoskeletal management of children with cere

Myelomeningocele (Spina Bifida)

Myelomeningocele is a complex birth defect affecting the spinal co

Embryologic Defect

The basic embryologic defect is a failure of complete tubulation an
outside of the spinal canal, without neurologic deficit). The more s

Figure 11–38.

Spina bifida (myelomeningocele). The sac includes dysplastic spina

Myelomeningocele can occur at any spinal level but usually is seen
This may be difficult because of anatomic variability, the age of th

Table 11–8. Muscle Function at Neurologic Levels in M

Neurologic Level	Functions	Muscles Active			
T12	Hip flexion (weak)	Iliopsoas (weak)	L1	Hip flexion	Iliopsoas

Treatment of Orthopedic Problems

Orthopedic problems associated with myelomeningocele include clu
usually include nonmusculoskeletal organ system problems such as
coordinate management. The most pressing needs of the infant bo

Orthopedic management depends on the deformities and the long-
usually require surgery. If foot deformities recur or progress, teth

Spina bifida is theoretically a static neurologic disease, but many c
occur in children with neurologic involvement at L2 to L4, which pr

A young child with scoliosis may require bracing until the thorax is
materials in contact with mucous membranes and internal tissues

Bunch WH: Myelomeningocele: Part I. General concepts. Instr Cou

CDC (Centers for Disease Control and Prevention): Spina bifida an

Mazur JM, Menelaus MB: Neurologic status of spina bifida patients

Oakshott P, Hunt GM: Long-term outcome in open spina bifida. Br

Wehby MC et al: Occult tight filum terminale syndrome: Results of

Muscular Dystrophy

Duchenne muscular dystrophy is an X-linked disorder that present
to rise from the floor without using the hands to walk up the body
strength and likely duration of ambulation after treatment. Most o

As weakness progresses, the child requires an electric wheelchair f
provides more information.

Myotonic Dystrophy

Myotonic dystrophy is a genetic muscle disease whose name reflec
Myotonic dystrophy worsens with each succeeding generation; ger

The most frequent foot deformity is equinovarus, often with weakn
muscle forces).

Spinal Muscular Atrophy

This heterogeneous group of disorders includes static and degener
devices), and control of scoliosis, which is similar to management o

Green NE: The orthopaedic care of children with muscular dystrop

Voisin V, de la Porte S: Therapeutic strategies for Duchenne and B

Arthrogryposis (Arthrogryposis Multiplex Congenita)

Arthrogryposis is not a disease per se but rather a symptom comp
movement during a critical period in limb development. This can b

Arthrogrypotic infants frequently have extension or flexion contrac
treated. Clubfeet require surgery, which is often of limited success

TUMORS

Skeletal neoplasms, particularly benign ones, are fairly common in
and osteosarcoma. Certain systemic diseases can be manifested ir

AMPUTATIONS

Congenital Amputations & Absence of Segments

Congenital absence of limb segments at birth can occur sporadical

Although congenital amputations can be dramatic in appearance, t example, nearly all congenital above-elbow amputees reject artific

It is not unusual for congenital amputations to require conversion simplifies management of the leg-length discrepancy, thus permitt

Boostra AM et al: Children with congenital deficiencies or acquired

Ephraim PL et al: Epidemiology of limb loss and congenital limb de

Fixsen JA: Major lower limb congenital shortening: A mini review. .

Krebs DE, Fishman S: Characteristics of the child amputee populat

Rijnders LJ et al: Lower limb deficient children in the Netherlands:

Traumatic Amputation

In contrast to the congenital amputee, the child with a traumatic a social, as well as medical, intervention is often appropriate.

The orthopedic management of traumatic amputees is modified in similar amputation in the adult. The child amputee rarely has vasc

Overgrowth of Amputation Stump

Amputations through the long bones of children exhibit the unique associated with the periosteal membrane.

Although overgrowth can occur in any bone, it is most troublesom maturity. Various attempts at capping the overgrowing bone end (

Tenholder M et al: Surgical management of juvenile amputation ov

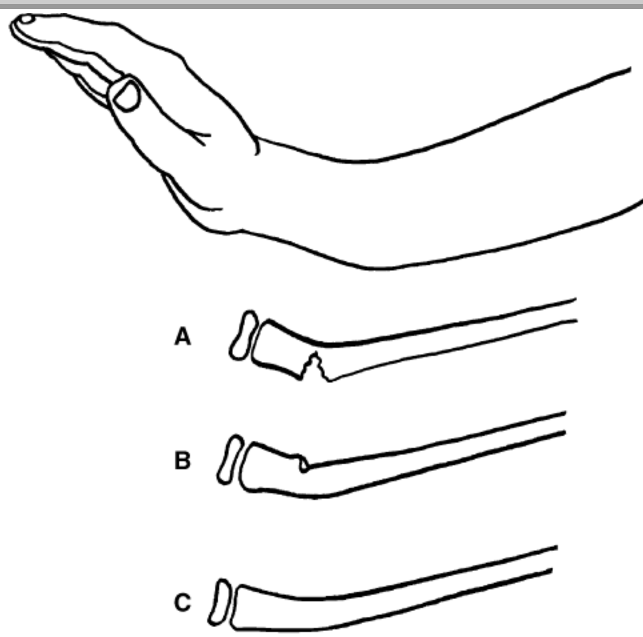
FRACTURES

Common Pediatric Fracture Patterns

Many fractures in children are similar to their counterparts in adul child than in the adult. In addition, the periosteal membrane in chi healing, so nonunions are extremely rare in children.

Less brittle pediatric bone is subject to fracture patterns unique to

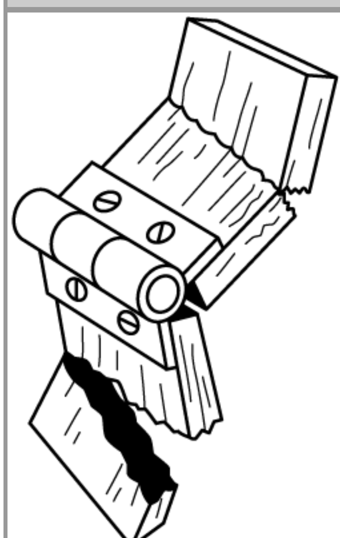
Figure 11–39.



Softer bone in children can lead to unique fracture behavior (in ad

A torus fracture is a small buckle or impaction of one cortex with a
Remodeling (gradual correction in alignment or size of a fractured
less reliable. Overgrowth is a singular feature of remodeling that o

Figure 11–40.



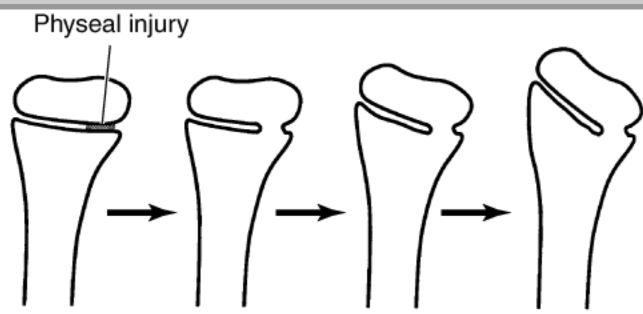
Remodeling of bone after fracture is most rapid when it is in the p

The combination of low-energy injury, rapid bone healing, and dep
satisfactory alignment.

Epiphyseal Fracture

The cartilage physeal plates are a region of low strength relative t
across it (from epiphyseal bone to metaphyseal bone), forming a b

Figure 11–41.



Progressive angular deformity can occur if there is asymmetric clo

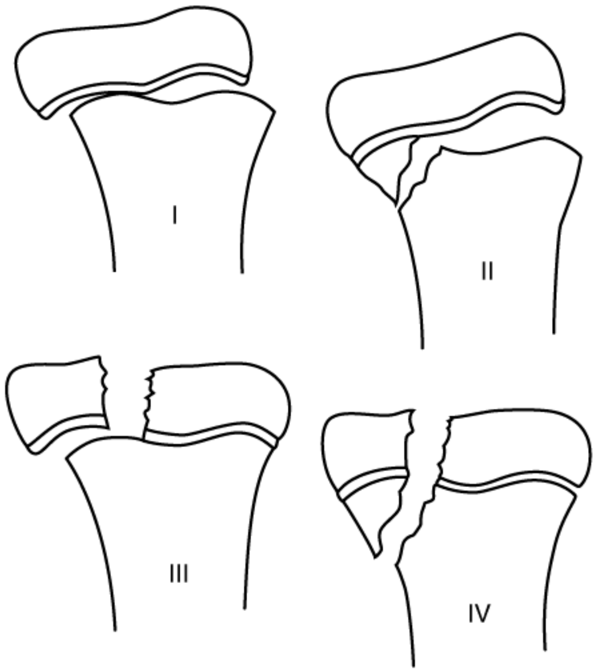
Because physes are near joints and physeal fractures are common

Most physeal fractures propagate through the weakest region of t
calcified and eventually ossify to form metaphyseal bone.

The weakest spot is usually the interface between hypertrophic dy
metaphyseal blood supply). Thus, physeal fractures do not often d

Although physeal fractures can occur in a wide variety of configura

Figure 11–42.



The Salter-Harris classification of physeal fractures is widely used

Physeal fractures heal rapidly, usually within 4 weeks. Careful mor
evaluation and treatment of limb-length inequality should be follow

Salter RB, Harris WR: Injuries involving the growth plate. J Bone J

Upper Extremity Fractures

Clavicle Fracture

Clavicle fractures are among the most common injuries in children

An extremely rare condition, atraumatic congenital pseudarthrosis

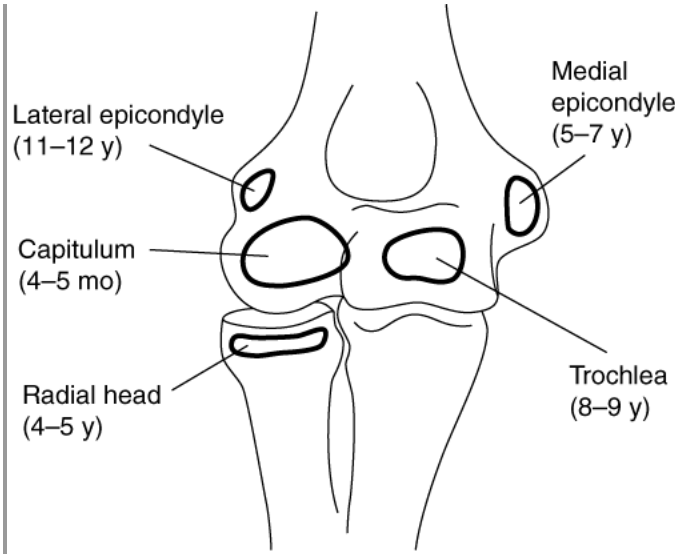
Proximal Humerus Fracture

Proximal humerus fractures are usually epiphyseal injuries (usually
weeks, without reduction. Rarely, fractures with extreme angulatic

Elbow Region Fracture

Most elbow region fractures are indirect injuries caused by a fall o
structures and lead to forearm compartment syndromes. Reductio

Figure 11–43.

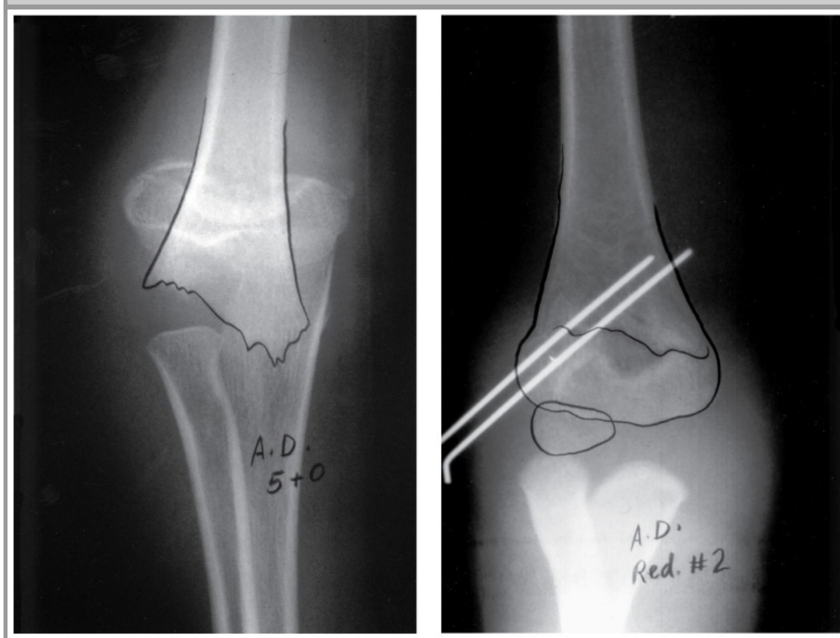


Ages of appearance of ossification centers. The ossification center

SUPRACONDYLAR FRACTURE OF HUMERUS

Supracondylar fracture of the humerus occurs at the metaphyseal

Figure 11–44.



A

B

Displaced supracondylar fracture of the humerus. Injury film (**A**);

The most appropriate treatment is rapid anatomic reduction under

Some displaced supracondylar humerus fractures are incompletely
any significant functional consequences. If desired, it may be corre

LATERAL CONDYLE FRACTURE

The lateral condyle fracture is an oblique shearing fracture of the l
Salter-Harris IV fractures (Figure 11–45). Because both the joint s

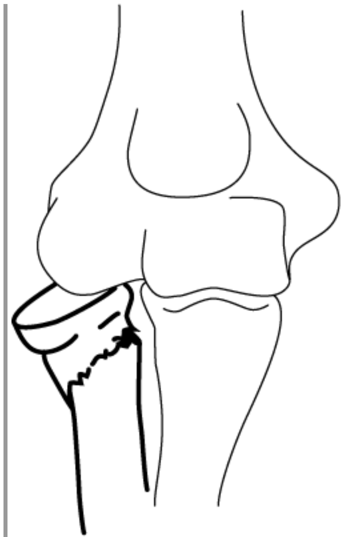
Figure 11–45.

Lateral condyle fracture of the humerus (**A**) can easily be mistake

RADIAL NECK FRACTURE

Fracture of the radial neck is similar to a lateral condyle fracture. T
spontaneously and requires only symptomatic treatment that perm

Figure 11–46.



Fracture of the radial neck may angulate greatly yet still remodel

FOREARM FRACTURE

Forearm fractures are a common result of falls. If they involve bot
bone ends is accurate. In addition, the ends of fractured bones oft

MONTEGGIA FRACTURE

Monteggia fracture is fracture of the ulna only, with the radius rem
fractures require open reduction. The physician should be alert to

In children, Galeazzi fracture of the radius, in which the distal radi

TORUS FRACTURE OF RADIUS

Torus fracture of the radius is a minor buckle of the dorsal cortex

Laumay F et al: Lateral humeral condyle fractures in children: A co

Mirsky EC et al: Lateral condyle fractures in children: Evaluation o

Wattenbarger JM, Gerardi J, Johnston CE: Late open reduction inte

Metacarpal & Phalangeal Fractures

Fractures of the metacarpals and phalanges commonly occur from

Lower Extremity Fractures

Pelvic Fracture

Pelvic fractures in children are usually seen in conjunction with ma
satisfactorily.

Adolescents exhibit a special type of avulsion fracture of apophyse
enough to withstand the pull of growing muscles suddenly grown p
do not require reduction, they may heal with a significant bump th

Tsirikos AI et al: Transepiphyseal fracture-dislocation of the femora

Hip Fracture

Pediatric hip fractures are rare but may be serious because trauma
may result in such severe collapse that hip fusion is required.

Femoral neck fractures in children are highly unstable and treated

Odent T et al: Traumatic dislocation of the hip with separation of t

Femoral Shaft Fracture

Fractures of the femoral shaft are common injuries caused by falls
muscle ensures rapid solid union (usually within 6 weeks).

Longitudinal muscle pull and spasm cause femoral shaft fractures t

Femur fractures in children 2–10 years of age have a strong tende

Femoral overgrowth following fracture becomes unlikely in children
they do not require reaming prior to insertion, and they are less lil

After healing or cast removal, the child may begin walking. Limpin

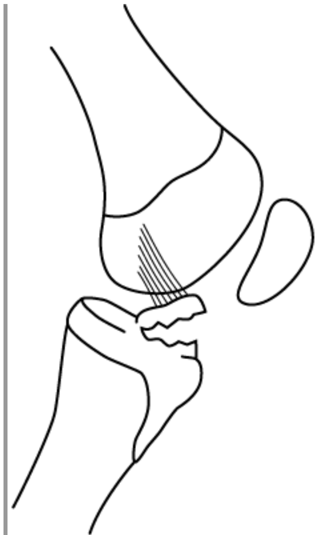
Epiphyseal Separation

Epiphyseal separations (fracture) of the distal femoral physis are u
reduction under general anesthesia. Some are so unstable, howeve

Tibial Eminence Injury

The tibial eminence (spine), located entirely on the proximal tibial
weeks, until the bone heals (Figure 11–47). Unlike many other pe

Figure 11–47.



Tibial eminence fracture usually includes an anterior cruciate avuls

Tibial Tubercle Avulsion Fracture

Tibial tubercle avulsion fractures are most often seen in adolescen
joint surface. Tibial tubercle avulsions are transitional fractures in

Proximal Tibial Metaphyseal Fracture

Proximal tibial metaphyseal fractures are usually undisplaced or m
tendency to remodel, so the best approach is observation.

Figure 11–48.

Even when not displaced, fracture of the proximal tibial metaphys

Tibial Shaft Fracture

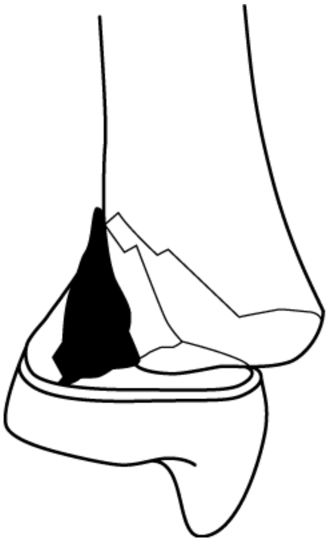
Tibial shaft fractures, which are usually accompanied by fibula frac compartment syndromes are major risks (see Chapter 3, Musculos

Most tibial fractures in children can be adequately aligned and imn however.

Ankle Fracture & Distal Tibial Fracture

Ankle fractures and distal tibial fractures in younger children are o Salter-Harris type IV fracture that disrupts both the joint and the elongation. If this occurs, either epiphyseal bar resection or correc

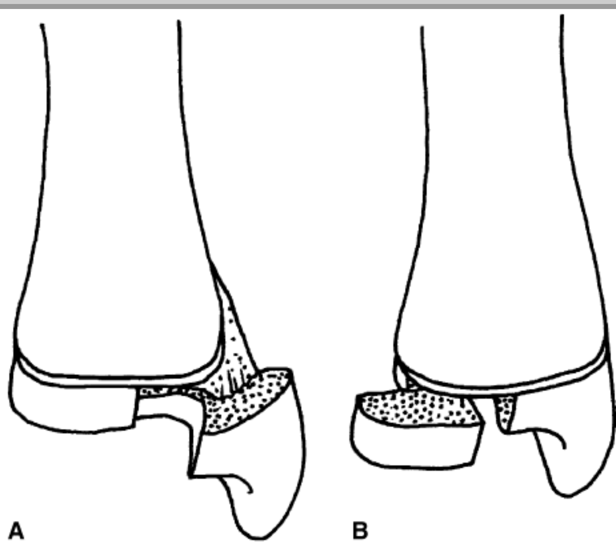
Figure 11–49.



Simple fracture of the distal tibia (and fibula) at the ankle is usual

The distal tibia is the site of several distinct transitional fracture pa
applied (ie, mechanism of injury). When just the medial physis is c
may be necessary to define the exact fracture configuration for ac

Figure 11–50.



The triplane (**A**) and juvenile Tillaux (**B**) fractures are variations o

In slightly older patients, when only a small anterolateral segment

Spiegel PG et al: Epiphyseal fractures of the distal ends of the tibi

INJURIES RELATED TO CHILD ABUSE

Child abuse crosses all socioeconomic boundaries and takes many

The classic radiographic picture of abuse is the presence of multipl
bones (femur or humerus) are the bones most commonly fracture
never the cause of serious skeletal injury, and the dichotomy betw

Figure 11–51.

The presence of multiple fractures of various ages as well as unex

The orthopedic management of abuse fractures is rarely complex,

McMahon P et al: Soft-tissue injury as an indication of child abuse.

Oral R, Blum KL, Johnson C: Fractures in young children: Are phys

AMPUTATIONS: INTRODUCTION

Amputations are performed to remove extremities that are severely diseased, injured, or no longer functional. Although medical advances in antibiotics, trauma care, vascular surgery, and the treatment of neoplasms have improved the prospects for limb salvage, in many cases prolonged attempts to save a limb that should be amputated lead to excessive morbidity or even death. To counsel a patient regarding amputation versus limb salvage adequately, the physician must provide sufficient information about the surgical and rehabilitative steps involved with each procedure and must also appraise the probable outcome for function realistically with each alternative. Attempting to salvage a limb is not always in the best interest of the patient.

The decision to amputate is an emotional process for the patient, the patient's family, and the surgeon. The value of taking a positive approach to amputation cannot be overemphasized. It is not a failure and should never be viewed as such. The amputation is a reconstructive procedure designed to help the patient create a new interface with the world and to resume his or her life. The residual limb must be surgically constructed with care to maintain muscle balance, transfer weight loads appropriately, and assume its new role of replacing the original limb.

For patients to achieve maximal function of the residual limb, they also need a clear understanding of what to expect for an early postoperative prosthetic fitting, a rehabilitation program, and for long-term medical and prosthetic needs. For these discussions, the team approach to meeting the patient's needs can be especially rewarding. Nurses, prosthetists, physical and occupational therapists, and amputee support groups can be invaluable in providing the physical, psychologic, emotional, and educational support needed in returning patients to a full and active life. Many new amputees state that a peer visitor program was one of the most helpful events during their hospitalization and rehabilitation. The Amputee Coalition of America, a not-for-profit organization, supports this peer visitor training and can help locate programs that are available throughout the country.

SPECIAL CONSIDERATIONS IN THE TREATMENT OF PEDIATRIC PATIENTS

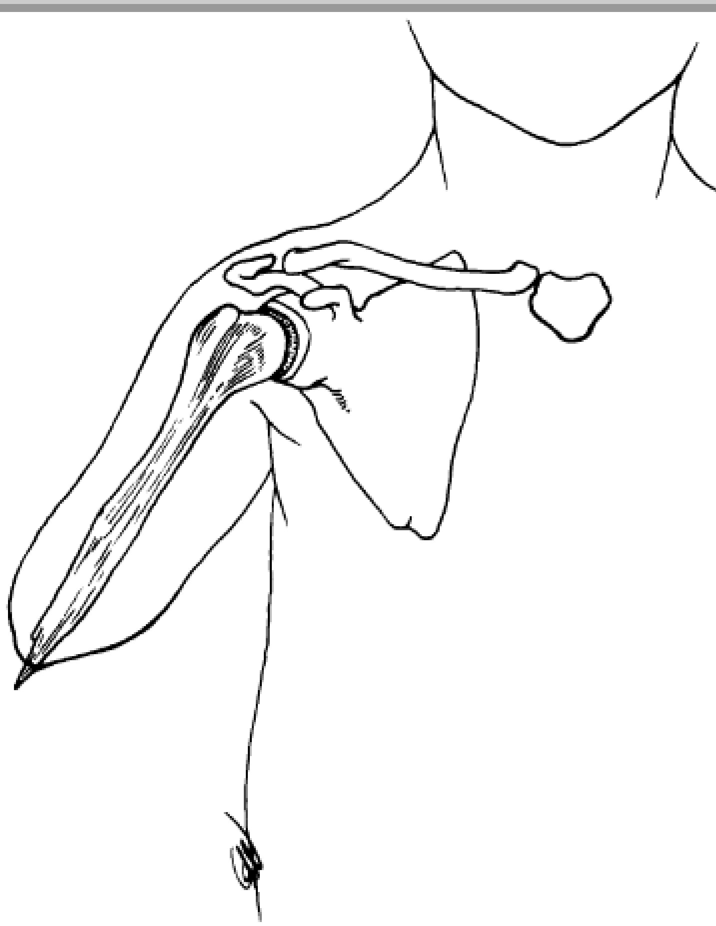
In infants and children, amputations are frequently associated with congenital limb deficiencies, trauma, and tumors. Congenital limb deficiencies are commonly described using the Birch revision of the Frantz and O'Rahilly classification system. Amelia is the complete absence of a limb; hemimelia is the absence of a major portion of a limb; and phocomelia is the attachment of the terminal limb at or near the trunk. Hemimelias can be further classified as terminal or intercalary. A terminal hemimelia is a complete transverse deficit at the end of the limb. An intercalary hemimelia is an internal segmental deficit with variable distal formation. In discussions of limb deficiencies, preaxial refers to the radial or tibial side of a limb, and postaxial refers to the ulnar or fibular side. The International Organization for Standardization (ISO) published a recommended classification for limb deficiencies in 1989 based on standard anatomic and radiologic characteristics and terminology. Although the ISO intentionally avoided the use of the terminology in the Frantz and O'Rahilly system, the older system is widely used, and the definitions and unusual language must still be understood by those caring for children with limb deficiency.

Reamputation of a congenital upper limb deficiency is rarely indicated, and even rudimentary appendages can often be functionally useful. In the lower limb, however, the ability to bear weight and the relative equality of leg lengths are mandatory for maximal function. Reamputation may be indicated in proximal femoral focal deficiency and congenital absence of the fibula or tibia to produce a more functional residual limb and improve prosthetic placement.

In the growing child, proportional change occurs in residual limb length from childhood to adulthood—an important concept to keep in mind when determining the surgical approach. A diaphyseal amputation in an infant or young child removes one of the epiphyseal growth centers, and the involved bone therefore does not keep proportional growth with the rest of the body. What initially appears to be a long transfemoral amputation in a small child can turn out to be a short and troublesome residual limb when the child reaches skeletal maturity. All attempts should be made to save the distal-most epiphysis by disarticulation. If this is not technically possible, the greatest amount of bone length should be saved.

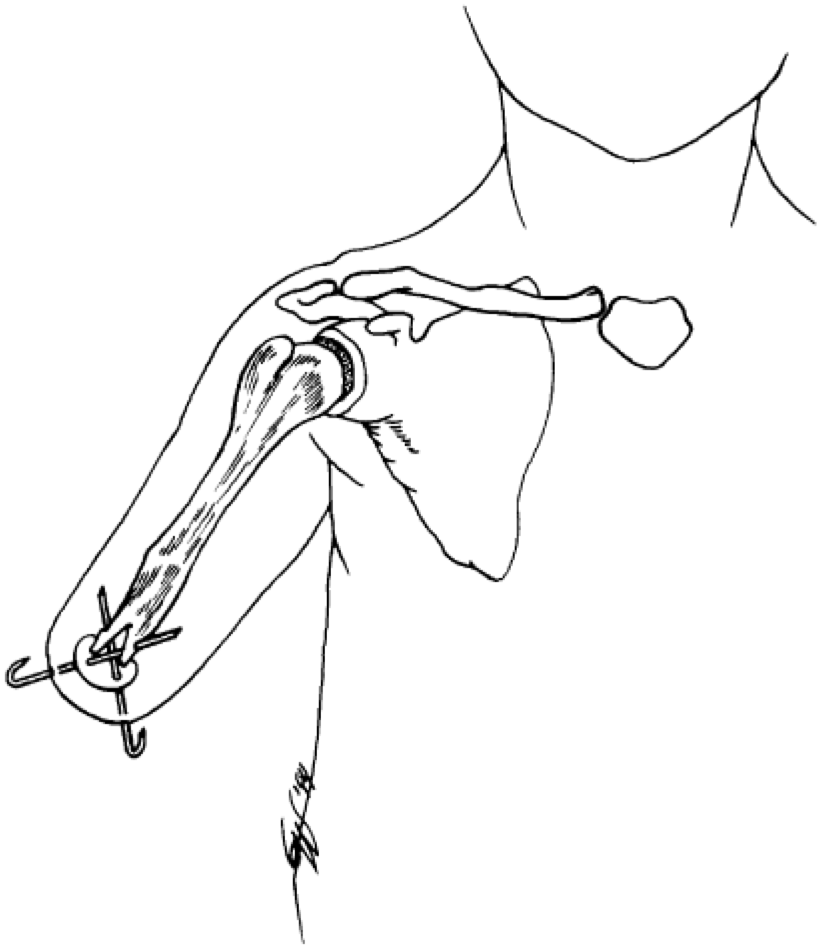
Terminal overgrowth occurs in 8–12% of pediatric patients who had a surgical amputation. The growth of appositional bone at the transected end of a long bone exceeds the growth of the surrounding soft tissues. If left untreated, the appositional bone can penetrate through the skin (Figure 12–1). Terminal overgrowth of the transected bone does not occur as a result of the normal growth from the proximal physis pushing the distal end of the bone through the soft tissues, nor does it occur in limb disarticulations. Terminal overgrowth occurs most commonly in the humerus, fibula, tibia, and femur, in that order. Although numerous surgical procedures are used to manage this problem, the best approach consists of stump revision with adequate bone resection or autogenous osteochondral stump capping as originally described by Marquardt (Figure 12–2). If the stump-capping procedure is done at the time of original amputation, the graft material can be obtained from part of the amputated limb, such as the distal tibia, talus, or calcaneus. If a procedure is done later, the graft material can be obtained from the posterior iliac crest. Although techniques with nonautologous material are used, significant complications are reported. A report of using a modified Ertl osteomyoplasty to prevent terminal overgrowth in childhood limb deficiencies was not successful.

Figure 12–1.



Terminal overgrowth of the transected bone in a pediatric amputee.

Figure 12–2.



Stump-capping procedure. The bone end was split longitudinally and the osteochondral graft fixed temporarily with K-wires.

In a growing child, the fitting of a prosthesis can be challenging and requires frequent adjustments. Specialty pediatric amputee clinics can ease this process, provide family support, and make care more cost effective. The timing of prosthetic fitting should be initiated to coincide closely with normal motor skill development.

Prosthetic fitting for the upper limb should begin near the time the child gains sitting balance, usually around 4–6 months of age. A passive terminal device with blunt rounded edges is used initially. Active cable control and a voluntary opening terminal device are added when the child exhibits initiative in placing objects in the terminal device, usually in the second year of life. Myoelectric devices are usually not prescribed until the child masters traditional body-powered devices. The physical demand placed on prosthetic devices by children can often exceed the durability of current myoelectric designs, so maintenance and repair costs must be considered. The decision to prescribe a myoelectric device for a child is individual and depends on many factors, including the physical characteristics of the residual limb, the desires of the child, the training available, the proximity of prosthetic facilities for fitting and maintenance, and issues about funding.

Prosthetic fitting for the lower limb commonly begins when the child develops the ability to crawl and pull to a standing position, which is usually at 8–12 months. A child with a Syme amputation or a transtibial amputation generally adapts to a prosthesis with surprising ease, and although formal gait training is not required, educational efforts are focused on teaching the parents about the prosthesis. For a child with a transfemoral amputation, control of a knee unit should not be expected immediately. The knee unit should be eliminated or locked in extension until the child is ambulating well and demonstrates proficient use of the prosthesis. The initial gait pattern used by a child with a transfemoral amputation is not a normal heel strike, midstance, toe-off gait pattern but is instead a more circumducted gait pattern with a prolonged foot flat phase. Formal gait training is seldom warranted until the child reaches 5 or 6 years of age. Attempts to force gait training too early can be frustrating for all involved. When pediatric patients are allowed to develop their own gait patterns as they grow and gain improved motor coordination, they are surprisingly adept at discovering the most efficient gait pattern without formal training.

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GENERAL PRINCIPLES OF AMPUTATION

Epidemiology

Epidemiologic data on the incidence of amputation in the United States from 1993 to 2001 show the number of lower extremity amputations increased 14% from 99,522 to 113,379, and the average hospital charge for this procedure increased 38% from $24,332 to $33,562. Nearly two thirds of amputations are performed in individuals with diabetes, even though people with diabetes represent only 6% of the population.

Preoperative Evaluation & Decision Making

The decision to amputate a limb and the choice of amputation level can be difficult and are often subject to differences in opinion. Advances in the treatment of infection, peripheral vascular disease, replantation, and limb salvage complicate the decision-making process. The goals are to optimize a patient's function and reduce the level of morbidity.

VASCULAR DISEASE AND DIABETES

Ischemia resulting from peripheral vascular disease remains the most frequent reason for amputation in the United States. Nearly two thirds of patients with ischemia also have diabetes. The preoperative assessment of these patients includes a physical examination and an evaluation of perfusion, nutrition, and immunocompetence. Preoperative screening tests can be helpful, but no single test is 100% accurate in predicting successful healing. Clinical judgment based on experience in examining and following many patients with vascular disease and diabetes is still the most important factor in preoperative assessment.

Doppler Ultrasound Studies

The most readily available objective measurement of limb blood flow and perfusion is by Doppler ultrasound. Arterial wall calcification increases the pressure needed to compress the vessels of patients with vascular disease, and this often gives an artificially elevated reading. Low-pressure levels are indicative of poor perfusion, but normal and high levels can be confusing because of vessel wall calcification and are not predictive of normal perfusion or of wound healing. Digital vessels are not usually calcified, and blood pressure levels in the toes appear to be more predictive of healing than do those in the ankles.

Transcutaneous Oxygen Tension Measurements

Tests to measure transcutaneous partial pressure of oxygen (Po_2) are noninvasive and becoming more readily available in many vascular laboratories. These tests use a special temperature-controlled oxygen electrode to measure the P_{O_2} diffusing through the skin. The ultimate reading is based on several factors: the delivery of oxygen to the tissue, the utilization of oxygen by the tissue, and the diffusion of oxygen through the tissue and skin. Caution in interpreting the transcutaneous P_{O_2} measurements during acute cellulitis or edema is warranted because the presence of either of these disorders can increase oxygen utilization and decrease oxygen diffusion, thereby resulting in lower measurements of P_{O_2}. Paradoxical measurements are also reported on the plantar skin of the foot. In spite of these limitations, transcutaneous P_{O_2} and transcutaneous partial pressure of carbon dioxide (P_{CO_2}) are both statistically accurate in predicting amputation healing, but this does not rule out false-negative results.

Xenon Studies

Xenon-133 (^{133}Xe) skin clearance studies are used successfully to predict healing of amputations, but the preparation of the mixture containing xenon-133 gas and saline solution and the administration of the test are time consuming, highly technician dependent, and expensive. A small amount of the xenon and saline solution is injected intradermally at various sites, and the rate of washout is monitored by gamma camera. Xenon-133 is almost never used today and is primarily of historical interest.

Fluorescence Studies

Skin fluorescence studies use intravenous injection of fluorescein dye and subjective observation or digital fluorometers to assess skin blood flow and correlate this with the likelihood of successful wound healing. The technique is not commonly used, and studies to assess its accuracy yielded conflicting results.

Arteriography

Arteriography is not helpful in predicting successful healing of amputations, and this invasive test is probably not indicated solely for the purpose of selecting the proper level of amputation. Arteriography is indicated if the patient is truly a candidate for arterial reconstruction or angioplasty.

Nutrition and Immunocompetence Studies

Both nutrition and immunocompetence correlate directly with amputation wound healing. Many laboratory tests are available to assess nutrition and immunocompetence, but some are quite expensive. Screening tests for albumin level and total lymphocyte count are readily available and inexpensive. Several studies show increased healing of amputations in patients who have vascular disorders but have a serum albumin level of at least 3 g/dL and a total lymphocyte count exceeding 1500/mL. Nutritional screening is recommended to allow for nutritional improvement preoperatively and to help determine whether a higher level of amputation is needed.

Other Issues

Activity level, ambulatory potential, cognitive skills, and overall medical condition must be evaluated to determine if the distal-most level of amputation is really appropriate for the patient.

For patients who are likely to remain ambulatory, the goals are to achieve healing at the distal-most level that can be fit with a prosthesis and to make successful rehabilitation possible. Newer studies of patients with vascular insufficiency and diabetes demonstrate that successful wound healing can be achieved in 70–80% of these patients at the transtibial or more distal amputation level. This is in sharp contrast to 25 years ago, when because of a fear of wound failure, surgeons elected to perform 80% of all lower extremity amputations at the transfemoral level.

For nonambulatory patients, the goals are not simply to obtain wound healing but also to minimize complications, improve sitting balance, and facilitate position transfers. Occasionally, a more proximal amputation more successfully meets these goals. For example, a bedridden patient with a knee flexion contracture might be better served with a knee disarticulation than a transtibial amputation, even if the biologic factors are present to heal the more distal amputation. Preoperative assessment of the patient's potential ability to use a prosthesis, the patient's specific needs for maintaining independent transfers, and the best weight distribution for seating can help in making wise decisions concerning the appropriate level of amputation and the most successful type of postoperative rehabilitation program.

Some nonambulatory patients do benefit from a partial foot amputation, or even transtibial amputation with prosthetic fitting, not with the goal of walking but to use that leg as a standing pivot for independent transfers. In these cases, prosthetic fitting is justified.

TRAUMA

As vascular reconstruction techniques improved, more attempts to salvage limbs were initially made, often with the result that multiple surgical procedures were subsequently required. In many cases, amputation was ultimately performed after a substantial investment of time, money, and emotional energy. Current studies offer guidelines for immediate or early amputation and show the value of amputation not only in saving lives but also in preventing the emotional, marital, and financial disasters that can follow unwise and desperate limb salvage attempts. Although several scoring systems for mangled limbs are published, none can perfectly predict when an amputation should be performed. These scores can help in the decision-making process, but good clinical experience and judgment are still required.

The absolute indication for amputation in trauma remains an ischemic limb with unreconstructable vascular injury. Massively crushed muscle and ischemic tissue release myoglobin and cell toxins, which can lead to renal failure, adult respiratory distress syndrome, and even death. In two groups of high-risk patients (multiply injured patients and elderly patients with a mangled extremity), limb salvage, even though technically possible, can become life-threatening and generally should be avoided. In all patients, the decision about whether to undertake immediate or early amputation of a mangled limb must also depend on whether it is an upper extremity or lower extremity.

An upper extremity can function with minimal or protective sensation, and even a severely compromised arm can serve as an assistive limb. An assistive upper extremity often functions better than the currently available prosthetic replacements. The decision of salvage versus amputation in the upper limb should be based on the chance of maintaining some useful function, even if that function is limited.

In the lower extremity, weight bearing is mandatory. A lower limb functions poorly without sensation, and an assistive limb is not useful. A salvaged lower limb often functions worse than a modern prosthetic replacement unless the limb can tolerate full weight bearing, is relatively pain free, has enough sensation to provide protective feedback, and has durable skin and soft-tissue coverage that does not break down whenever walking is attempted. The decision to salvage a mangled lower extremity should be based on providing a limb that can tolerate the demands of walking.

FROSTBITE

Exposure to cold temperatures can directly damage the tissue and cause a related vascular impairment from endothelial vessel injury and increased sympathetic tone. If the foot or hand is wet or directly exposed to the wind, cold injury can result even in temperatures above freezing. The immediate treatment involves restoring the core body temperature and then rewarming the injured body part in a water bath at a temperature of 40–44°C for 20–30 minutes. Rewarming can be painful, and the patient often requires opiate analgesia. After rewarming, the involved part should be kept dry, blisters left intact, and dry gauze dressings used. The goals are to keep the injured extremity clean and dry and to prevent maceration, especially between the digits.

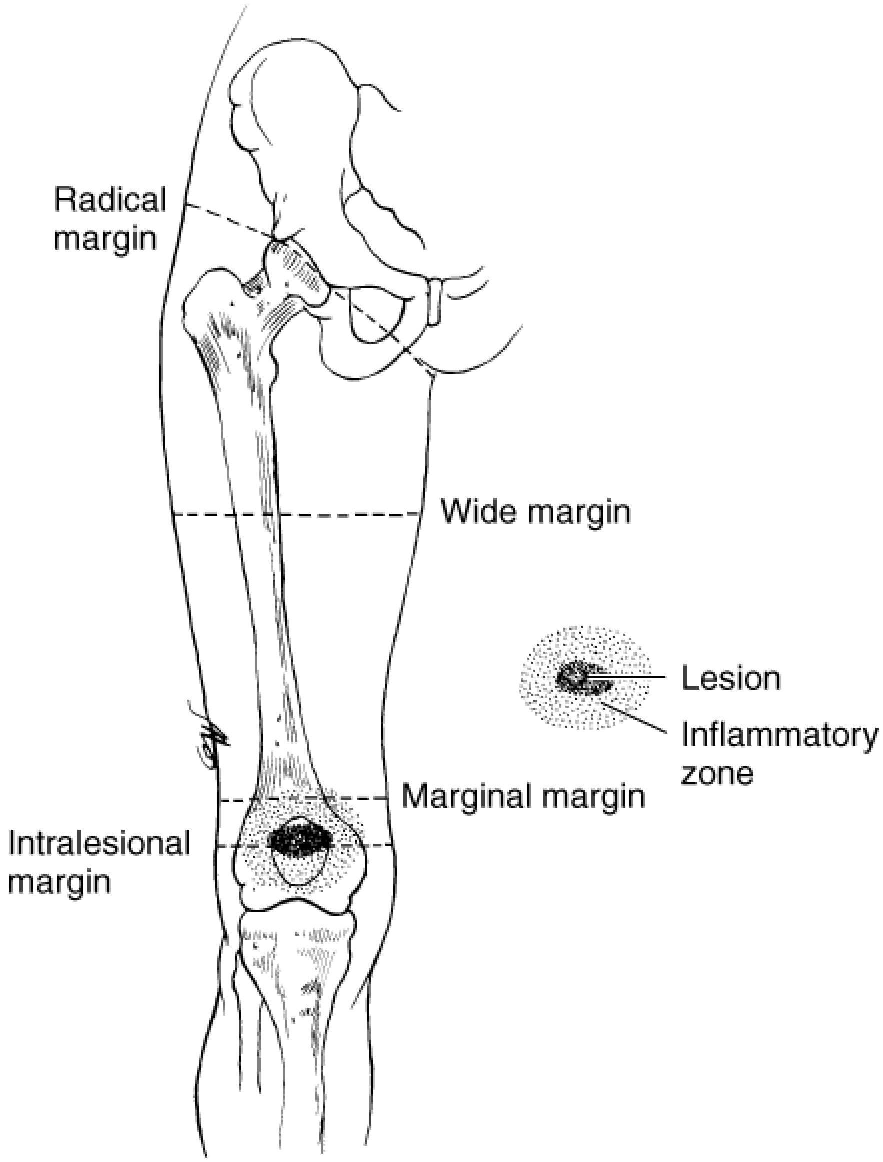
The temptation to perform early amputation should be avoided because the amount of recovery can be dramatic. As the extremity recovers from frostbite, a zone of mummification (dry gangrene) develops distally, and a zone of intermediate tissue injury forms just proximal to this. Even at the time of clear demarcation, the tissue just proximal to the zone of mummification continues to heal from the cold insult, and although the outward appearance is often pink and healthy, this tissue is not totally normal. Delaying amputation can improve the chance of primary wound healing. It is not unusual to wait 2–6 months for definitive surgery. In spite of having mummified tissue, infection is rare if the tissue is kept clean and dry.

TUMORS

Patients with musculoskeletal neoplasms face new choices in treatment with the development of limb salvage techniques and adjuvant chemotherapy and radiation therapy. If an amputation is chosen, the amputation incisions must be carefully planned to achieve the appropriate surgical margin.

Surgical margins (Figure 12–3) are characterized by the relationship of the surgical incision to the lesion, to the inflammatory zone surrounding the lesion, and to the anatomic compartment in which the lesion is located. The four types of margins are the intralesional margin, in which the surgical incision enters the lesion; the marginal margin, in which the incision enters the inflammatory zone but not the lesion; the wide margin, in which the incision enters the same anatomic compartment as the lesion but is outside of the inflammatory zone; and the radical margin, in which the incision remains outside of the involved anatomic compartment. Biopsy incisions and amputation incisions must be planned with careful consideration as to the tumor margin required.

Figure 12–3.



Surgical margins in tumors of the extremity.

Newer studies continue to evaluate the complex issues and outcomes of amputation versus limb-sparing procedures for patients with extremity sarcomas. Studies still suggest that functional outcomes in terms of kinesiologic parameters are comparable with either limb salvage or amputation. Both treatment groups report quality of life problems involving employment, health insurance, social isolation, and poor self-esteem. Overall survival remains comparable with either treatment. In some tumors, amputation may achieve better local disease control. These results confirm that the decision about treatment must be made on an individual basis, according to the specific lifestyle and needs of the patient.

Surgical Definitions & Techniques

Terminology for amputation level now uses an accepted international nomenclature. *Transtibial* should be used instead of below knee, and *transfemoral* instead of above knee. In the upper extremity, the terms *transradial* and *transhumeral* replace the older terms below elbow and above elbow.

Careful surgical techniques, especially in soft-tissue handling, are more critical to wound healing and functional outcome in amputation procedures than in many other surgical procedures. The tissues are often traumatized or poorly vascularized, and the risk of wound failure is high, particularly if close attention is not paid to soft-tissue technique. Flaps should be kept thick, avoiding unnecessary dissection between the skin and subcutaneous, fascial, and muscle planes. In adults, periosteum should not be stripped proximal to the level of transection. In children, however, removing 0.5 cm of the distal periosteum may help prevent terminal overgrowth. The rounding of all bone edges and the beveling of prominences are necessary for optimal prosthetic use.

Muscle loses its contractile function when the skeletal attachments are divided during amputation. Stabilizing the distal insertion of muscle can improve residual limb function by preventing muscle atrophy, providing counterbalance to the deforming forces resulting from amputation, and providing stable padding over the end of the bone. Myodesis is the direct suturing of muscle or tendon to the bone or the periosteum. Myodesis techniques are most effective in stabilizing strong muscles needed to counteract strong antagonistic muscle forces, such as in cases involving transfemoral or transhumeral amputation and in cases involving knee or elbow disarticulation. Myoplasty involves the suturing of muscle to muscle over the end of the bone. The distal stabilization of the muscle is more secure with myodesis than with myoplasty. Care must be taken to prevent a mobile sling of muscle over the distal end of the bone, which usually results in a painful bursa.

The transection of nerves always results in neuroma formation, but all neuromas are not symptomatic. Historical attempts to diminish symptomatic neuromas include clean transection, ligation, crushing, cauterization, capping, perineural closure, and end-loop anastomosis. No technique is more effective than careful and meticulous isolation, retraction, and clean transection of the nerve. This allows the cut end to retract into the soft tissues, away from the scar, pulsating vessels, and prosthetic pressure points. Ligation of a nerve is still indicated to control bleeding from the blood vessels contained within larger nerves, such as the sciatic.

Split-thickness skin grafts are generally discouraged except as a means to save a knee or elbow joint that has a stable bone and good muscle coverage. Skin grafts do best with adequate soft-tissue support and are least durable when closely adherent to bone. New prosthetic interfaces, such as silicone-based liners, can help reduce the shear at the interface and improve durability in skin-grafted residual limbs.

An open amputation is occasionally necessary to control a severe ascending infection. The term *guillotine amputation* should be avoided because it gives the impression that the limb is transected at one level through skin, muscle, and bone. Open amputations need to be performed with careful planning and forethought as to how the amputation will eventually be closed. The surgical plan must obviously consider adequate debridement of tissue necrosis and drainage of infection but must also consider the surgical flaps and tissue needed for a functional closure of the amputation to allow prosthetic fitting.

The problem of ascending infection is seen, for example, in a diabetic patient with a severe infection of the foot and cellulitis extending upward to the calf. The open amputation removes the source of infection, provides adequate drainage, and allows the acute cellulitis to resolve. After resolution, a definitive amputation and closure can be done safely. In the case of a diabetic foot infection, an open ankle disarticulation is simple, relatively bloodless, and preserves the posterior calf flap for a definitive transtibial amputation. Occasionally, it is necessary to make a longitudinal incision to drain the posterior tibial, anterior tibial, or peroneal tendon sheaths, in which case care should be taken not to violate the posterior flap of the definitive amputation. This approach often prevents having open, transected muscle bellies that can retract and become edematous—a problem that commonly occurs if an open calf-level amputation was initially performed and one that can make the definitive amputation difficult. In more severe infections or in cases in which the level of the definitive amputation will clearly be transfemoral, an open knee disarticulation has the same advantages as the open ankle disarticulation.

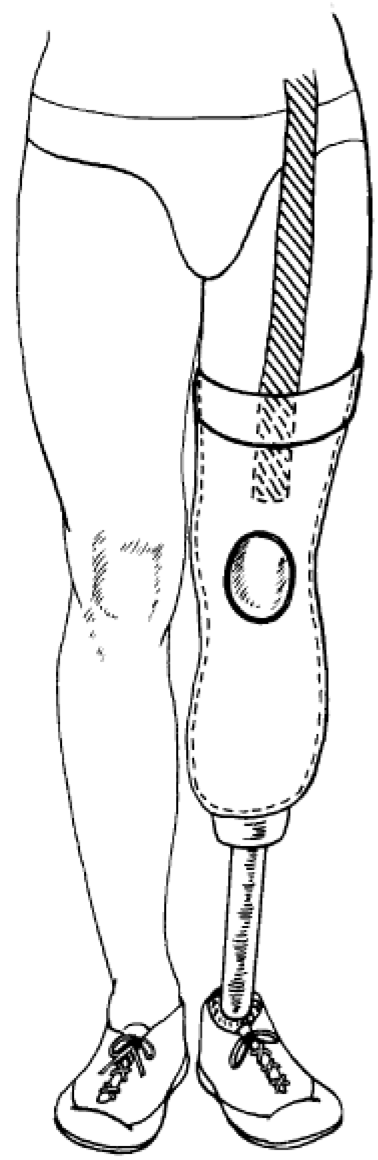
Postoperative Care

POSTOPERATIVE CARE AND PLANNING

The terminal amputation allows the unique opportunity to manipulate the physical environment of the wound during healing. A variety of methods are described, including rigid dressings, soft dressings, controlled environment chambers, air splints, and skin traction. The use of a rigid dressing controls edema, protects the limb from trauma, decreases postoperative pain, and allows early mobilization and rehabilitation.

The use of an immediate postoperative prosthesis, or IPOP (Figure 12–4), is effective in decreasing the time to limb maturation and the time to definitive prosthetic fitting. In most cases involving a lower limb amputation, the surgeon has the patient start with partial weight bearing if the wound appears stable after the first cast change, which usually takes place between the fifth and tenth day after surgery. Immediate postoperative weight bearing can be initiated safely in selected patients, usually young patients in whom an amputation was performed following a traumatic injury and above the zone of injury. Rigid dressings and the IPOP need to be applied carefully, but their application is easily learned and well within the scope of interested physicians. For upper extremity amputations, an IPOP can be applied immediately. Early training with an IPOP is believed to increase the long-term acceptance and use of a prosthesis. Chapter 13 offers a detailed discussion of rehabilitation.

Figure 12–4.



Immediate postoperative prosthetic cast for transtibial amputation.

To counsel patients adequately , some insight into the typical surgical and postoperative course can be helpful. Many patients require inpatient hospital care for 5–8 days after a transtibial amputation. Epidural or patient-controlled analgesia is usually required for pain control. Assistance with basic mobility and emotional support are also necessary. Antibiotics can minimize the risk of infection. The cast applied at the end of the surgical procedure is changed about postoperative day 5. If the wound healing is adequate, a new cast with a foot attachment is applied, and the patient can begin ambulating with approximately 30 lb of weight on the amputated extremity. Transtibial amputees are discharged to home or a nursing facility typically 5 or 8 days after surgery. Outpatient visits are scheduled weekly to change the cast, which frequently becomes loose as edema lessens, and to monitor wound healing and allow suture removal. Active and active-assisted knee range of motion (ROM) is performed between each cast.

On average, approximately six casts are applied on a weekly basis until the wound heals, edema resolves, wrinkles return to the skin, and the patient is ready for prosthetic fitting. The cast and the prosthetic foot attachment are applied and aligned by either the surgeon or the prosthetist. New prefabricated, removable postoperative prosthetic systems are alternatives to the traditional casting techniques. Unfortunately, comparison trails versus traditional techniques have not been done.

Close interaction between the patient, the physical therapist, and the prosthetist is required in the first 12–18 months. The socket made for the first prosthesis must allow modifications as the residual limb continues to change shape during this time. Volume changes and mismatch between the shape of the socket and the evolving shape of the residual limb are treated with amputation socks and by adding pads to the socket or socket liner. Pads are usually needed in the region that contacts the anteromedial and anterolateral tibial flares, and posteriorly, in the popliteal region. Even with careful modifications, the prosthetic socket must be changed two or three times in the first 18 months. Because of these frequent prosthetic modifications, encouraging the patient to work with a prosthetic provider who is located close to the patient's residence can help tremendously in this rehabilitation phase. Many patients have an immediate desire to have the most advanced and high-tech components in their first prosthesis. But often these components are designed for higher activity levels than are typically achieved in the rehabilitation phase and are too rigid. Discussing how the prosthesis will evolve and be upgraded as the patient's activity increases can ease this process. A new prosthesis is typically required around month 18; the old components often can be turned into a shower leg.

PREVENTION AND TREATMENT OF COMPLICATIONS

Failure of the Wound to Heal Properly

Problems with wound healing, especially in diabetic and ischemic limbs, occur as the result of insufficient blood supply, infection, or errors in surgical technique. Healing failure rates are difficult to interpret because they depend so much on the level of amputation selected. Low failure rates can be achieved by doing amputations at an extremely proximal level in the majority of cases, but this sacrifices the rehabilitation potential of many patients because the ability to ambulate decreases dramatically with a transfemoral amputation. Wound healing failure that necessitates reamputation at a more proximal level occurs in approximately 5–10% of cases at centers specializing in amputee treatment.

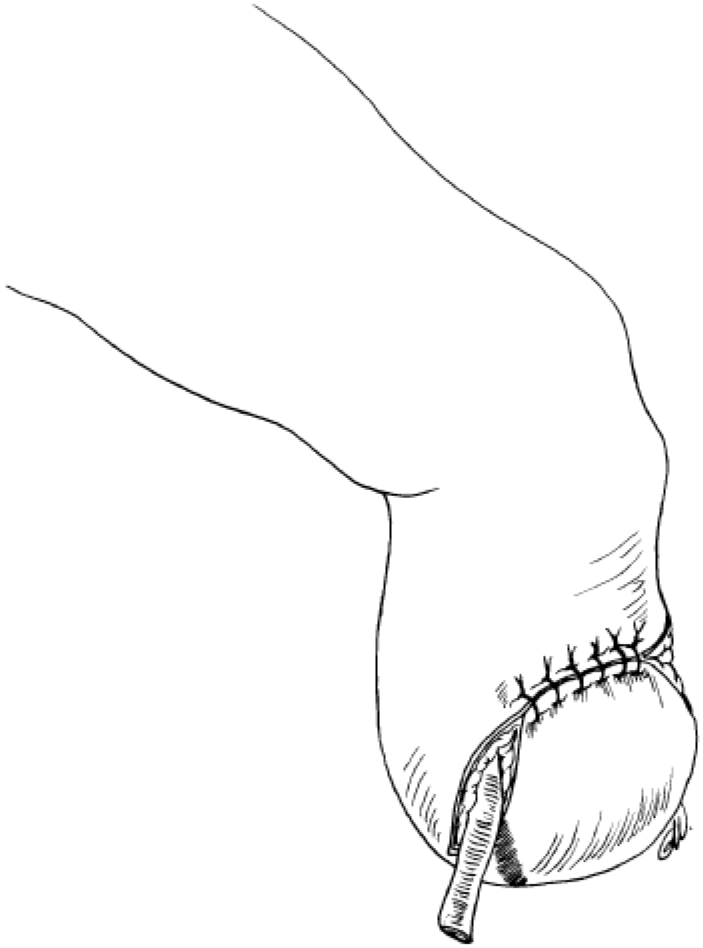
Most surgeons prefer open wound care if the wound gap is less than 1 cm wide and prefer revision surgery if the gap is wider. If the surgical edema has resolved and some atrophy has already occurred, a wedge excision of all nonviable tissue can be performed and still allow primary closure without any tension at the original level. If it is not possible to oppose the viable tissue gently without tension, bone shortening or reamputation at a more proximal level should be performed.

In patients with small local areas of wound-healing failure, successful treatment with rigid dressings and an IPOP is reported. The wounds are debrided weekly and packed open, and the IPOP is applied to allow some weight bearing. The stimulation of weight bearing can increase local circulation, decrease edema, and promote wound healing.

Infection

Infection without widespread tissue necrosis or flap failure may be seen after surgery, especially if active distal infection was present at the time of the definitive amputation or if the amputation was done near the zone of a traumatic injury. Hematomas can also predispose a wound to infection. In cases involving infection or hematomas, the wound must be opened, drained, and debrided. If the wound is allowed to remain open for an extended time, the flaps retract and become edematous, which makes delayed closure difficult or impossible without shortening the bone. One solution, which can be instituted after thorough debridement and irrigation, is to close only the central one third to one half of the amputation wound and to use open packing for the medial and lateral corners (Figure 12–5). This method provides coverage of the bone but also allows adequate drainage and open wound management for the edges. If the original problem was truly infection and not tissue failure, the open portions of the wound heal secondarily, and the result is still a residual limb suitable for prosthetic fitting.

Figure 12–5.



Partial closure of the infected transtibial amputation.

Phantom Sensation

Phantom sensation is the feeling that all or a part of the amputated limb is still present. This sensation is felt by nearly everyone who undergoes surgical amputation, but it is not always bothersome. Phantom sensation usually diminishes over time, and telescoping (the sensation that the phantom foot or hand has moved proximally toward the stump) commonly occurs.

Pain and Phantom Pain

Phantom pain is defined as a bothersome, painful, or burning sensation in the part of the limb that is missing. Although from 80% to 90% of patients with acquired amputation experience some episodes of phantom pain, the episodes are often infrequent and brief. The dreaded problem of unrelenting phantom pain fortunately occurs only in a much smaller minority of patients. Surgical intervention for this problem is not very successful.

Local physical measures, including massage, cold packs, exercise, neuromuscular stimulation by external electrical currents, acupuncture, and regional sympathectomy, may under given circumstances have a place in therapy when the pain is intractable. A technique that has gained some acceptance and success is the use of transcutaneous electrical nerve stimulation (TENS), incorporated either into a prosthesis or used as an isolated unit. The TENS system can be worn by the amputee at night and even during the day with the battery pack attached to the belt or inside a pocket. We use this TENS system with moderate short-term success, but it is rare to see a patient who continues to use a TENS system for more than a year.

Pharmacologic treatment shows some success with several oral agents including gabapentin, amitriptyline, carbamazepine, phenytoin, and mexiletine. Medications can decrease the frequency of phantom pain episodes and decrease the intensity of these episodes. The appropriate use of an intravenous lidocaine challenge is predictive of a favorable response to oral mexiletine. Unfortunately, no indicators are good at predicting who will respond to treatment with gabapentin, amitriptyline, carbamazepine, or phenytoin. Psychological support can be beneficial, particularly when personality problems seem to accentuate the occurrence of pain. The individual needs patience and reassurance that the discomfort will improve with time, especially when a supportive social environment is present.

The sensations described by patients with phantom pain may be similar to the symptoms of reflex sympathetic dystrophy after an injury. Reflex sympathetic dystrophy can occur in amputated limbs and should be treated aggressively if present. Although rare, pain unrelated to the amputation can easily be overlooked. The differential diagnosis includes radicular nerve pain from proximal entrapment or disk herniation, arthritis of proximal joints, ischemic pain, and referred visceral pain.

Research has progressed in the prevention of phantom limb pain. Several authors document that the use of perioperative epidural anesthesia or intraneural anesthesia can block the acute pain associated with amputation surgery and decrease the opiate requirements in the immediate postoperative period. They also suggest that perioperative analgesia can prevent or decrease the later incidence of phantom pain, although this is difficult to document. The literature unfortunately is not conclusive on whether preemptive measures can truly reduce the frequency or severity of phantom limb pain. Some reports dispute the claims that preemptive analgesia reduces the frequency of phantom limb problems. A randomized trial by Lambert and colleagues found that perioperative epidural block started 24 hours before amputation is not superior to infusion of local anesthetic via a perineural catheter in preventing phantom pain but does give better relief in the immediate postoperative period.

Edema

Postoperative edema is common in patients who have undergone amputation. Rigid dressings can help reduce this problem. If soft dressings are used, they should be combined with stump wrapping to control edema, especially if the patient is a prosthetic candidate. The ideal shape of a residual limb is cylindrical, not conical. One common mistake is wrapping the stump too tightly at the proximal end, which can lead to congestion and worsening edema and also cause the residual limb to become shaped like a dumbbell. Another common mistake is not wrapping transfemoral amputations in a waist-high soft spica cast that includes the groin. If wrapped incorrectly, the limb has a narrow, conical shape, and a large adductor roll develops. Because of the difficulty in wrapping the transfemoral amputation with elastic bandages, shrinker socks with a waist belt are frequently used as a safer alternative for the transfemoral level.

Stump edema syndrome is a condition commonly caused by proximal constriction and characterized by edema, pain, blood in the skin, and increased pigmentation. The syndrome usually responds to temporary removal of the prosthesis, elevation of the residual limb, and compression.

Joint Contractures

Joint contractures usually develop between the time of amputation and prosthetic fitting. Contractures that exist preoperatively can seldom be corrected postoperatively.

In transfemoral amputees, the deforming forces are flexion and abduction. Adductor and hamstring stabilization can oppose the deforming forces. During the postoperative period, patients should avoid propping up the residual limb on a pillow and should begin active and passive motion exercises early, including lying prone to stretch the hip.

In transtibial amputees, knee flexion contractures greater than 15 degrees can cause major prosthetic problems and failure. Long leg rigid dressings, early postoperative prosthetic fitting, quadriceps-strengthening exercises, and hamstring stretching can prevent this complication. Because contractures in below-knee amputees can seldom be corrected, their prevention is paramount.

In the upper extremity amputee, shoulder and elbow flexion contractures often follow amputation, especially with short residual limbs. Efforts should be directed at prevention, with aggressive physical therapy beginning soon after surgery.

Dermatologic Problems

Good general hygiene includes keeping the residual limb and prosthetic socket clean, rinsed well to remove all soap residual, and thoroughly dry. Patients should avoid the application of foreign materials and be encouraged not to shave a residual lower limb. Shaving seems to increase the problems with ingrown hairs and folliculitis.

Reactive hyperemia is the early onset of redness and tenderness after amputation. It is usually related to pressure and resolves spontaneously.

Epidermoid cysts commonly occur at the prosthetic socket brim, especially posteriorly. These cysts are difficult to treat and commonly recur, even after excision. The best initial approach is to modify the socket and relieve pressure over the cyst. Warm heat, often with a warm tea bag; topical agents; and oral antibiotics can be required as local treatment.

Verrucous hyperplasia is a wartlike overgrowth of skin that can occur on the distal end of the residual limb. It is caused by a lack of distal contact and failure to remove normal keratin. The disorder is characterized by a thick mass of keratin, sometimes accompanied by fissuring, oozing, and infection. The infection should be addressed first, and then the limb should be soaked and treated with salicylic acid paste to soften the keratin. Topical hydrocortisone is occasionally helpful in resistant cases. Prosthetic modifications to improve distal contact must be made to prevent recurrences. Because the distal limb is often tender and prosthetic modifications are uncomfortable, an aggressive preventive approach is warranted.

Contact dermatitis sometimes occurs in amputees and can be confused with infection. The primary irritation type of dermatitis is caused by contact with acids, bases, or caustics and frequently results from failure to rinse detergents and soaps from prosthetic socks. Patients should be instructed to use mild soap and to rinse extremely well. Allergic contact dermatitis is commonly caused by the nickel and chrome in metal, antioxidants in rubber, carbon in neoprene, chromium salts used to treat leather, and unpolymerized epoxy and polyester resins in plastic laminated sockets. After infection is ruled out and contact dermatitis is confirmed, treatment begins and consists of removal of the irritant and use of soaks, corticosteroid creams, and compression with elastic wraps or shrinkers.

Superficial skin infections are common in amputees. Folliculitis occurs in hairy areas, often soon after the patient starts to wear a prosthesis. Pustules develop in the eccrine sweat glands surrounding the hair follicles, and this problem is often worse if the patient shaves. Hidradenitis, which occurs in apocrine glands in the groin and axilla, tends to be chronic and responds poorly to treatment. Socket modification to relieve any pressure in these areas can be helpful. Candidiasis and other dermatophytoses present with scaly, itchy skin, often with vesicles at the border and clearing centrally. Dermatophytoses are diagnosed with a potassium hydroxide preparation and treated with topical antifungal agents.

LENGTHENING OF RESIDUAL LIMBS

The ultimate function of an amputation depends on both the length of the bone and the quality of the soft-tissue envelope for the residual limb. Ilizarov techniques of distraction osteogenesis are applied to lengthen the tibia or ulna in amputees. Bone lengthening can be successful, but often issues of soft-tissue coverage remain. Although great success is described in a small series of congenital short transradial amputations, another author describes the pending necrosis of the skin over the tip of the lengthened ulna. Nonadherent, mobile soft tissue that can pad the distal end of the bone is vitally important to successful prosthetic fitting. Microsurgical techniques are also applied to use free tissue transfer to supply this type of coverage over bone in select patients, most often in trauma or tumor surgery. By using these techniques, the gracilis or latissimus dorsi muscle can be transferred to the end of the residual limb and covered with skin graft. The transposed tissues do not have sensation, and the bulk of the flap can lead to tremendous volume changes over the first 2 years. Lack of sensation and volume issues do complicate prosthetic fitting and function. These extraordinary techniques are probably best reserved for very select and unique circumstances.

PRESCRIPTION OF PROSTHETIC LIMBS

For lower limb prostheses, the major advances include the development of new lightweight structural materials (see Chapter 1), the incorporation of elastic response ("energy-storing") designs, the use of computer-assisted design and computer-assisted manufacturing technology in sockets, and microprocessor control of the prosthetic knee joint. For upper limb use, new electronic technology has increased the success and durability of myoelectric prostheses. The surgeon who prescribes prosthetic limbs should have a basic understanding of the general features available to match optimally the components with the patient's specific needs.

A good prosthetic prescription specifies the socket type, suspension, shank construction, specific joints, and terminal device. The socket can be a hard socket with no or minimal interface, or it can incorporate a liner. For the transfemoral amputee, a wide variety of socket shapes are available and range from the traditional quadrilateral design to the newer narrow mediolateral design. The prosthesis is suspended from the body by straps, belts, socket contour, liners that roll on the limb and then lock to the socket, suction, friction, or physiologic muscle control.

Shank construction can be either exoskeletal or endoskeletal. The older exoskeletal type has a rigid outer shell that is hollow in the center. The endoskeletal type has a central pylon or pipe surrounded by a soft and lightweight cosmetic foam cover. In the past, exoskeletal systems were more durable; however, as materials technology has improved, so has the durability and cosmetic appearance of endoskeletal systems. The endoskeletal systems also allow more adjustment and fine tuning of alignment and are now considered structurally as durable as the older exoskeletal designs. However, the cosmetic and foam covers for the endoskeletal systems are not as durable as an exoskeletal shell. Exoskeletal systems are rarely prescribed, except for very active patients without easy access to prosthetic services or for those involved in activities that would stain, tear, or destroy the endoskeletal cover. As the public's impression of disability has evolved, many active patients now decide not to cover the prosthesis and often take pride in the high-tech look of the titanium or carbon fiber components incorporated in an endoskeletal prosthesis.

A large variety of elbow, wrist, knee, and ankle joints are now available, as well as numerous terminal devices, including hands, hooks, feet, and special adaptive equipment for sports and work. The choice of an appropriate terminal device is extremely important. For an upper extremity amputee, there is no sensation in the prosthesis, and the critical feedback of touch and proprioception is missing. Initially, a hook may be a better choice than a prosthetic hand because vision must substitute for upper extremity proprioception, and a prosthetic hand blocks vision and makes dexterous use of the terminal device difficult and clumsy. In each case, the prosthetic prescription must be individualized to ensure the most efficient system for a particular patient.

Nearly all prosthetic sockets are fabricated by forming a thermoplastic or laminate socket over a plaster mold. An exact mold of the residual limb does not make a good socket for a prosthesis. The original mold must be modified to relieve the socket over areas that cannot tolerate pressure and to indent the socket over areas that can. Test sockets of clear plastic are commonly made to visualize the blanching of the skin at troublesome areas. Automated fabrication of mobility aids (AFMA) technology uses computer-assisted design and manufacturing to aid the prosthetist by digitizing the residual limb, adding the standard modifications usually applied to a mold, and allowing additional fine manipulation of the shape on the computer screen. The computer can direct the carving of the mold or fabrication of the socket. AFMA technology can decrease the time needed for the fabrication of prostheses and increase the time available for the evaluation and training of patients. The best use of AFMA is to allow fabrication of multiple sockets for one patient during the fitting process. By using computer modifications, refinements are added in each iteration, ultimately to optimize the fit and comfort of the final socket. Before AFMA, this technique was not cost effective.

Myoelectric components are exciting but should generally not be prescribed for patients until they master traditional body-powered devices and their residual limb volume is stable. Myoelectric devices are used most successfully by patients with a midlength transradial amputation. Although a long below-elbow limb has better rotation, it is less able to contain the electronics. The need for myoelectric devices is greater in patients with a more proximal upper extremity amputation, but the weight and slow speed of the myoelectric components is a deterrent for their use. Hybrid devices utilizing body power and myoelectric components can be effective. Muscles stabilized by myodesis or myoplasty techniques seem to generate a better signal for myoelectric use.

Microprocessor control systems are applied to the knee units for transfemoral amputees. The microprocessor control alters the resistance of the knee unit to flexion or extension appropriately by sensing the position and velocity of the shank relative to the thigh. The current microprocessor-controlled knee units still do not provide power for active knee extension that would assist in rising from the sitting position or in providing power to the amputee's gait and rise up stairs. The new microprocessor-controlled so-called intelligent knee units do offer superior control when walking at varied speeds, descending ramps and stairs, and walking on uneven surfaces. Patients report improved confidence and a decrease in the tendency for the knee unit to buckle. One transfemoral amputee credits this new technology for his survival by allowing him to descend 70 stories in the World Trade Center at a normal pace during the terrorist attacks.

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UPPER EXTREMITY AMPUTATIONS & DISARTICULATIONS

Hand Amputation

Although microsurgical replantation techniques have reduced the incidence of hand amputations, for many patients replantation is still not feasible or results in failure. There is considerable controversy about the best treatment for any given hand injury, and the optimal treatment takes into consideration the injured patient's occupation, hobbies, skills, and hand of dominance. The hand is a highly visible and important part of body image. Many patients with partial hand amputations can benefit tremendously from using a cosmetic partial hand prosthesis.

FINGERTIP AMPUTATION

Fingertip injuries occur frequently, and fingertip amputation is the most common type of amputation. The treatment of choice usually depends on the geometry of the defect and whether or not bone is exposed. Although a large variety of local flap procedures are used to cover defects of different shapes and sizes, there is also a growing understanding that allowing secondary healing of fingertip injuries is the treatment least prone to complications in adults as well as in children. Even if bone is exposed, simply rongeuring back the exposed bone proximal to the soft-tissue defect and allowing secondary healing can give excellent results. The amount of the bone that can be removed is limited because at least a third of the distal phalanx must be left intact to prevent a hook deformity of the nail.

Two problems frequently result from fingertip amputations: cold intolerance and hypersensitivity. Overall, regardless of which treatment is chosen, approximately 30–50% of patients experience these problems. One criticism of the many local flap procedures used to obtain coverage and primary wound healing is that all of them involve incising and advancing uninjured tissue, which extends the area of scarring and damages the fine branches of the digital nerves. Newer studies suggest that the incidence of cold intolerance and hypersensitivity may be lower with secondary healing than with skin grafts or local flaps.

THUMB AMPUTATION

The thumb, with its unique range of motion, plays the major role in all three prehensile activities of the hand: palmar grip, side-to-side pinch, and tip-to-tip pinch. Amputation of the thumb can result in the loss of virtually all hand function. Thumb amputations can involve (1) the distal third of the thumb (ie, distal to the interphalangeal joint), (2) the middle third of the thumb (ie, from the metacarpophalangeal joint to the interphalangeal joint), or (3) the proximal third of the thumb.

Thumb amputation of the distal third allows the patient to retain a tremendous amount of thumb function. Cold intolerance and hypersensitivity are frequent problems, as noted in the previous discussion of fingertip amputations. Treatment of distal third injuries should allow secondary healing of the thumb or should use relatively uncomplicated techniques for coverage.

Thumb amputation in the middle third is more complicated. The issues here are length, stability, and sensate skin coverage. More aggressive procedures may well be warranted and may consist of cross-finger flaps, volar advancement flaps, neurovascular island flaps from the dorsal index finger (radial nerve) or volar middle finger (median nerve), bone lengthening, or web space deepening.

Thumb amputation in the proximal third has a devastating impact on hand function. Local reconstruction for this degree of loss is not generally successful. Pollicization of another digit, a toe-to-hand transfer, or other complicated surgical techniques may be indicated to restore function.

DIGIT AMPUTATION

Isolated amputation of a lesser digit can cause a variety of functional and cosmetic problems. Digit amputations distal to the insertion of the sublimis flexor tendon retain active flexor tendon activity and maintain useful metacarpophalangeal joint flexion. The long flexor tendon should not be sewn to the extensor tendon because it limits the excursion of both tendons and definitely limits the function of the remaining digits.

Amputations proximal to the sublimis tendon insertion retain approximately 45 degrees of proximal phalanx flexion at the metacarpophalangeal joint through the action of the intrinsic muscles. This is usually enough to keep small objects from falling through the defect and to allow the residual finger to participate to some degree in grip. If the patient uses a cosmetic finger prosthesis and wears a ring to cover the proximal edge of the prosthesis, the amputation is almost unnoticeable.

The index finger participates principally in side-to-side and tip-to-tip pinch with the thumb. After an amputation of the index finger at the metacarpophalangeal joint, the middle finger assumes this important role. The residual second metacarpal can interfere with side-to-side pinch between the thumb and the middle finger, however. Converting this amputation to a ray amputation often can improve function and cosmesis, but the drawback is that it also narrows the width of the palm and can decrease grip and torque strength significantly. Surgical decisions must be individualized, but the second metacarpal should probably be retained if the patient uses hand tools extensively, as does a carpenter or machinist.

Amputation of the middle or ring finger at the metacarpophalangeal joint can make it difficult for the patient to hold small objects because they tend to fall through the defect. Full ray resection can narrow the central defect and occasionally improve function, but narrowing the palm can decrease grip and torque strength.

Amputation of the small finger at the metacarpophalangeal joint is often cosmetically unacceptable because of the abrupt and noticeable change in contour of the hand. Although converting a fifth digital amputation to a ray amputation by including the metacarpal can improve cosmesis, it also narrows the width of the palm and can decrease grip and torque strength. Surgical decisions must be based on individual factors and concerns.

CARPUS AMPUTATION

Amputations through the carpus are generally discouraged. Most surgeons believe the result to have no real advantages over a wrist disarticulation or transradial amputation. There are isolated reports of patients valuing the little bit of wrist flexion and extension that allows them to hold objects against their body and to stabilize objects for two-handed grasp. The flexor and extensor carpi radialis and ulnaris tendons must be reattached to provide this limited motion. The prosthetic options are less standard and generally considered to be less functional than the traditional transradial designs.

Carpus amputations should probably be considered in bilateral cases. Although rare, more patients sustaining tissue loss from ischemia are seen in the intensive care unit after prolonged resuscitations and the use of vasopressors. Without the vasopressors, these patients would die. Unfortunately, part of the body's response to these lifesaving medications can be to shunt blood flow from the distal extremities, resulting in demarcation and dry gangrene in the hands and feet. Just as in frostbite, if infection is not present, it is worthwhile to delay any surgical intervention and allow adequate time for tissue demarcation and recovery. Partial hand amputation is occasionally necessary, and if required, the carpus level should be considered.

Wrist Disarticulation

Wrist disarticulation continues to be controversial. Proponents frequently argue that it has two advantages over the shorter transradial amputation: It retains the distal radioulnar joint, which preserves more forearm rotation, and it retains the distal radial flare, which dramatically improves prosthetic suspension. Volar and dorsal fish-mouth incisions are usually best, and removal of the radial and ulnar styloids can prevent painful pressure points. Tenodesis of the major forearm motors stabilizes the muscle units and thereby improves physiologic and myoelectric performance.

Opponents of wrist disarticulation argue that prosthetic substitution after this procedure is slightly more complicated than it is after a standard transradial amputation. The prosthetic socket is more difficult to fabricate because of the bone contours. Conventional wrist units add too much length to the prosthetic arm after wrist disarticulation and therefore cannot be used. The terminal device for a wrist disarticulation also needs to be modified because of length. Myoelectric prostheses are difficult to fit because there is less space to conceal the electronics and power supply.

In spite of these prosthetic concerns, wrist disarticulation patients are often excellent upper extremity prosthetic users. Some patients with an unsatisfactory hand can gain improved function by undergoing a wrist disarticulation and using a standard prosthesis. This decision must be individualized and based on contributory factors such as severity of tissue loss, pain, functional requirements, and the patient's body image.

Transradial Amputation

The transradial amputation is extremely functional, and successful prosthetic rehabilitation and sustained use are achieved in 70–80% of patients who undergo amputation at this level. Forearm rotation and strength are proportional to the length retained. Surgical incisions are best with equal volar and dorsal flaps. A myodesis should be performed to prevent a painful bursa, facilitate physiologic muscular suspension, and allow for myoelectric prosthetic use. An extremely short transradial residual limb requires the use of a Muenster-type socket, which molds up around the humeral condyles for added suspension. Occasionally, side hinges and a humeral cuff are required to achieve suspension of the prosthesis. Both of these types of suspension preserve elbow flexion and extension but limit rotation.

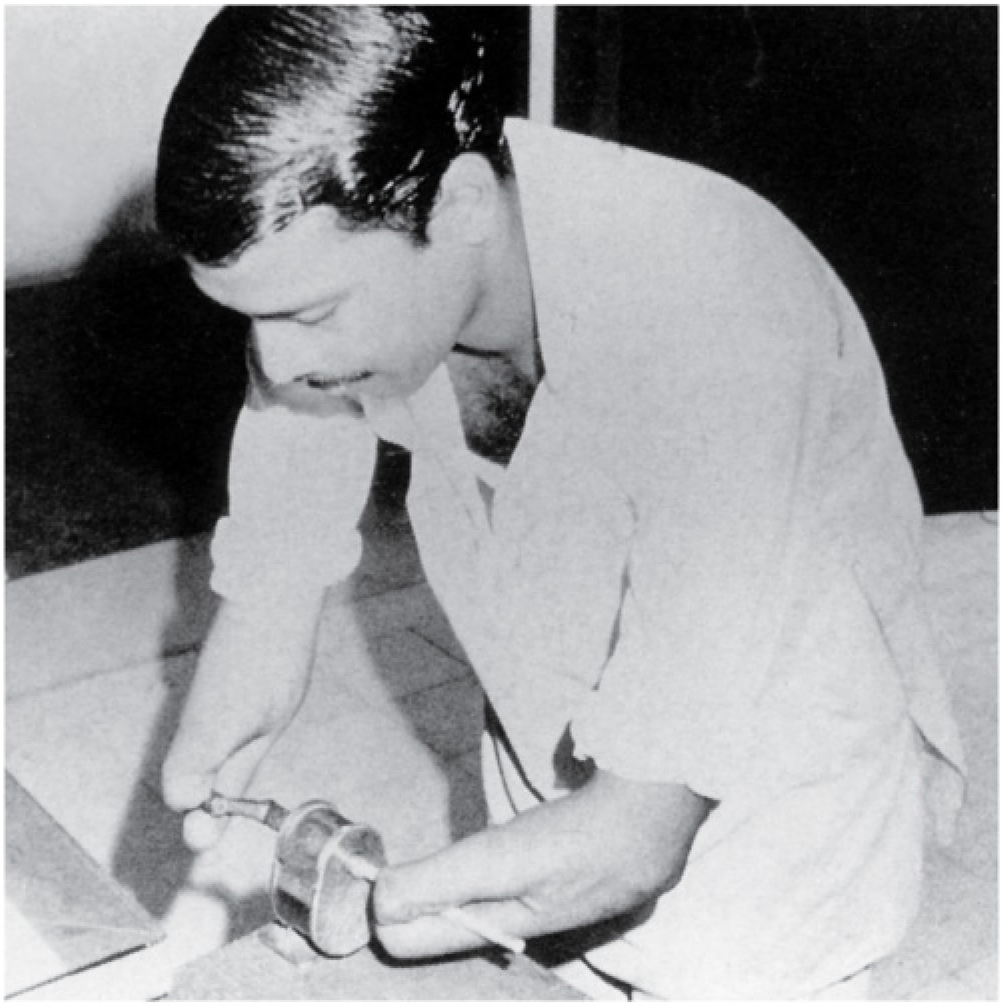
The value of preserving the elbow joint cannot be overemphasized. Skin grafts and even composite grafts should be considered to retain the tremendous functional benefit of an elbow with some active motion. Even a limited range of elbow motion can be useful, and an ingeniously designed, geared step-up elbow hinge can convert a limited active range of elbow motion to an improved prosthetic ROM. Although body-powered prostheses are extremely functional at the transradial level of amputation, this level is also the most successful level at which to use myoelectric devices.

Krukenberg Amputation

The Krukenberg kineplastic operation transforms the transradial amputation stump into radial and ulnar digits that are capable of strong prehension and have excellent manipulative ability because of retained sensation on the "fingers" of the forearm. The operation should not be performed as a primary amputation.

The Krukenberg amputation can be performed as a secondary procedure in a transradial amputee who has a residual limb of at least 10 cm from the tip of the olecranon, an elbow flexion contracture of less than 70 degrees, and good psychological preparation and acceptance. In this case, the amputee can become completely independent in daily activities because of the retained sensory ability of the pincers as well as the quality of the grasping mechanism (Figure 12–6). The Krukenberg amputation traditionally was indicated for blind patients with bilateral below-elbow amputations, but it also may be indicated at least unilaterally in bilateral below-elbow amputees who are able to see and in those who have limited access to prosthetic facilities.

Figure 12–6.



A patient with bilateral Krukenberg hands demonstrates bimanual dexterity in sharpening a pencil.

(Reproduced, with permission, from Garst RJ: The Krukenberg hand. J Bone Joint Surg Br 1991;73:385.)

A conventional prosthesis can be worn over the Krukenberg forearm, and myoelectric devices can be adapted to use the forearm motion. The major disadvantage is the appearance of the arm, which many people consider grotesque and do not accept. As society continues to become more understanding and accepting of disabled individuals, concerns about appearance may diminish. Intensive preoperative preparation and counseling are mandatory.

Elbow Disarticulation

Elbow disarticulation can be a satisfactory amputation level and has the advantage of retaining the condylar flare to improve prosthetic suspension and allow for the transfer of humeral rotation to the prosthesis. The longer lever arm improves strength. The disadvantage is in the design of the prosthetic elbow hinge. An outside hinge is bulky and hard on clothing, whereas the conventional elbow unit provides a disproportionately long upper arm and short forearm. Whether the advantages of the elbow disarticulation outweigh the disadvantages remains controversial. Surgically, volar and dorsal flaps work best, and myodesis of the biceps and triceps tendons are needed to preserve the distal muscle attachments.

Transhumeral Amputation

When transhumeral amputation is performed, efforts should be made to retain as much as possible of the bone length that has suitable soft-tissue coverage. Even if only the humeral head remains and no functional length is salvageable, an improved shoulder contour and cosmetic appearance results. Myodesis helps preserve biceps and triceps strength, prosthetic control, and myoelectric signals. In most cases of transhumeral amputation, an immediate postoperative prosthesis and rigid dressings can be used successfully. Physical therapy should focus on proximal joint and muscle function. Because the terminal prosthetic device is usually controlled by active shoulder girdle motion, early prosthetic use and therapy can prevent contracture and maintain strength.

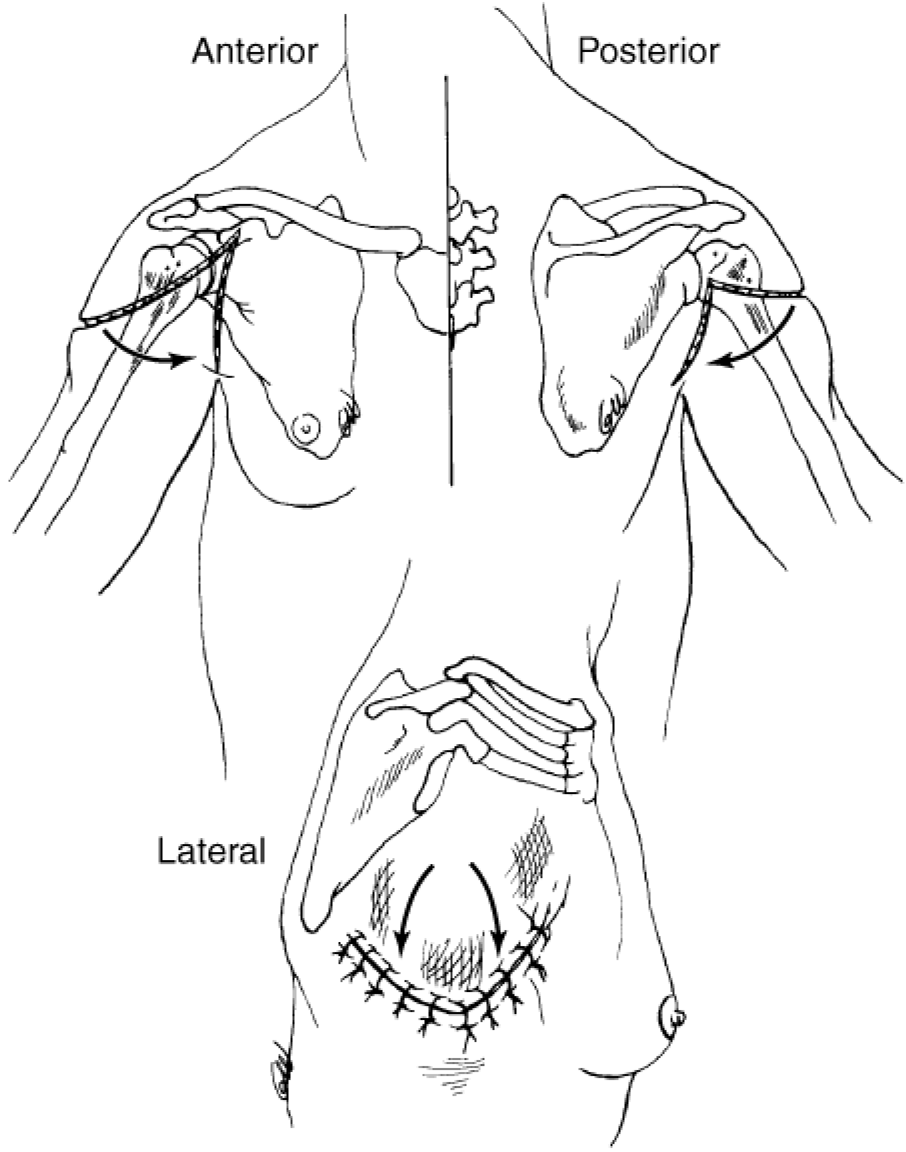
Prosthetic suspension traditionally was incorporated in the body-powered harness, which can be somewhat uncomfortable. Among the alternative techniques are humeral angulation osteotomy (rarely used), socket-suction suspension, and the newer elastomeric roll on locking liners. Many prosthetic options are available for the transhumeral amputee. One option is a prosthesis that is totally body powered. Another is a hybrid prosthesis that uses myoelectric control of one component (either the terminal device or the elbow device) and body-powered control of the other. The transhumeral prosthesis is heavy, often considered slow, and requires much mental concentration to use effectively. These issues lead many unilateral transhumeral amputees to choose not to wear a prosthesis at all or to wear only a lightweight cosmetic prosthesis for special occasions.

Transhumeral amputation is sometimes elected to manage a dysfunctional arm following a severe brachial plexus injury. The advantages of amputation are that it unloads the weight from the shoulder and scapulothoracic joints and eliminates the problem of having a paralyzed arm that gets in the way and hinders body function. The decision to undertake shoulder arthrodesis in combination with transhumeral amputation is controversial and should be made on an individualized basis. Investigators who compared two groups of patients with transhumeral amputation because of brachial plexus injury—one group without shoulder arthrodesis and one group with it—found a somewhat better return-to-work rate in the group without shoulder arthrodesis. Prosthetic expectations in these patients should be limited because prosthetic fitting adds weight to a dysfunctional shoulder girdle, often defeating one of the original goals of the amputation.

Shoulder Disarticulation & Scapulothoracic (Forequarter) Amputation

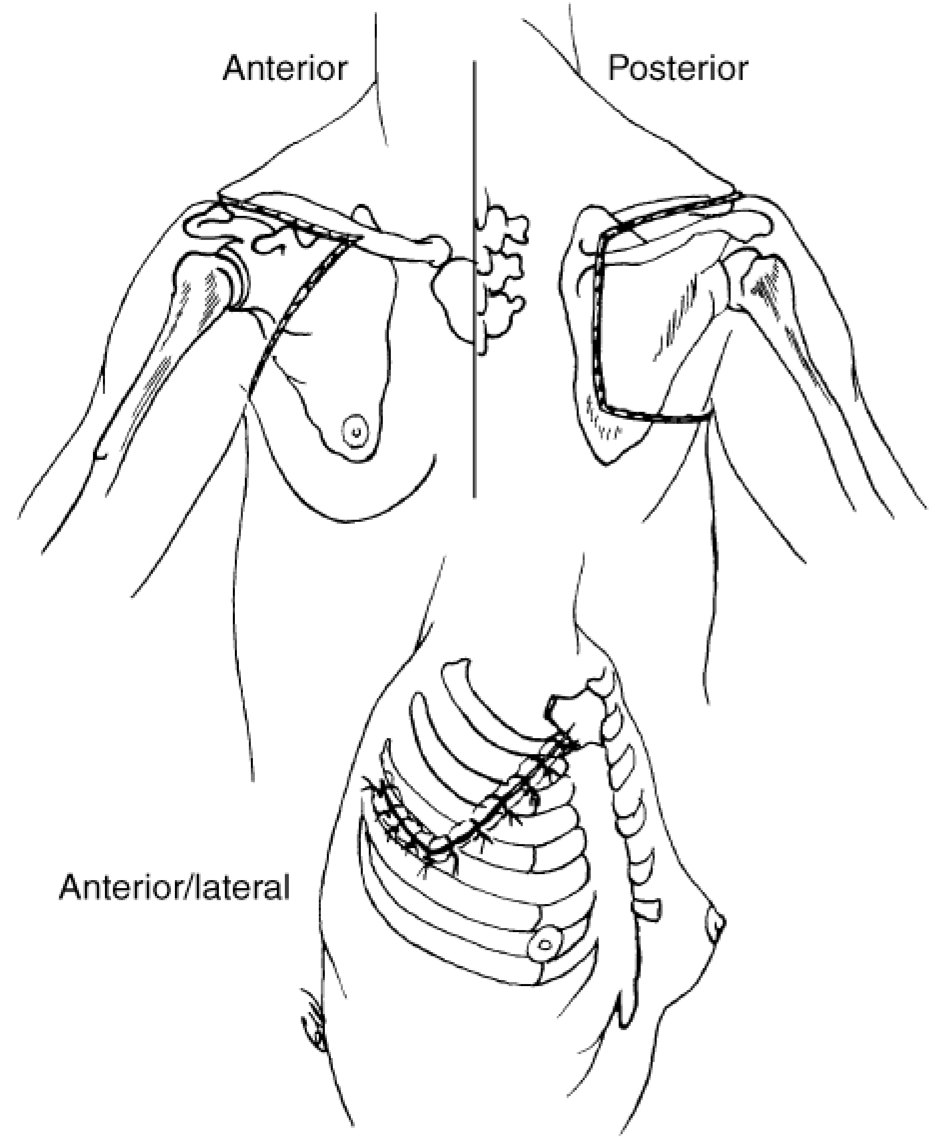
The performance of shoulder disarticulation (Figure 12–7) or scapulothoracic amputation (Figure 12–8) is rare. When either operation is performed, it is usually in cases of cancer or severe trauma. Either operation results in a loss of the normal shoulder contour and causes the patient difficulty because clothing does not fit well. Saving the humeral head, if possible, can improve the contour of a shoulder disarticulation tremendously. The scapulothoracic amputation, usually performed for proximal tumors, removes the arm, scapula, and clavicle. Dissection often extends into the neck and into the thorax.

Figure 12–7.



Shoulder disarticulation.

Figure 12–8.



Forequarter amputation.

Elaborate myoelectric prostheses are available for patients but are expensive, heavy, and require intensive maintenance. Body-powered prostheses are also heavy, hard to suspend comfortably, and difficult to use. Most patients request prosthetic help for improved cosmesis and fitting of clothes. Often a simple soft mold to fill out the shoulder meets these expectations and is an alternative to a full-arm cosmetic prosthesis.

Postural Abnormalities after High Upper Extremity Amputation

Normally, the weight of the arm and the muscle activity associated with shoulder and arm function keep the shoulders appropriately level. Unilateral hypertrophy of an upper limb, including the shoulder girdle, occurs in certain occupations and is also seen in some sports. Some people are born with a degree of asymmetry of their shoulders, which is a relatively minor postural abnormality and does not require special clothing.

When the arm is removed and the clavicle and scapula remain, the muscles elevating the shoulder girdle are unopposed by both the weight of the arm and those muscles that pass across the shoulder and tend to depress the shoulder and arm. The consequence of this imbalance is an upward elevation described as "hiking" of the shoulder girdle. This high shoulder tends to accentuate the cosmetic loss, even when the individual is wearing a cosmetic shoulder filler or a cosmetic limb. Abnormal shoulder elevation can be countered by corrective exercises beginning as soon as they can be tolerated after the amputation. The wearing of a prosthesis with its dependent weight also diminishes shoulder hike. In most circumstances, the shoulder girdle elevation is inevitable; however, its degree can be minimized by appropriate physical measures.

Removal of the entire upper limb in the growing skeleton can result in a scoliosis of the spine. Muscular imbalance is considered to be the cause of the deformity. It may be seen to a slighter degree in the adult but is primarily confined to the growing skeleton. The combined postural deformity of upper dorsal spine scoliosis and elevation of the shoulder girdle produces asymmetry of the head and neck on the trunk, with the head appearing to be placed asymmetrically as the person stands.

In general, no corrective splinting or orthotic device can successfully counteract the postural changes associated with shoulder-level amputation. Neck and shoulder-girdle exercises offer the most effective prophylaxis and treatment. The postural deficits are particularly evident with forequarter amputation. Soft, light polyurethane cosmetic restoration, either as part of a cosmetic prosthesis or separately used with the empty sleeve, counters to some degree the unsightly upper body contour.

Hand Transplantation

Hand transplantation and the suppression of rejections is now technically possible. Approximately 25 documented cases of hand transplantation have been performed with varying degrees of success. The potential benefits for the amputee are certainly many, but they must be balanced against the real risks. In general, skin, muscle, and bone marrow appear to reject earlier and more aggressively than bone, cartilage, or tendon. Preventing this rejection is an ongoing and lasting issue, with real consequences for the individual's health and life expectancy. The current immunosuppressive drugs needed to prevent rejection of a composite hand transplant include toxic side effects, opportunistic infections, and increase in malignancies.

Also, the real psychological impact following hand and other organ transplantation should not be underestimated. One study examining the issues 5 years following heart transplant showed a significant increase in emotional issues such as irritability, depression, and low self-esteem. Even for a patient with no preexisting psychological issues, living with a hand transplantation, which remains constantly in view, may not be easy.

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LOWER EXTREMITY AMPUTATIONS & DISARTICULATIONS

Foot Amputation

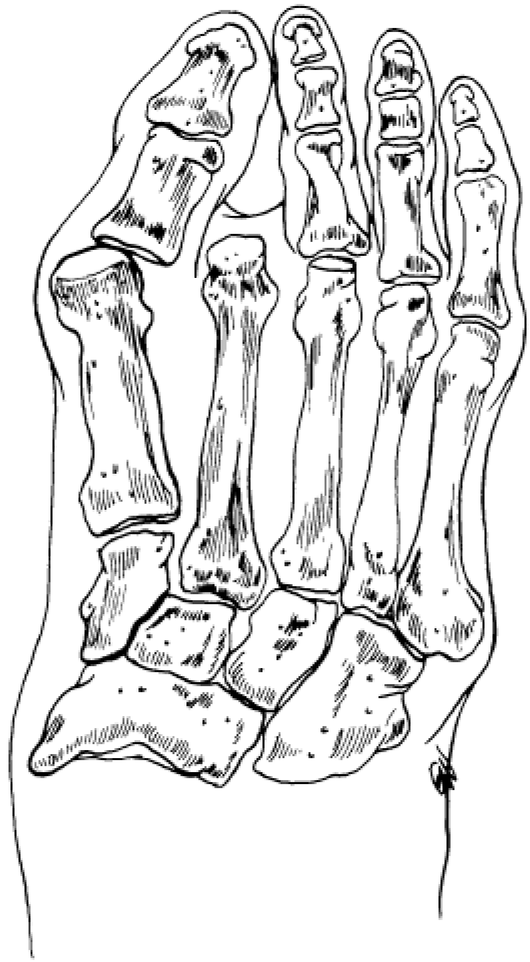
TOE AMPUTATION

Toe amputations can be performed with side-to-side or plantar-to-dorsal flaps to use the best available soft tissue. The bone should be shortened to a level that allows adequate soft-tissue closure without tension.

In great toe amputations, if the entire proximal phalanx is removed, the sesamoids can retract and expose the keel-shaped plantar surface of the first metatarsal to weight bearing. This often leads to high local pressure, callous formation, or ulceration. The sesamoids can be stabilized in position for weight bearing by leaving the base of the proximal phalanx intact or by performing tenodesis of the flexor hallucis brevis tendon.

An isolated amputation of the second toe commonly results in severe hallux valgus deformity of first toe (Figure 12–9). This situation may be prevented by amputation of the second ray or by fusion of the first metatarsal and phalanx. In the shorter toe amputations at the metatarsophalangeal joint level, transferring the extensor tendon to the capsule may help elevate the metatarsal head and maintain an even distribution for weight bearing. Prosthetic replacement is not required after toe amputations.

Figure 12–9.



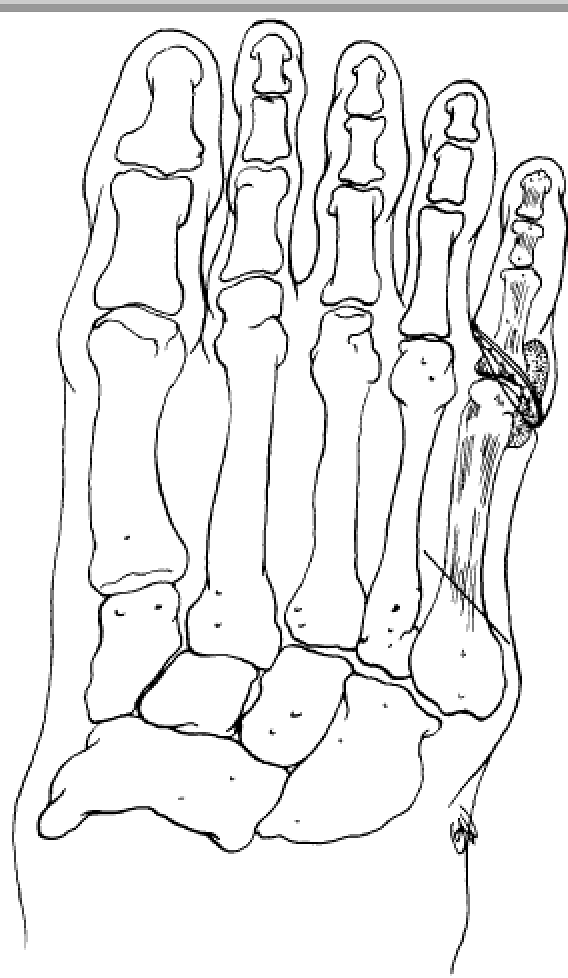
Severe hallux valgus deformity occurring after isolated second toe amputation.

RAY AMPUTATION

A ray amputation removes the toe and all or some of the corresponding metatarsal. Isolated ray amputations can be durable. Multiple ray amputations, however, especially in patients with vascular disease, can narrow the foot excessively. This increases the amount of weight that must be borne by the remaining metatarsal heads and can lead to new areas of increased pressure, callous formation, and ulceration. Surgically, it is often difficult to achieve primary closure of ray amputation wounds because more skin is usually required than is readily apparent. Instead of closing these wounds under tension, it is usually advisable to leave them open and allow for secondary healing.

The fifth ray amputation is the most useful of all the ray amputations. Plantar and lateral ulcers around the fifth metatarsal head often lead to exposed bone and osteomyelitis. A fifth ray amputation allows the entire ulcer to be excised and the wound to be closed primarily (Figure 12–10). In general, for more extensive involvement of the foot, a transverse amputation at the transmetatarsal level is more durable. Prosthetic requirements after ray amputations include extra-depth shoes with custom-molded insoles. The insole should include a metatarsal pad that loads the shafts of the metatarsal and unloads some of the pressure at the metatarsal heads.

Figure 12–10.

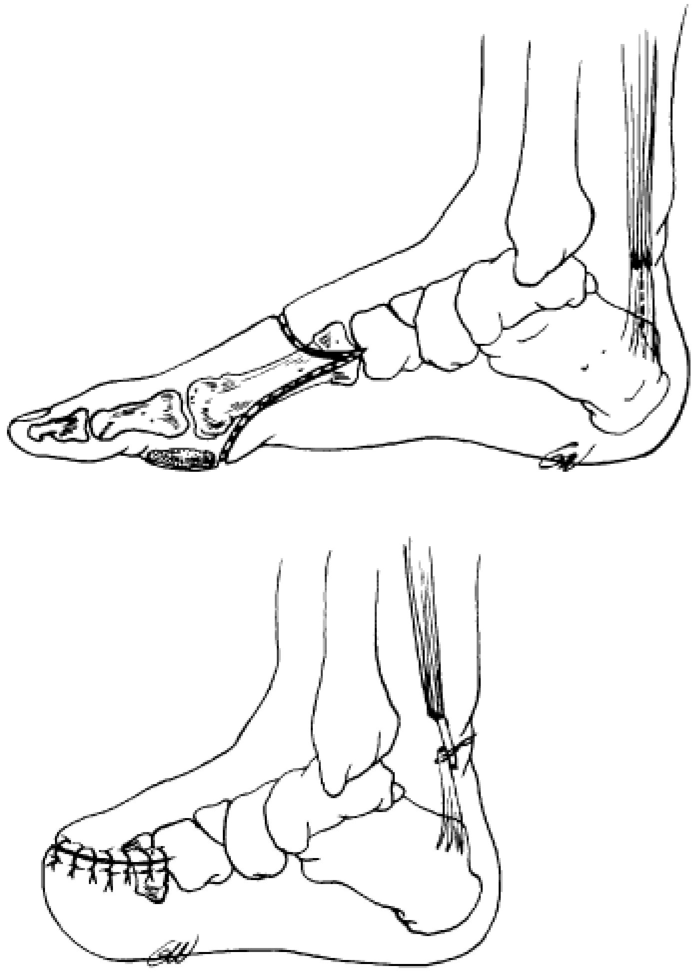


Fifth ray amputation for fifth metatarsal head ulcer.

MIDFOOT AMPUTATION

The transmetatarsal and Lisfranc amputations are reliable and durable. The Lisfranc amputation is actually a disarticulation just proximal to the metatarsals where the cuneiform and cuboid bones are retained. Surgically, a healthy, durable soft-tissue envelope is more important than a specific anatomic level of amputation, so the length of bone to be removed should be based on the ability to perform soft-tissue closure without tension. A long plantar flap is preferable, but equal dorsal and plantar flaps work well, especially for transmetatarsal amputation in the treatment of metatarsal head ulcers (Figure 12–11).

Figure 12–11.



Transmetatarsal amputation with Achilles tendon lengthening.

Muscle balance around the foot should be carefully evaluated preoperatively, with specific attention to tightness of the heel cord and strength of the anterior tibial, posterior tibial, and peroneal muscles. Midfoot amputations significantly shorten the lever arm of the foot, so lengthening of the Achilles tendon should be done if necessary. Tibial or peroneal muscle insertions should be reattached if they are released during bone resection. For example, if the base of the fifth metatarsal is resected, the peroneus brevis tendon should be reinserted into the cuboid bone. In patients with vascular disease, this can be performed with a minimal amount of dissection to prevent further compromise of the tissues.

Postoperative casting prevents deformities, controls edema, and speeds rehabilitation. Prosthetic requirements can vary widely. During the first year following amputation, many patients benefit from the use of an ankle-foot orthosis (AFO) with a long footplate and a toe filler. To prevent an equinus deformity from developing, patients should be advised to wear the orthosis except when taking a bath or shower. Later, the use of a simple toe filler combined with a stiff-soled shoe may be adequate. Cosmetic partial foot prostheses are also available.

HINDFOOT AMPUTATION

A Chopart amputation removes the forefoot and midfoot and saves only the talus and calcaneus. Rebalancing procedures are required to prevent equinus and varus deformities. Achilles tenotomy, transfer of the anterior tibial or extensor digitorum tendons, and postoperative casting are all usually necessary. Although tendon transfer to the talus was previously recommended, transfer to the calcaneus is now done to minimize varus positioning. Beveling the inferior, anterior surface of the calcaneus can remove a potential bone pressure point.

Two other types of hindfoot amputations are the Boyd and the Pirogoff amputations. The Boyd procedure consists of a talectomy and calcaneal-tibial arthrodesis after forward translation of the calcaneus. The Pirogoff procedure consists of a talectomy with calcaneal-tibial arthrodesis after the vertical transection of the calcaneus through the midbody and a forward rotation of the posterior process of the calcaneus under the tibia. These two types of hindfoot amputations are done mostly in children to preserve length and growth centers, prevent heel pad migration, and improve socket suspension.

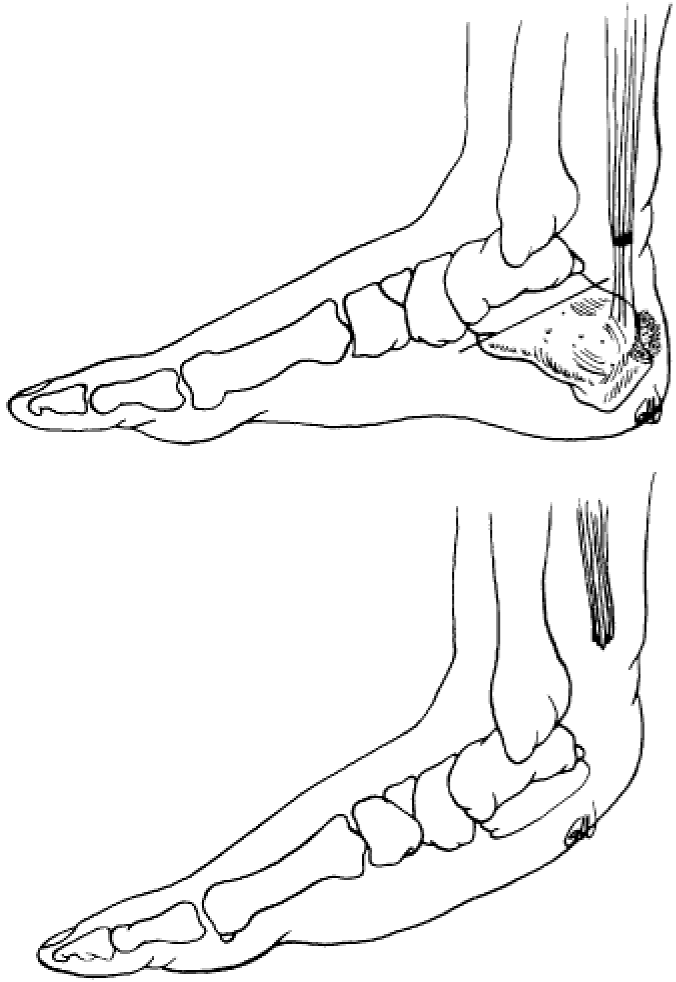
Studies in which various procedures in children are compared showed that a hindfoot amputation results in better function than a Syme amputation (see section on Syme amputation) in cases in which the hindfoot is balanced and no equinus deformity has developed.

The hindfoot prosthesis requires more secure stabilization than a midfoot prosthesis to keep the heel from pistoning during gait. An anterior shell can be added to an ankle-foot prosthesis, or a posterior opening socket prosthesis can be used.

PARTIAL CALCANECTOMY

Partial calcanectomy, which consists of excising the posterior process of the calcaneus (Figure 12–12), should be considered an amputation of the back of the foot. In selected patients with large heel ulcerations or calcaneal osteomyelitis, partial calcanectomy can be a functional alternative to transtibial amputation. The removal of the entire posterior process of the calcaneus allows for fairly large soft-tissue defects to be closed primarily. Patients must have adequate vascular perfusion and nutritional competence for wound healing to occur. As with other amputations, partial calcanectomy creates a functional and cosmetic deformity. Use of an ankle-foot prosthesis with a cushion heel is usually required to replace the missing heel and prevent further skin ulceration.

Figure 12–12.

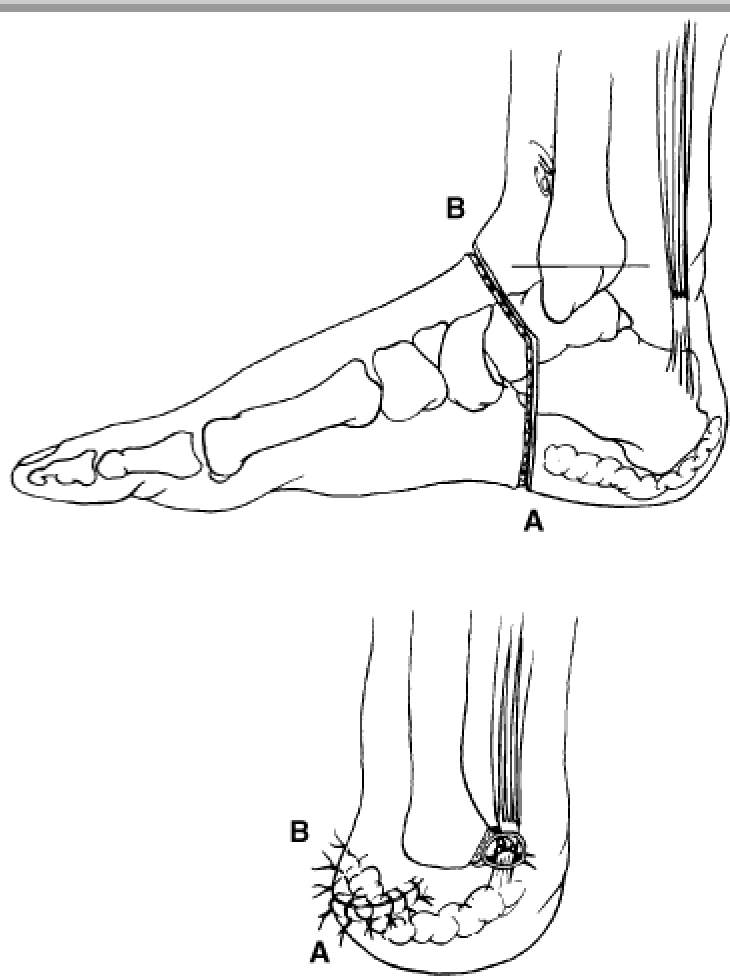


Partial calcanectomy.

Syme Amputation

In the Syme amputation, the surgeon removes the calcaneus and talus while carefully dissecting on bone to preserve the heel skin and fat pad to cover the distal tibia (Figure 12–13). The surgeon must also remove and contour the malleoli, but whether this should be done during the initial operation or 6–8 weeks later remains controversial. Proponents of the two-stage procedure argue that it can improve healing in patients with vascular disease. Opponents point out that it delays rehabilitation because the patient cannot bear weight until after the second stage of the operation. One series supports the use of the one-stage procedure, even in the presence of vascular disease or diabetes. A late complication of the Syme amputation is the posterior and medial migration of the fat pad. One of these surgical procedures can be done to stabilize the fat pad: tenodesis of the Achilles tendon to the posterior margin of the tibia through drill holes; transfer of the anterior tibial and extensor digitorum tendons to the anterior aspect of the fat pad; or removal of the cartilage and subchondral bone to allow scarring of the fat pad to bone, with or without pin fixation. Careful postoperative casting can also help keep the fat pad centered under the tibia during healing. The Syme amputation is one of the most difficult amputations to perform in terms of surgical technique and achievement of primary healing and heel pad stability.

Figure 12–13.



Syme amputation with tenodesis of the Achilles tendon to the distal tibia.

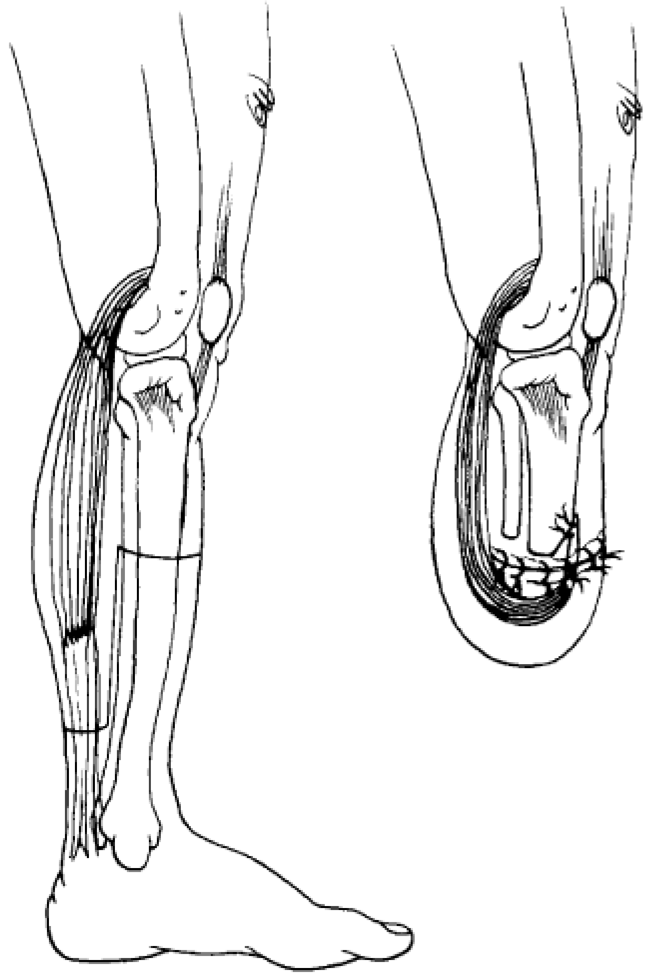
Syme amputation should be designed to allow end bearing. Retaining the smooth, broad surface of the distal tibia and the heel pad allows direct transfer of weight from the end of the residual limb to the prosthesis. A transtibial or transfemoral amputation does not allow this direct transfer of weight. Because of the ability to end-bear, the amputee can occasionally ambulate without a prosthesis in emergency situations or for bathroom activities.

The Syme prosthesis is wider at the ankle level than is a transtibial prosthesis, and this cosmetic problem can be bothersome to some patients. The surgical narrowing of the malleolar flare and the use of new materials in the prosthesis, however, can improve the appearance of the final prosthesis. Moreover, patients can now benefit from energy-storing technology provided by the newly designed lower profile elastic response feet. Sockets do not need the high contour of a patellar-tendon bearing design because of the end-bearing quality of the residual limb. The socket can be windowed either posteriorly or medially if the limb is bulbous, or a flexible socket within a rigid frame design can be used if the limb is less bulbous. Because of the tibial flare, the socket used following Syme amputation is usually self-suspending.

Transtibial Amputation

Transtibial amputation is the most commonly performed major limb amputation. The long posterior flap technique (Figure 12–14) is now standard, and good results can be expected even in the majority of patients with vascular disease. Anterior and posterior flaps, sagittal flaps, and skewed flaps can be helpful in specific patients.

Figure 12–14.



Transtibial amputation with long posterior flap technique.

Efforts should be made to preserve as much bone length as possible between the tibial tubercle and the junction of the middle and distal thirds of the tibia, based on the available healthy soft tissues. Amputations in the distal third of the tibia should be avoided because they result in poor soft-tissue padding and are more difficult to fit comfortably with a prosthesis. The goal is a cylindrically shaped residual limb with muscle stabilization, distal tibial padding, and a nontender and nonadherent scar (Figure 12–15). The transtibial amputation is especially well suited to rigid dressings and immediate postoperative prosthetic management.

Figure 12–15.

Bilateral transtibial amputations that emphasize the benefits of the long posterior flap technique. The right limb, amputated by using equal anterior and posterior flaps, is conically shaped and atrophic. The left limb, amputated by using the long posterior flap technique, is cylindrical and well padded.

(Reproduced, with permission, from Smith DG, Burgess EM, Zettl JH: Fitting and Training the Bilateral Lower-Limb Amputee, in Bowker JH, Michael JW (eds): *Atlas of Limb Prosthetics Surgical, Prosthetic, and Rehabilitation Principles.* Rosemont, IL, American Academy of Orthopaedic Surgeons, 2002, pp 599–622.)

Distal tibiofibular synostosis (Ertl procedure) should be considered for the treatment of a wide trauma-induced diastasis to improve stabilization of the bone and soft tissue. The procedure is less often indicated in the treatment of patients with vascular disease. The synostosis is developed to create a broad bone mass terminally to improve the distal end-bearing property of the limb and minimize motion between the tibia and fibula. Although there is renewed interest in these techniques, true comparison of patients with osteomyoplastic techniques versus standard techniques has not been done.

A wide variety of prosthetic designs are available for the transtibial amputee. Sockets can be designed to incorporate a liner, which offers the advantages of increased comfort and accommodation of minor changes in residual limb volume. Disadvantages include increased perspiration and a less sanitary, less comfortable feeling in hot humid weather. Hard sockets are designed to have cotton or wool stump socks of an appropriate ply or thickness as the interface between the leg and the socket. Hard sockets are easier to clean and more durable than the liners are.

The Icelandic-Swedish-New York (ISNY) socket refers to the use of a more flexible socket material that is supported by a rigid frame. The flexible socket changes shape to accommodate underlying muscle contraction. This socket style can also be useful for limbs that are scarred or difficult to fit. Open-ended sockets with side joints and a thigh corset are not used much today except by patients who wore them successfully in the past and by patients with limited access to prosthetic care. The patellar tendon-bearing shape is most commonly used for the transtibial amputee. In spite of its name, the majority of the weight is borne on the medial tibial flare and laterally on the interosseus space, whereas the rest of the weight is borne on the patellar tendon area. Even the new so-called total-contact transtibial socket, which is designed to have increased contact on all areas of the residual limb, preferentially loads the tibial flare and patellar tendon regions.

Numerous types of suspension devices are available for the transtibial prosthesis. The simplest and most common is a suprapatellar strap, which wraps above the femoral condyles and patella. Sockets can be designed to incorporate a supracondylar mold or wedge to grip above the femoral condyles, but this higher profile is bulkier and less cosmetic when the patient is sitting. A waist belt and fork strap are helpful for the patient who has a very short transtibial residual limb because these devices decrease pistoning in the socket; they are also helpful for the patient whose activities require extremely secure suspension. If the patient has a limb with poor soft tissue or has intrinsic knee pain, side hinges and a thigh corset can help unload the lower leg and transfer some of the weight to the thigh.

External suspension sleeves made of latex or neoprene are still used quite frequently. Latex is more cosmetic but less durable and can be constricting. Neoprene is more durable and not as constricting but sometimes causes contact dermatitis. The newest suspension uses an elastomeric or silicone-based liner that is rolled on over the residual leg and offers an intimate friction fit. A small metal post on the distal end of the liner then locks into a catch in the prosthetic socket to suspend the socket securely to the liner. Many patients who use these elastomeric locking liners like the secure suspension and feeling of improved control of the prosthesis. The liners have the disadvantages of being less durable and requiring frequent replacement. These elastomeric locking liners can be expensive. Although elastomeric locking liners were originally touted as preventing skin problems; rashes, skin irritation, and skin breakdown remain a frequent complaint even with this new technology, however. Approximately a third of amputees cannot tolerate the forces generated at the distal part of the amputation with liners using the metal post or pin lock system. New techniques were designed to attach the elastomeric liner to the socket with vacuum pumps, clips on the side of the liner, or sealing liners and one-way socket valves to maintain a suction between the liner and the socket. Suspension must be individualized, and no system is yet proven acceptable to all amputees.

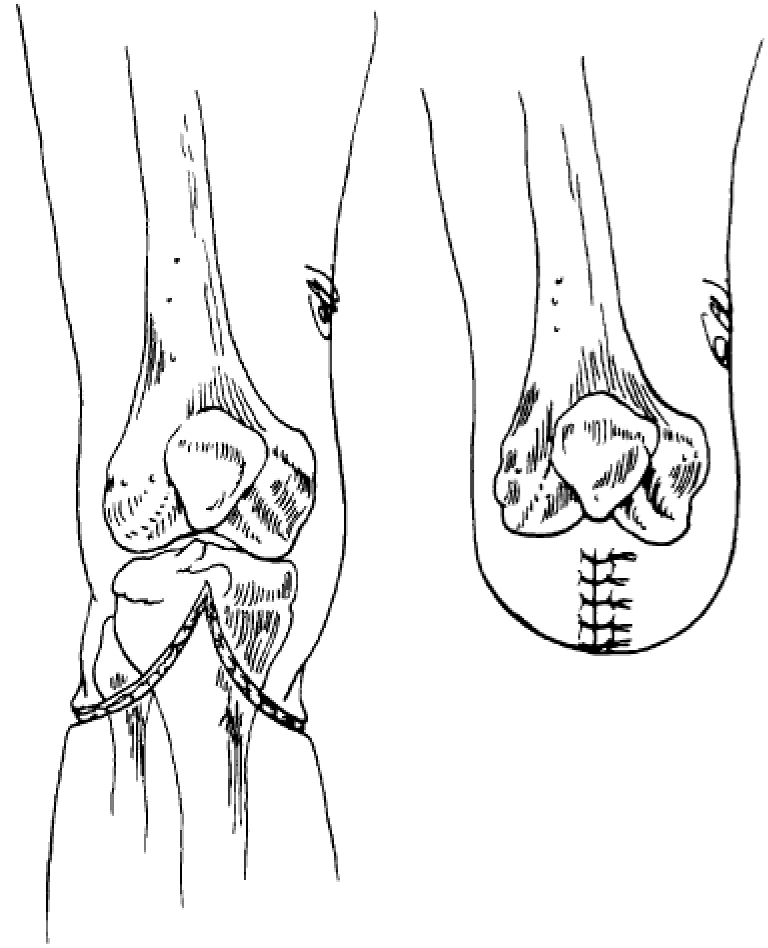
Many different designs for prosthetic feet are now available, ranging from the original solid ankle cushion heel (SACH) foot to the newer elastic response technology with a variety of keel, ankle, and pylon designs. Cost and function can vary widely, and care should be used in prescribing an appropriate prosthetic foot for an individual patient. A common error is to prescribe a foot that is either too stiff or does not get to feel flat quickly enough for an individual patient, especially in the first 12–18 months after an amputation.

Knee Disarticulation

Disarticulation through the knee joint (Figure 12–16) is indicated in ambulatory patients when a below-knee amputation is not possible but suitable soft tissue is present for a knee disarticulation. These circumstances are most commonly found in cases involving traumatic injuries. In patients with vascular disease, the blood supply is such that if a knee disarticulation would heal, a short transtibial amputation would usually heal as well. The knee disarticulation is indicated in patients who have vascular problems and are nonambulatory, especially if knee flexion contractures or spasticity are present.

Although sagittal flaps or the traditional long posterior flap can be used to take advantage of the best available soft-tissue coverage, newer literature supports use of the posterior flap technique when possible. The patella is retained and the patellar tendon sutured to the cruciate stumps to stabilize the quadriceps muscle complex. The biceps tendons can also be stabilized to the patellar tendon. A short section of gastrocnemius muscle can be sutured to the anterior capsule to pad the distal end. Although many techniques are described to trim the condyles of the femur, trimming is rarely necessary, and radical trimming can decrease some of the advantages of the knee disarticulation.

Figure 12–16.



Knee disarticulation.

For ambulatory patients, the advantages of a knee disarticulation over a transfemoral amputation include improved socket suspension by contouring above the femoral condyles, the added strength of a longer lever arm, the retained muscle balance of the thigh, and, most important, the end-bearing potential to transfer weight directly to the prosthesis. In the past, the objections to a bulky prosthesis and asymmetric knee-joint level led many surgeons to abandon the practice of performing knee disarticulations. New materials allow a less bulky prosthesis to be fabricated, and the four-bar linkage knee unit, which can fold under the socket, improves the appearance of the prosthesis when the patient is sitting. The four-bar linkage knee remains the prosthetic knee of choice for a knee disarticulation. It is low profile, has excellent stability, and can incorporate a hydraulic unit for control during the swing phase of gait in patients who can walk at different cadences.

For nonambulatory patients, a knee disarticulation eliminates the problem of knee flexion contractures, provides a balanced thigh to decrease hip contractures, and provides a long lever arm for good sitting support and transfers.

The Gritti-Stokes amputation is not recommended. In this operation, the patella is advanced distally and fused by arthrodesis to the distal femur, theoretically to allow direct weight bearing. The concept behind this operation is flawed because even in normal kneeling, the weight is borne on the pretibial and patellar tendon areas and not on the patella. The added length and the asymmetry of the knee joints complicate prosthetic fitting.

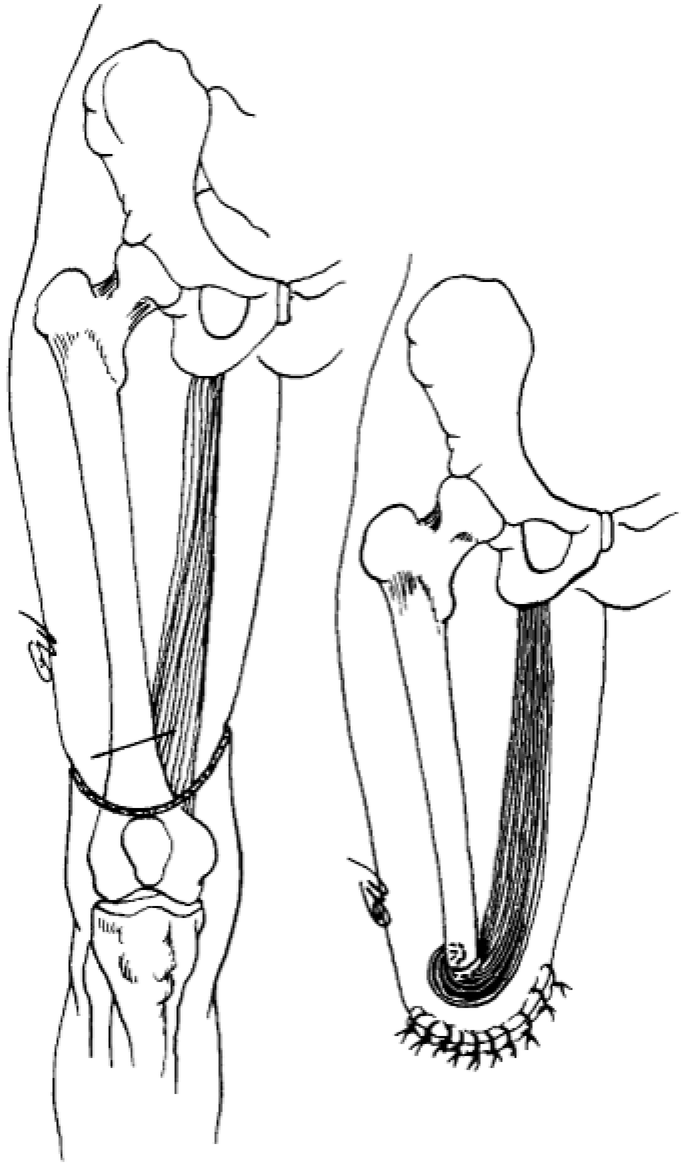
Transcondylar amputation can be performed, but the end-bearing comfort and improved suspension of a transcondylar amputation appear to be diminished when compared with the true knee disarticulation.

Transfemoral Amputation

Transfemoral amputation is usually performed with equal anterior and posterior fish-mouth flaps. Atypical flaps can and should be used to save all possible femoral length in cases of trauma because the amount of function is directly proportional to the length of the residual limb.

Muscle stabilization is more important in the transfemoral amputation than in any other major limb amputation. The major deforming force is into abduction and flexion. Myodesis of the adductor muscles through drill holes in the femur can counteract the abductors, prevent a difficult adductor tissue roll in the groin, and improve prosthetic control (Figure 12–17). Without muscle stabilization, the femur commonly migrates laterally through the soft-tissue envelope to a subcutaneous location. Newer transfemoral socket designs attempt to better control the position of the femur, but they are not as effective as muscle stabilization. Even in nonambulatory patients, muscle stabilization is helpful in creating a more durable, padded residual limb by preventing migration of the femur.

Figure 12–17.



Transfemoral amputation with adductor myodesis.

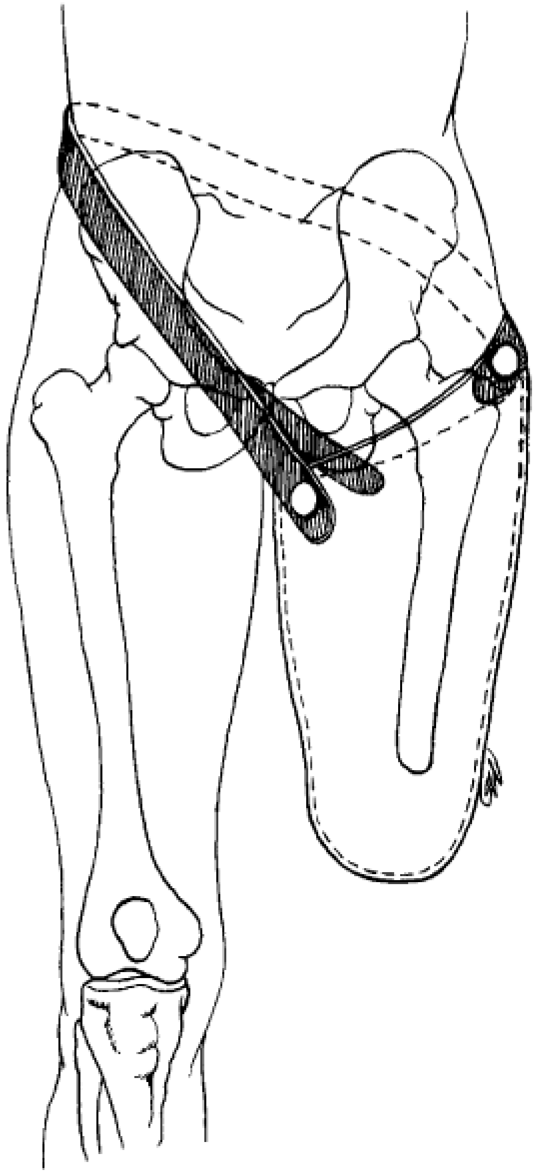
An IPOP and rigid dressings are more difficult to apply and keep positioned after a transfemoral amputation than after more distal amputations. IPOP techniques do offer the advantages of early rehabilitation and control of edema and pain, and these techniques are preferred if the expertise to use them is available. The major complaints of patients with the transfemoral IPOP are the weight of the cast and the discomfort when sitting. In many cases, only a soft compressive dressing alone is used, and in these patients, the dressing should be carried proximally around the waist as a spica to better suspend the dressing and to include the medial thigh and prevent the development of an adductor roll of tissue. Proper postoperative positioning and therapy are essential to prevent hip flexion contractures. The limb should be positioned flat on the bed, rather than elevated on a pillow, and hip extension exercises and prone positioning should be started early.

Suspension of the prosthesis is more complicated in transfemoral amputations than in more distal amputations because of the short residual limb, the lack of bony contours, and the increased weight of the prosthesis. The transfemoral amputation prosthesis can be suspended by suction, Silesian bandage, hip-joint and pelvic band, or by the newer elastomeric locking liners.

Traditional socket-suction suspension works when the skin forms an airtight seal against the socket. Air is forced distally through a small one-way valve when the prosthesis is donned and with each step during gait, thus maintaining negative pressure distally in the socket. No prosthetic sock or other liner is used between the hard socket and the limb because air leaks out around the sock and prevents suction from developing. Donning a socket-suction prosthesis requires skill and exertion, and patients must have good coordination, upper extremity function, and balance to perform this task. Socket-suction systems work well for average-to-long transfemoral residual limbs that have adequate soft tissues and stable shape and volume. It is usually comfortable and the most cosmetically acceptable method of socket suspension.

A Silesian bandage is a flexible strap that attaches laterally to the prosthesis, wraps back around the waist and over the contralateral iliac crest, and then comes forward to attach to the anterior proximal socket (Figure 12–18). It provides good suspension and added rotational control of the prosthesis. A Silesian bandage is commonly used to augment suction suspension for patients who have shorter-length limbs or for patients whose activities require more secure suspension than suction alone can offer.

Figure 12–18.



Silesian band suspension of a transfemoral prosthesis.

As with the transtibial prosthesis, the newer elastomeric locking liners can provide excellent suspension and control. An elastomeric or silicone-based liner is rolled onto the leg similar to the way a condom is applied. This liner has an intimate fit with the residual limb and avoids pistoning and rotational forces. A small metal post at the distal end of the liner locks down into a catch at the bottom of the prosthetic socket to create a secure mechanical suspension. A small button must be pushed to disengage the lock and release the prosthesis. Many amputees express an improved sense of security and improved proprioception with these systems. The disadvantages continue to be the added cost, the need to replace the liners as they tear, and, rarely, developing a contact dermatitis. As discussed with transtibial amputees, approximately a third of amputees cannot tolerate the forces generated at the distal part of the amputation with liners using the metal post or pin lock system. For these patients, new methods to attach the liner to the socket must be explored.

The hip joint and pelvic band provides extremely secure suspension and control, but the band is bulky, the least cosmetically acceptable method of suspension, and the least comfortable, especially when the patient is sitting. The pelvic band, made of metal or plastic, is thicker than a Silesian bandage. The pelvic band runs from the hip hinge, around the waist, between the contralateral iliac crest and trochanter, and back to the hip hinge. The hinge is located laterally, just anterior to the trochanter, over the anatomic axis of the hip joint. Hip joint and pelvic band suspension is indicated for very short transfemoral limbs, geriatric patients who cannot don a suction suspension, and obese patients who cannot get adequate control with suction, silicone suspension sleeves, or Silesian band suspension.

Socket design for the transfemoral amputation has changed. The traditional quadrilateral socket has a narrow anteroposterior diameter to keep the ischium positioned back and up on top of the posterior brim of the socket for weight bearing. The anterior wall of the socket is 5–7 cm higher than the posterior wall to hold the leg back on the ischial seat. Anterior pain is a frequent complaint and should be addressed by modification of the prosthetic socket in a small local area such as over the anterior superior iliac spine. If the entire anterior wall is lowered or relieved, the ischium slips inside the socket and totally alters the load transfer and pressure areas. Even though the lateral wall is contoured to hold the femur in adduction, the overall dimensions of the quadrilateral socket are not anatomic and provide poor femoral stability in the coronal plane.

Narrow mediolateral transfemoral socket designs attempt to solve the problems of a traditional quadrilateral socket by contouring the posterior wall to set the ischium down inside the socket, not up on the brim. Weight is transferred through the gluteal muscle mass and lateral thigh instead of the ischium, which eliminates the need for anterior pressure from a high anterior wall. Attention is then focused on a narrow mediolateral contour to better hold the femur in adduction and minimize the relative motion between the limb and the socket. The normal shape and normal alignment (NSNA) socket and the contoured adducted trochanteric-controlled alignment method (CAT-CAM) socket are two of the narrow mediolateral designs available.

A socket made of flexible material with a rigid frame can also be used. The flexible material allows socket wall expansion with underlying muscle contraction. A flexible socket can be made in either the traditional quadrilateral or narrow mediolateral shapes. Advantages of this type of socket include improved comfort in walking and sitting and possibly improved muscular efficiency. One drawback is that the flexible material is less durable, and cracks can result in the loss of suction suspension and skin irritation.

Prosthetic knee joints are available in many designs to address specific patient needs. The traditional standard was the single-axis constant-friction knee. The constant-friction knee is simple, durable, lightweight, and inexpensive. The friction can be set at only one level to optimize function at one cadence, and patients have difficulty when walking at different speeds.

Outside hinges were the old standard for the knee disarticulation patient, to better approximate the center of motion of the knee. Outside hinges are cosmetically poor but still available for patients who used them successfully in the past and remain satisfied with them. For new patients, other types of knee units are used.

The term *stance control knee* has replaced the term *safety knee.* It refers to a knee unit that has weight-activated friction to increase stability and resistance to buckling as more of the amputee's body weight is applied. This unit is particularly useful for patients who are older, feel less secure, and have a very short residual limb, weak hip extensors, or hip flexion contractures.

A polycentric knee provides a changing center of rotation that is located more posteriorly than other knee joints. The posterior center of rotation offers more stability during stance and the first few degrees of flexion than other knee units do. The four-bar knee is one of many polycentric knee units available.

A hydraulic or pneumatic unit can be added to most knee joints to provide superior control of the prosthesis in swing phase by using fluid hydraulics to vary the resistance according to the speed of gait. This option is useful in active amputees who walk and run at different speeds.

The variable-friction knee unit can be a less expensive way to accommodate patients who walk at different speeds. This knee changes the friction according to the degree of flexion in the knee unit and leads to an improvement in the swing phase of walking. Although a variable-friction knee is less costly and requires less maintenance than a hydraulic unit, it is not as effective in allowing the amputee to walk at different cadences.

A manual locking option can also be added to most knee units to lock the knee in full extension. Locking is helpful if the patient is blind, feels less secure, has a very short residual limb, or is a bilateral amputee.

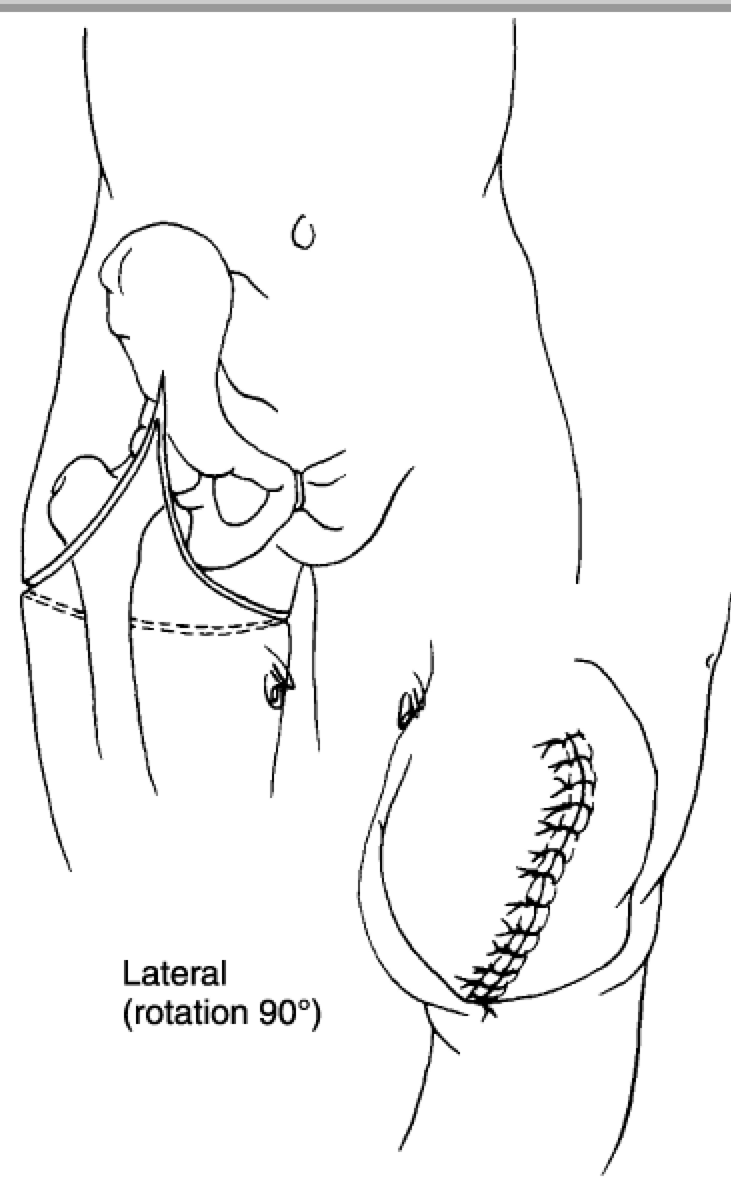
As mentioned previously, microprocessor-controlled so-called intelligent knee units incorporate the latest technology to provide superior control of the swing and stance characteristics or the knee and respond to the amputee's speed, cadence, and accelerations. Technology has not yet advanced enough for knee units to replace the tremendous motor power lost when an amputation is done above the knee.

Specifically designed prostheses known as *stubbies* are initially recommended for bilateral knee disarticulation or transfemoral amputees, regardless of age, who have lost both legs simultaneously but are candidates for ambulation. Stubbies consist of prosthetic sockets mounted directly over rocker-bottom platforms that serve as feet. The rocker-bottom platforms have a long posterior extension to prevent the patient from falling backward, and they have a shortened anterior process that allows smooth rollover into the push-off phase of gait. These prostheses look as if the foot were positioned backward. The use of stubbies results in a lowering of the center of gravity, and the rocker bottom provides a broad base of support that teaches trunk balance, provides stability, and allows the patient to build confidence during standing and ambulation. As the patient's confidence and skills improve, periodic lengthening of the stubbies is permitted until the height becomes nearly compatible with full-length prostheses, at which time the transition is attempted. Many patients reject full-length prostheses and prefer the stability and balance afforded by the stubbies.

Hip Disarticulation

Hip disarticulation (Figure 12–19) is rarely performed. Surgically, the traditional racket-shaped incision with an anterior apex is used in patients with vascular problems and in trauma-injured patients when possible. In tumor surgery, creative flaps based on the uninvolved anatomic compartments must be designed.

Figure 12–19.



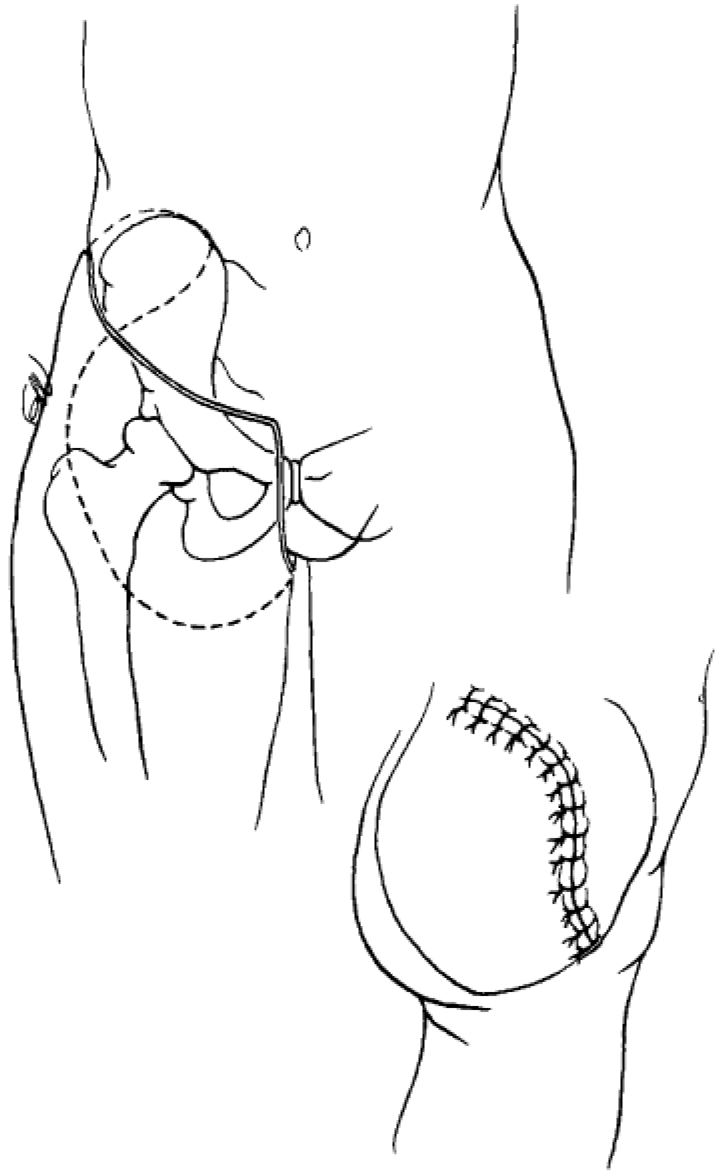
Hip disarticulation.

Prosthetic replacement can be successful in healthy young patients who required hip disarticulation because of trauma or cancer but is generally not indicated for patients with vascular disease. The standard prosthesis is the Canadian hip disarticulation prosthesis. The socket contains the involved hemipelvis and suspends over the iliac crests. Although the hip joint and other endoskeletal components are made of lightweight materials in an effort to keep the weight to a minimum, the prosthesis is still heavy and difficult to manipulate. Ambulation with the prosthesis usually requires more energy than it would take to ambulate with crutches and a swing-through gait. For this reason, many ambulatory patients use crutches and no prosthesis. The advantage of the prosthesis is that it does allow freer use of the upper extremities.

Hemipelvectomy

Although a hemipelvectomy (Figure 12–20) is even less frequently required than a hip disarticulation, it is sometimes indicated for trauma injuries or cancer involving the pelvis. Use of a prosthesis after this procedure is extremely rare because the body weight must be transferred onto the sacrum and thorax. Special considerations for seating are usually required after hemipelvectomy.

Figure 12–20.



Hemipelvectomy.

Prosthetic Prescription Following Amputation at or above the Knee

To be considered a candidate for a high anatomic level prosthesis (knee disarticulation and higher), a patient must be able to transfer independently, rise from sitting to standing independently, and ambulate using one leg and a swing-through gait over a distance of 100 feet on the parallel bars or with a walker. Although these requirements seem extreme, they are necessary for the successful use of this heavy and complicated prosthesis. The use of a transtibial prosthesis can make it easier to transfer and to ambulate. But a current transfemoral prosthesis can make it much more difficult to rise from sitting to standing because the powerful motor force required to extend the knee is not present. High-level prosthetic devices can actually increase the energy required for walking compared with one-leg swing-through gait. Unfortunately, without the ability to meet the activity demands unassisted, a prosthesis acts as an anchor to decrease overall independence. We use these same activity requirements as a functional test before prescribing a prosthesis for all transfemoral, hip disarticulation, and hemipelvectomy amputees.

Percutaneous Direct Skeletal Attachment of Artificial Limbs

The benefits of attaching prosthetic limbs through the skin, directly to the skeleton, was envisioned for nearly 100 years. Documentation of temporary external fixation for fractures dates to Malgaigne in 1845. During and just after World War II, independent attempts were made in Germany and the United States to attach a transtibial prosthesis directly to the tibia. Four humans were fit in May 1946 by Drummer, a general surgeon in Pinneberg, Germany. The two major hurdles continue to be the bone–implant interface, and the skin–implant interface. Breakthrough work by Branemark in Gothenburg, Sweden, advanced the use of titanium and improved design implants that led to over 30 years of successful dental and maxillofacial reconstruction with prosthetic devices directly connected to the bone of the mouth and face.

The skin of the extremities posed a larger challenge to the cutaneous–implant interface. Improvements in implant design and surgical technique, however, made it possible to implant and fit thumb, forearm, and transfemoral amputees successfully. Approximately 60 amputees have undergone surgical implantation and prosthetic fitting in Sweden, the United Kingdom, and Australia.

The early results confirm the potential promise of major improvements in attachment, proprioception, and function of osseointegrated prosthetic limbs compared with socket-style prostheses. Much work remains to be accomplished, however, especially in the skin–implant interface. A tremendous improvement in the bone–implant interface led to results that far outdistance historical attempts at directly attaching artificial limbs to the skeleton. Without true cutaneous–implant integration that provides a durable and biologic barrier, however, the risk of bacterial migration causing infection and loosening continues. It is fantastic to see this dream continue and advance.

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GENERAL PRINCIPLES OF REHABILITATION

In the past, rehabilitation was regarded as aftercare, but today, re

The most successful model for rehabilitation addresses the physica

Management of Common Problems in Rehabilitation

Inadequate nutrition, decubitus ulcers, urinary tract infections, im

INADEQUATE NUTRITION

Good nutritional status is the basis for avoiding many of the previo

DECUBITUS ULCERS (PRESSURE SORES)

The combination of poor nutritional status, lack of sensation at pre

Figure 13–1.

Patient with contractures and a decubitus ulcer over the greater t

URINARY TRACT INFECTIONS AND IMPAIRED BLADDER CON

Urinary tract infections are a common source of sepsis and prolon

Restoring bladder function to achieve adequate reflex voiding or a

MUSCLE WEAKNESS AND PHYSIOLOGIC DECONDITIONING

During sustained exercise, the metabolism is mainly aerobic. The

Prolonged immobilization of extremities, bed rest, and inactivity le

SPASTICITY

Patients with spasticity exhibit an excessive response to the quick

Spasmolytic Drugs

Drugs can be of some assistance in controlling spasticity associate

Baclofen (Lioresal) can inhibit both polysynaptic and monosynaptic

Baclofen pump technology has an advantage over oral drug therap

Dantrolene (Dantrium), another drug that can be used to control s
medications. When using dantrolene, the lowest effective dose sho

Casts

Casting temporarily reduces muscle tone and is frequently used to

Splints

Anterior and posterior clamshell splints can be used to control join

Nerve-Blocking Agents

Anesthetic and phenol nerve blocks are often combined with a cas

Anesthetic nerve blocks are commonly used to eliminate muscle to

When muscle spasticity requires control for an extended period of
the percutaneous injection of muscle motor points with an aqueou

Figure 13–2.

Use of a Teflon-coated needle and nerve stimulator to locate the r

BOTULINUM TOXIN—

Ordinarily, an action potential propagating down to a motor nerve
to check the result. Because botulinum toxin is the most potent bi

Surgical Procedures

If muscle spasticity is permanent and no change in muscle tone is

JOINT CONTRACTURES

Inactivity and uncontrolled spasticity often lead to joint contractur

Figure 13–3.

Upper extremity contractures in a patient with untreated spasticit

Muscle weakness is accentuated by contractures and malalignmen

To prevent contractures, exercises to maintain ROM must be perfo

Splinting can help maintain joints in a functional position when mo

Treatment of established contractures can be time consuming and technique is the application of a dropout cast (Figure 13–4), which

Figure 13–4.

An elbow dropout cast used to increase elbow extension while pre

When contractural deformities are long standing and fixed, surgica

OTHER ACQUIRED MUSCULOSKELETAL DEFORMITIES

Paralysis or weakness of trunk muscles can lead to scoliotic deform

Disuse and lack of muscle tone lead to osteoporosis, which in turn

Peripheral nerve palsy can result from pressure secondary to decr

Evaluation of Impairment

NERVES

Many disabilities requiring rehabilitation result from diseases affect

Motor activity can be considered as a hierarchic system of volunta

Voluntary Muscle Activity

Two types of voluntary muscle activity are clinically identifiable: se
motor control for ambulation, but patterned motion does not provi

Involuntary Muscle Activity

Spasticity relates to two types of involuntary muscle activity: cloni
move and the triceps surae to stretch may not prevent clonus fror

If the muscle is stretched slowly below the threshold of the velocit

Patients with injury involving the brainstem may exhibit severe hy

When a spastic patient is sitting or standing, labyrinthine activatio

Sensory Perception

The final steps of sensory integration occur in the cerebral cortex,

MUSCLES

Manual muscle testing is often useful for evaluating an individual's

Table 13–1. Muscle Strength.

Grade	Strength	Description			
0	Absent	Muscle does not contract.	1	Trace	Muscle contracts

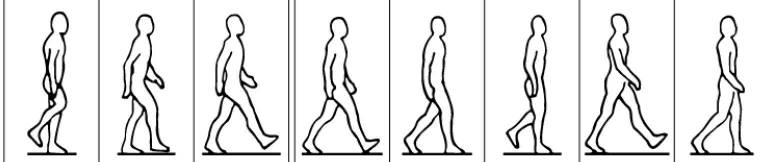
GAIT

Normal Gait

Normal gait is the combination of postures and muscle activities th

Figure 13–5.

	SWING 40%			STANCE 60%				
	Initial swing	Mid-swing	Terminal swing	Initial contact	Loading response	Mid-stance	Terminal stance	Pre-swing
TRUNK	Erect neutral	Erect neutral	Erect neutral	Erect neutral	Erect neutral	Erect neutral	Erect neutral	Erect neutral
PELVIS	Level: backward rotation 5°	Level: neutral rotation	Level: forward rotation 5°	Level: maintains forward rotation	Level: less forward rotation	Level: neutral rotation	Level: backward rotation 5°	Level: backward rotation 5°
HIP	Flexion 20° Neutral rotation abduction adduction	Flexion 20°–30° Neutral rotation abduction adduction	Flexion 30° Neutral rotation abduction adduction	Flexion 30° Neutral rotation abduction adduction	Flexion 30° Neutral rotation abduction adduction	Extending to neutral Neutral rotation abduction adduction	Apparent hyperext 10° Neutral rotation abduction adduction	Neutral extension Neutral rotation abduction adduction
KNEE	Flexion 60°	Flexion 60°–30°	Extension to 0°	Full extension	Flexion 15°	Extending to neutral	Full extension	Flexion 35°
ANKLE	Plantar flexion 10°	Neutral	Neutral	Neutral heel first	Plantar flexion 15°	From plantar flexion to 10° dorsiflexion	Neutral with tibia stable and heel off prior to initial contact opposite foot	Plantar flexion 20°
TOES	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral IP extended MP	Neutral IP extended MP



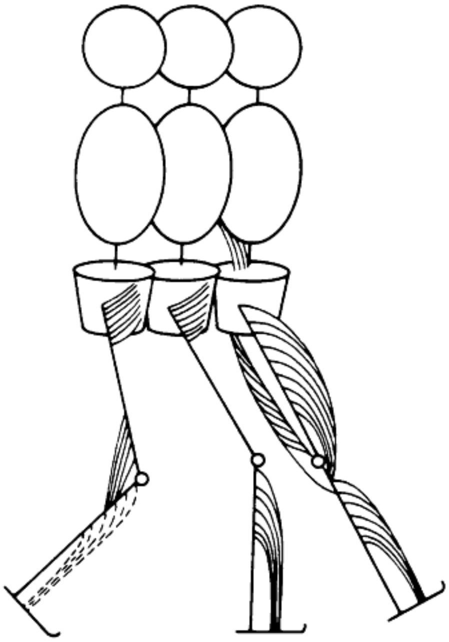
The normal gait cycle.

(Reproduced, with permission, from American Academy of Orthop

SWING PHASE

The swing phase (Figures 13–5 and 13–6) is divided into three equ

Figure 13–6.



Swing phase of gait.

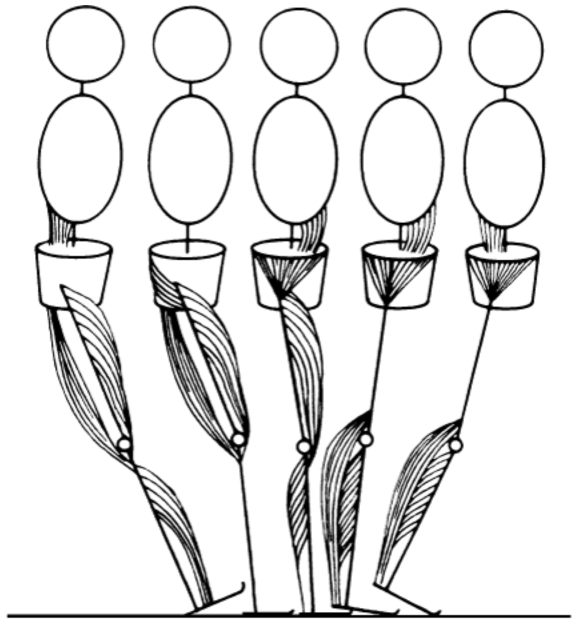
(Reproduced, with permission, from American Academy of Orthop

The hip flexor muscles provide the power for advancing the limb a

STANCE PHASE

The stance phase (Figures 13–5 and 13–7) accounts for 60% of th
to stabilize the ankle and allow the heel to rise from the floor. In te

Figure 13–7.



Stance phase of gait.

(Reproduced, with permission, from American Academy of Orthop

Throughout the stance phase, the hip gradually extends and the p

Abnormal Gait

The study of movement (kinesiology) provides many important too

Three of the many specialized tools used in these studies are dyna

Muscle strength can be accurately measured using torque, which c

Measurement of velocity, stride length, cadence, and single- and d

OXYGEN CONSUMPTION AND AEROBIC CAPACITY

Perhaps the most important measurement for understanding the c

Effects of Disease and Aging on Energy Expenditure

Cardiorespiratory disease, anemia, muscle atrophy, and any other

During normal walking, the rate of energy expenditure by adults v

Effects of Exercise on Energy Expenditure

When exercise is performed at less than 50% of an individual's ma

Effects of Musculoskeletal Impairment on Energy Expenditu

Gait abnormalities that interfere with efficient, coordinated limb m

Among amputees, patients progressively walk slower at increasing

Patients requiring crutches and exerting considerable force to supp

Patients with hip and knee flexion deformities caused by fixed or d

Children who have cerebral palsy and diplegia and who walk in a c

Use of Orthoses

Orthotic (brace) prescription plays a vital role in rehabilitation. The

A temporary orthosis may be used in an early stage of illness until

The bichannel adjustable ankle-locking (BiCAAL) type of AFO is cor

Figure 13–8.

The bichannel adjustable ankle-locking (BiCAAL) type of ankle-foo

Figure 13–9.

The molded polypropylene ankle-foot orthosis.

The use of plastic materials in lower extremity orthotics is now wic

ANKLE-FOOT ORTHOSIS

Types

Of several currently available orthoses classified as limited-motion
metatarsal heads. Total circumferential orthoses combining anteric

Insertion of a polypropylene orthosis inside a shoe generally requir

Indications

The primary requirement for orthotic support is that all joints mus

INADEQUATE DORSIFLEXION FOR FOOT CLEARANCE DURIN

An AFO is indicated for inadequate toe clearance (footdrop) during

INADEQUATE DORSIFLEXION FOR INITIAL CONTACT

A patient with inadequate dorsiflexion from any cause contacts the

MEDIAL-LATERAL SUBTALAR INSTABILITY DURING STANCE

Varus deformity is more common than valgus deformity. The patie

INADEQUATE TIBIAL STABILITY DURING STANCE

Some patients have inadequate strength or control of the plantarfl

A knee extension thrust, caused by inadequate calf control as desc

A T-strap (a leather T-shaped strap attached to the brace at the a

KNEE-ANKLE-FOOT ORTHOSIS

A KAFO may be used if quadriceps muscle weakness or hamstring
Most patients with lower extremity quadriceps paresis resulting fro
When a KAFO is prescribed for quadriceps paresis, it is necessary
If proprioception is intact, as is the case with poliomyelitis, even p
The substitution of plastic components, such as a pretibial shell, ha

Esquenazi A. Evaluation and management of spastic gait in patient

Hebela N, Smith DG, Keenan MA: What's new in orthopaedic rehab

Hsu JD: Rancho Los Amigos Medical Center. A unique orthopaedic

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Pearson OR, Busse ME, van Deursen RW et al: Quantification of w

Schmalz T, Blumentritt S, Jarasch R: Energy expenditure and biom

Ulkar B, Yavuzer G, Guner R et al: Energy expenditure of the para

SPINAL CORD INJURY

Trauma to the spinal cord causes dysfunction of the cord, with nor
Patients are generally categorized into three groups. The first cons

Terminology

TETRAPLEGIA

The term *tetraplegia* (preferred to *quadriplegia*) refers to loss or in

PARAPLEGIA

Paraplegia refers to loss or impairment of motor or sensory functio

COMPLETE INJURY

The term *complete injury* refers to an injury with no spared motor

INCOMPLETE INJURY

Incomplete injury refers to an injury with partial preservation of se

Neurologic Impairment & Recovery

NEUROLOGIC EXAMINATION

The neurologic examination is critical to the classification and treat

Spinal Shock

The diagnosis of complete SCI cannot be made until the period of
several hours or as long as several months. Patients with complete

Sacral Reflexes

The presence or absence of sacral function determines the comple

SPINAL CORD SYNDROMES

Anterior Cord Syndrome

Anterior cord syndrome commonly results from direct contusion to

Central Cord Syndrome

Central cord syndrome can be understood on the basis of the spin

Brown-Séquard Syndrome

Brown-Séquard syndrome is caused by a complete hemisection of

Mixed Syndrome

Mixed syndrome is characterized by a diffuse involvement of the e

Management

ACUTE MANAGEMENT

Most patients with spinal cord injuries have associated injuries. In

Airway management in the setting of SCI, with or without a cervic

Hypotension may be hemorrhagic and/or neurogenic in acute SCI.

Once occult sources of hemorrhage are excluded, initial treatment

Associated head injury occurs in approximately 25% of SCI patient

Ileus is common. Placement of a nasogastric tube is essential. Asp

The National Acute Spinal Cord Injury Studies (NASCIS) II and III,

The NASCIS III study evaluated methylprednisolone 5.4 mg/kg/ho

The use of high-dose methylprednisolone in nonpenetrating acute

Two studies addressed the administration of GM-1 ganglioside follo

LOWER EXTREMITIES

Prevention of contractures and maintenance of ROM are important

Patients with extensive paralysis of the lower extremity need stren
impaired hip extensor and adductor muscles, but they are able to

Because most ambulatory patients with SCI have impaired hip ext

UPPER BODY AND EXTREMITIES

C4 Level Function

Patients with cervical lesions above C4 may have impairment of re

Phrenic nerve stimulation via implanted surgical electrodes enables

Patients with high tetraplegia can use chin or tongue controls to op

C5 Level Function

At the C5 level, the key muscles are the deltoid and biceps muscle

Surgery can further enhance upper extremity function. The goals (

C6 Level Function

At the C6 level, the key muscles are the wrist extensors, which en

If wrist extensor strength is poor, an orthosis is indicated. A WHO

Most patients with good wrist extensor strength are able to operat

The goals of surgery in the C6 patient are the restoration of latera

C7 Level Function

At the C7 level, the key muscle is the triceps. All patients with inta

The goals of surgery in the C7 tetraplegic patient are active thumb

C8 Level Function

At the C8 level, the key muscles are the finger and thumb flexors,

SKIN

Maintaining skin integrity is crucial to spinal injury care. From the

Once the patient is allowed to sit, a progressive program to increa

All patients must be taught to inspect their skin at least twice a da

If there is evidence of chronic skin inflammation over bony promin

Development of any open areas in the skin over the ischia or sacru

Excessive hip and knee flexor spasticity that prevents patients fro

In the neglected patient with a full-thickness pressure sore, surge

Ischial or trochanteric pressure sores commonly lead to septic arth

Pressure sores affecting the ankle commonly occur over the heel c

BLADDER FUNCTION

Intermittent catheterization is the factor most responsible for the
have an excessive amount of residual urine. Anticholinergic medica

Bladder diversion using an ileal conduit as a primary means of ach

SEXUAL FUNCTION

Women with or without intact reflex activity can perform coitus an

AUTONOMIC DYSREFLEXIA

Splanchnic outflow conveying sympathetic fibers to the lower body

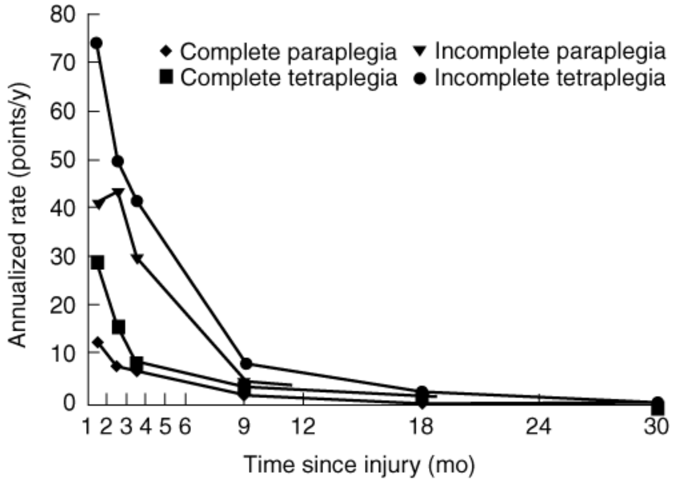
Recovery

The *International Standards for Neurological and Functional Classi*

Neurologic recovery is assessed by determining the change in ASI

The most important prognostic indicator of recovery is completene

Figure 13–10.



Recovery rates of ASIA Motor Score for persons with incomplete a

(Reproduced from Waters RL et al: Functional and neurological rec

COMPLETE PARAPLEGIA

Patients with paraplegia that remains complete 1 month after injur

INCOMPLETE PARAPLEGIA

Motor recovery is better in individuals with incomplete injuries. Be

COMPLETE TETRAPLEGIA

Ninety percent of individuals with complete tetraplegia 1 month af

INCOMPLETE TETRAPLEGIA

In patients with incomplete tetraplegia, motor recovery of upper a

Taken as a whole, a minority of individuals with SCI can ambulate injury are expected to be community ambulators 1 year after injur

Table 13–2. Community Ambulators at 1 Year Postinju

ASIA Lower Extremity Motor Score[a] (at 30 days postinjury)
0

[a]Score based upon five key muscles.

Total possible 50 points for both lower extremities for normals.

Reprinted, with permission, from Waters RL et al: Functional and r

American Spinal Injury Association, International Medical Society c

Banovac K et al: Prevention of heterotopic ossification after spinal

Bracken MB: Methylprednisolone and acute spinal cord injury: An

Bracken MB, Holford TR: Neurological and functional status 1 year

Burns AS, Ditunno JF: Establishing prognosis and maximizing func

Hebela N, Smith DG, Keenan MA: What's new in orthopaedic rehal

Hurlbert RJ: Methylprednisolone for acute spinal cord injury: An in

Keith MW, Hoyen H: Indications and future directions for upper lim

Kirshblum SC, O'Connor KC: Levels of spinal cord injury and predi

Lee TT, Green BA: Advances in the management of acute spinal cc

Little JW et al: Neurologic recovery and neurologic decline after sp

Macciocchi SN, Bowman B, Coker J et al: Effect of co-morbid traur

McKinley WO, Seel RT, Gadi RK et al: Nontraumatic vs. traumatic s

Nockels RP: Nonoperative management of acute spinal cord injury

Pollard ME, Apple DF: Factors associated with improved neurologic

Salisbury SK, Choy NL, Nitz J: Shoulder pain, range of motion, anc

Van der Putten JJ et al: Factors affecting functional outcome in pat

von Wild KR: New development of functional neurorehabilitation in

Waters RL, Sie IH: Spinal cord injuries from gunshot wounds to th

STROKE

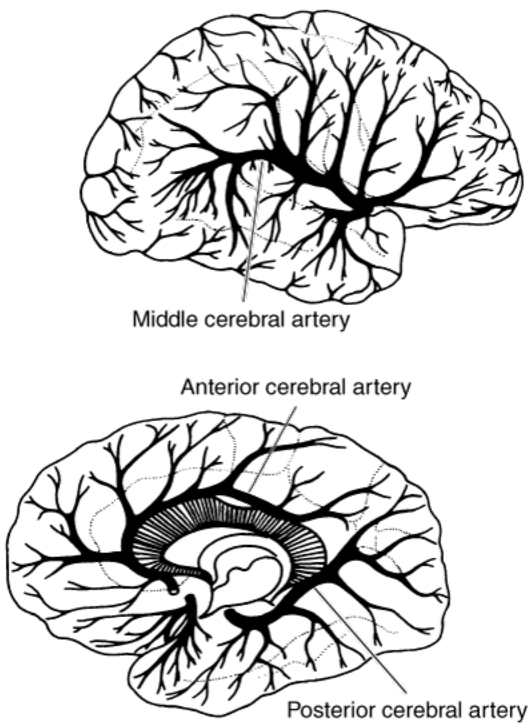
Stroke (cerebrovascular accident or brain attack) occurs when thr

In the United States, where cerebrovascular accidents are the lea

Neurologic Impairment & Recovery

Infarction of the cerebral cortex in the region of the brain supplied sufficient for walking.

Figure 13–11.



Cerebral artery circulation.

Infarction in the region of the anterior cerebral artery causes para

After stroke, motor recovery follows a fairly typical pattern. The si

Initially after a stroke, the limbs are completely flaccid. Over the r

Figure 13–12.

Equinovarus deformities of the feet in a patient with spasticity.

Whether the patient recovers the ability to move one joint indeper

The final processes in sensory perception occur in the cerebral cor

Management

ACUTE MANAGEMENT

Medical intervention in the treatment of a stroke is most effective

Thrombolytics

TISSUE PLASMINOGEN ACTIVATOR (T-PA) (ALSO KNOWN A

The efficacy of intravenous t-PA was established in two randomize

Key points about the administration of thrombolytic agents include

1. They must be administered within 3 hours of symptom onset. Patients who wake
2. An imaging study of the head (CT scan or MRI) must be performed prior to treat
3. Blood pressure should be lower than 185 systolic and 110 diastolic. Agents such
4. Blood must be tested for platelet count (should be over 100,000); international r

PROUROKINASE (ALSO KNOWN AS RECOMBINANT PROURO

This intraarterial therapy requires the involvement of a skilled inte

This therapy may be especially useful for patients who arrive later

Antiplatelet Agents

ASPIRIN

The Chinese Acute Stroke Trial (CAST) and the International Strok

ABCIXIMAB

An ongoing phase III study of the efficacy of abciximab (ReoPro) i

Anticoagulants

WARFARIN

No studies have evaluated use of warfarin for the acute treatment

HEPARIN AND HEPARINOIDS

At this time, only one randomized trial showed benefit for heparins

Neuroprotectants

Various classes of neuroprotectants were tested and include calciu

LOWER EXTREMITIES

Hemiplegia

To walk independently, the hemiplegic patient requires intact balar

Except for the correction of severe contractures in nonambulatory

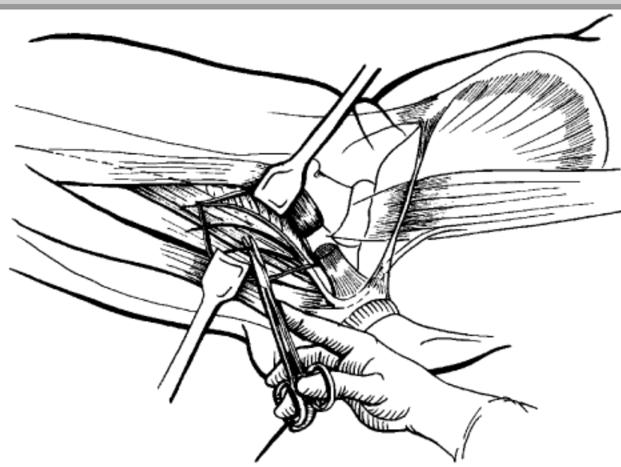
In the nonfunctional limb, surgery may be performed to relieve pa

Most hemiplegics with motor impairment have hip abductor and ex

Limb Scissoring

Scissoring of the legs caused by overactive hip adductor muscles i

Figure 13–13.



Release of the hip adductor tendons and neurectomy of the anteri

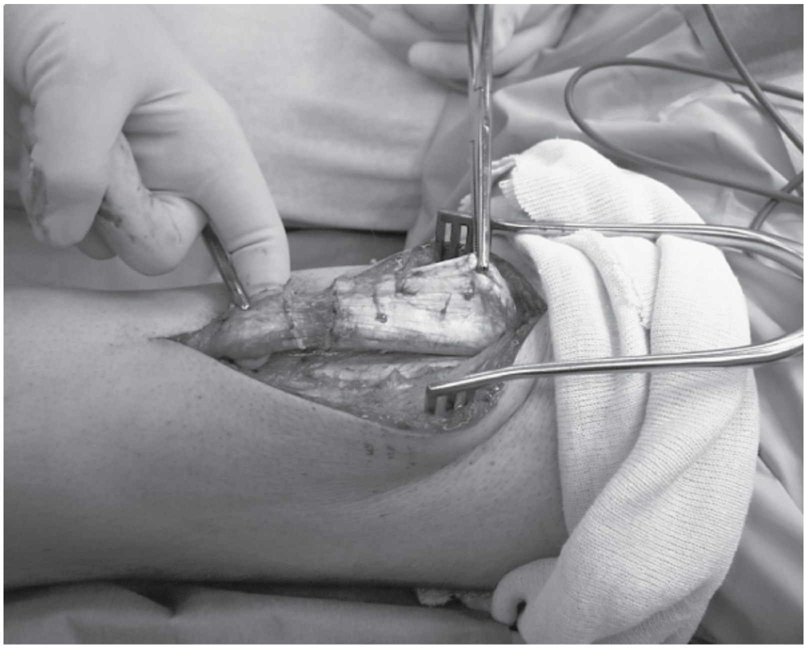
(Illustration by Anthony C. Berlet. Reproduced, with permission, fr

Stiff-Knee Gait

Patients with a stiff-knee gait are unable to flex the knee during th

A gait study with dynamic electromyography (EMG) should be don
also needed for a good result because the forward momentum of t

Figure 13–14.



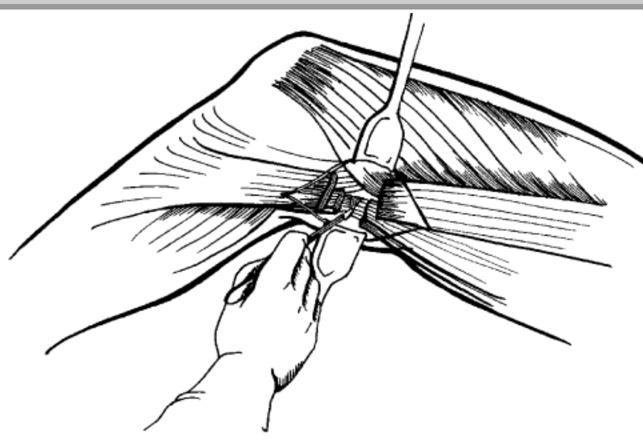
Selective lengthening of the rectus femoris tendon to correct a sti

Knee Flexion Deformity

A knee flexion deformity increases the physical demand on the qua

Surgical correction of the knee flexion deformity is the most desira

Figure 13–15.



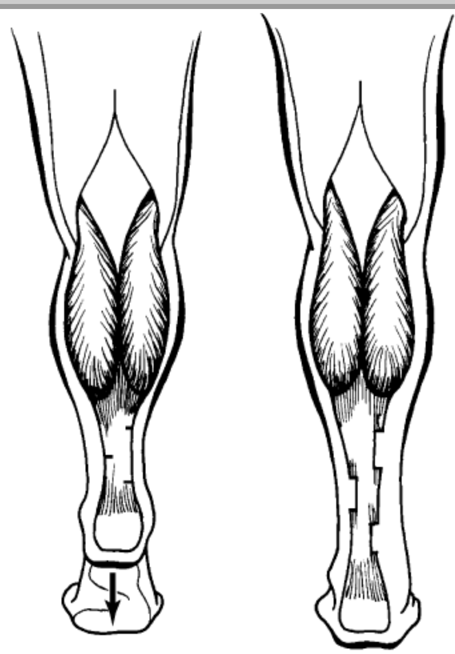
Distal release of the hamstring tendons to correct a knee flexion c

(Illustration by Anthony C. Berlet. Reproduced, with permission, fr

Equinus or Equinovarus Foot Deformity

Surgical correction of an equinus deformity is indicated when the f

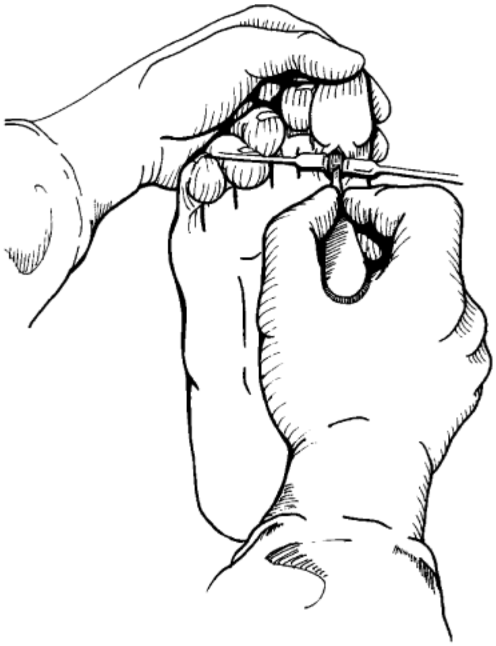
Figure 13–16.



Hoke triple hemisection Achilles tendon lengthening to correct an
(Illustration by Anthony C. Berlet. Reproduced, with permission, fr

An anesthetic block of the posterior tibial nerve can be a valuable
Surgical release of the flexor digitorum longus and brevis tendons

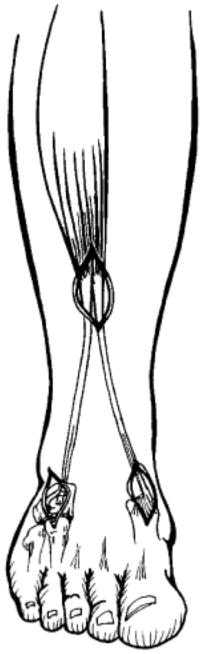
Figure 13–17.



Release of the flexor digitorum longus and brevis tendons to corre
(Illustration by Anthony C. Berlet. Reproduced, with permission, fr

Surgical correction of varus deformity is indicated when the proble
The tibialis anterior is the key muscle responsible for varus deform

Figure 13–18.



Split anterior tibial tendon transfer to correct a spastic varus foot

(Illustration by Anthony C. Berlet. Reproduced, with permission, fr

Treatment of equinovarus deformity consists of simultaneously per

UPPER EXTREMITIES

Spasticity

The first objective in treating the spastic upper extremity is to pre

Most hemiplegics do not use their hand unless some selective mot

An overhead suspension sling attached to the wheelchair is used fo

It is usually not possible to maintain the wrist in neutral position w

Shoulder or Arm Pain

The hemiplegic shoulder deserves special attention because it is a

The classic clinical signs of reflex sympathetic dystrophy (swelling

Figure 13–19.

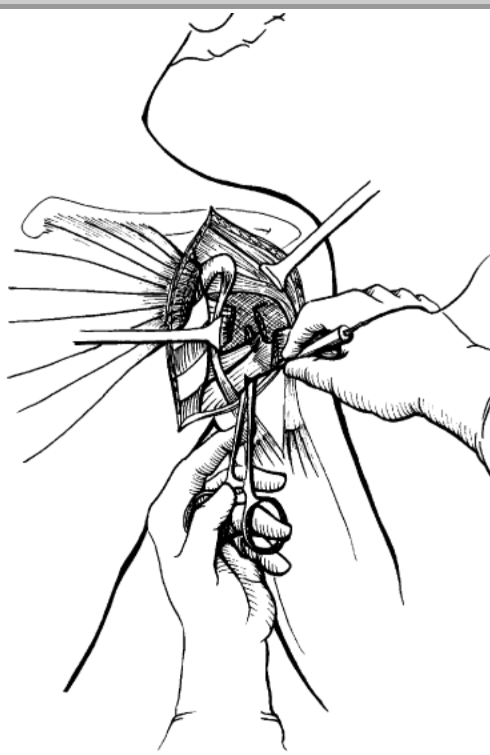
Technetium bone scan showing the periarticular increase in activit

Shoulder Contracture

Contracture of the shoulder can cause pain, hygiene problems in t

When the deformity is not fixed, lengthening of the pectoralis maj

Figure 13–20.



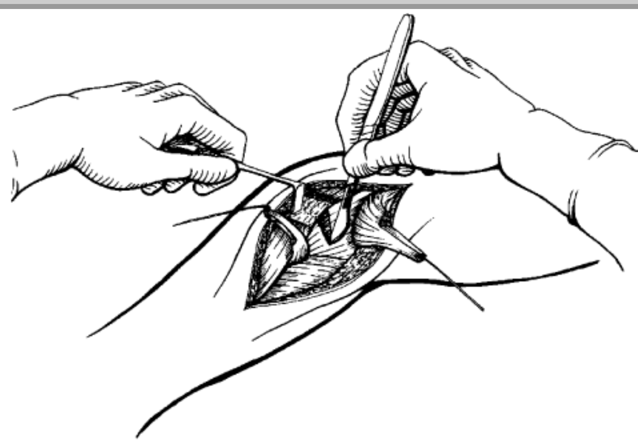
Release of the pectoralis major, subscapularis, latissimus dorsi, an

(Illustration by Anthony C. Berlet. Reproduced, with permission, fr

Elbow Flexion Contracture

Persistent spasticity of the elbow flexors causes a myostatic contra
Surgical release of the contracted muscles and gradual extension c

Figure 13–21.



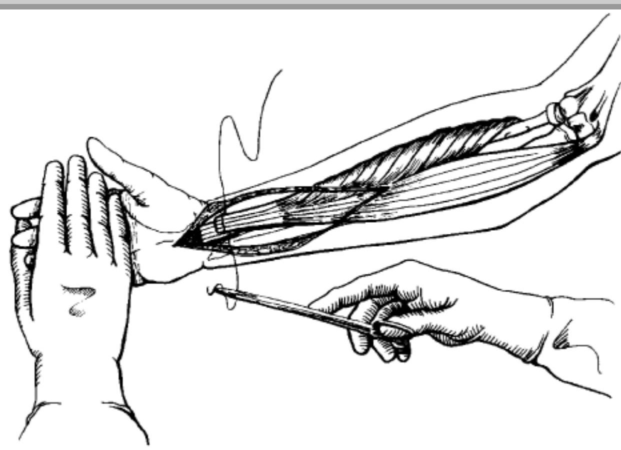
Surgery of the brachioradialis muscle, biceps tendon, and brachial
(Illustration by Anthony C. Berlet. Reproduced, with permission, fr

Approximately 50% correction of the deformity can be expected a

Clenched-Fist Deformity

A spastic clenched-fist deformity in a nonfunctional hand causes pa
Adequate flexor tendon lengthening to correct the deformity canno
branches of the ulnar nerve in the Guyon canal should be routinely

Figure 13–22.



The superficialis-to-profundus tendon transfer to correct a severe

(Illustration by Anthony C. Berlet. Reproduced, with permission, fr

After surgery, the wrist and digits are immobilized for 4 weeks in a

Botte MJ, Bruffey JD, Copp SN et al: Surgical reconstruction of acc

Fuller DA, Keenan MA, Esquenazi A et al: The impact of instrumen

Gardner MJ, Ong BC, Liporace F et al: Orthopedic issues after cere

Keenan MA, Fuller DA, Whyte J et al: The influence of dynamic pol

Keenan MA, Mehta S: Neuro-orthopedic management of shoulder d

Mayer NH: Choosing upper limb muscles for focal intervention afte

Pollock A, Baer G, Pomeroy V et al: Physiotherapy treatment appro

Vuagnat H, Chantraine A: Shoulder pain in hemiplegia revisited: C

GERIATRIC ORTHOPEDICS

General Principles

A major challenge facing society is the aging of the population. By

Although the passage of time, chronological age, is the convenient

The young elderly are those individuals 65 to 75 years of age. The

The frail very elderly are those persons older than 80 years. These

Disability

The leading causes of death in the elderly are heart disease, malig

When evaluating the elderly, five functional domains of disability n

1. *Physical ADLs* include activities such as bathing, dressing, eating, and walking.
2. *Instrumental ADLs* are home management tasks such as shopping, meal prepara
3. *Cognitive functioning* is particularly important in the elderly. Dementia is one of t
4. *Affective function* is important. Secondary depressions are common in the elderly
5. *Social functioning* is less of a problem. Only 1% of the elderly rate their social int

Disability in basic ADLs is common among community-dwelling olde
decline and disability includes not only management of acute episo

Challenges for the Orthopedic Surgeon

When working with the elderly, the orthopedic surgeon becomes a

Osteoporosis

Osteoporosis is an age-related disorder characterized by decrease

PRIMARY OSTEOPOROSIS

Primary osteoporosis, the most common form of the disease, occu

Type II, senile osteoporosis, is a consequence of aging. It causes a

SECONDARY OSTEOPOROSIS

Secondary osteoporosis results from a variety of causes. The most

Prevention Strategies

Restoration of bone is difficult. It is therefore imperative to maxim

Diagnosis

Osteoporosis is a clinical diagnosis often made following a fracture

Normal: within 1 standard deviation (SD) of young adult reference

Osteopenia: between 1.0 and 2.4 SD below reference

Osteoporosis: 2.5 or more SD below reference

Severe osteoporosis: 2.5 plus one or more fragility fractures

Treatment

Calcium alone does not prevent bone loss during the early postme

Newer treatments using bisphosphonates show promise in treating

Only approximately a third of women in the United States diagnos

Exercise

The ability to walk safely is vital for independent living. Both stren

1. a loss of muscle mass because of smaller and fewer fibers;
2. a loss of motor neurons (anterior horn cells);
3. changes in muscle architecture;
4. a defect in the excitation-contraction mechanism; and
5. psychosocial changes leading to reduced capacity to activate motor units.

Strength training can lead to major functional improvements in the

Aerobic exercise does lead to increased endurance and functional

Arthritis

Osteoarthritis is very prevalent in the elderly. Total joint arthroplas

Fractures

GENERAL CONSIDERATIONS

One of the most compelling reasons to determine the etiology of a
sixfold increased risk of subsequent fractures compared to those w

These findings emphasize that optimal care of fragility fracture pat
subsequent fractures.

In the elderly, fractures result from low-energy injuries. Falls in th

Many of the risk factors for fracture are also risk factors for falls. I

Genetic factors are seen in both gender and race. Women sustain

Other factors contribute to the risk of traumatic fractures occurrin

HIP FRACTURES

Fractures of the hip are classified by location and severity. The bas

Treatment of hip fractures is operative whenever possible. The nor

The basic principles of treatment of hip fractures are well establish

The postoperative rehabilitation of the elderly patient is critical to
to place the patient in a hip brace, which limits flexion and adducti

FRACTURES OF THE PELVIS

A common pelvic classification is based on whether or not the ring
Fractures of the coccyx and sacrum are treated in a similar manne

FRACTURES OF THE DISTAL FEMUR

The management of distal femur fractures in the elderly patients r

FRACTURES OF THE FOREARM

Most fractures of the distal radius (Colles fracture) can be treated

FRACTURES OF THE PROXIMAL HUMERUS

Fractures of the proximal humerus account for 4–5% of all fractur

Stroke

Stroke is a common cause of disability in the elderly. This topic wa

Foot Disorders

The foot tends to widen with age as the transverse arch support w
are used in combination with soft extra-depth shoes that provide r

Amputation

The majority of amputations done in a civilian population are of th

Chao EY, Inoue N, Koo TK et al: Biomechanical considerations of fr

Gehlbach SH et al: Recognition of osteoporosis by primary care ph

Gill TM, Allore HG, Holford TR et al: Hospitalization, restricted acti

Hardy SE, Gill TM: Factors associated with recovery of independen

Hooven F, Gehlbach SH, Pekow P et al: Follow-up treatment for os

Lorich DG, Geller DS, Nielson JH: Osteoporotic pertrochanteric hip

Phillips FM: Minimally invasive treatments of osteoporotic vertebra

Stromsoe K: Fracture fixation problems in osteoporosis. Injury 20

Tosi LL, Kyle RF: Fragility fractures: The fall and decline of bone h

BRAIN INJURY

Brain injury resulting from trauma to the head is a leading cause c

Neurologic Impairment & Recovery

The Glasgow Coma Score (Table 13–3) is frequently used to evalua

Table 13–3. the Glasgow Coma Score.

Response	Description	Numerical Value	
Eye opening	Spontaneous response	4	Respons
Motor response			
Verbal response			

Adapted, with permission, from: Teasdale G, Jennett B: Assessme

The incidence of good recovery declines not only with advancing a

Management

The rehabilitation process has three distinct phases: the acute inju

PHASES OF PATIENT CARE AND REHABILITATION

Acute Injury Phase

The initial phase of rehabilitation begins as soon as the patient rea

Under the circumstances, three important principles should be foll

Subacute Phase of Neurologic Recovery

During the subacute phase, when the patient is generally in a reha

Residual Phase or Period of Functional Adaptation

When neurologic recovery reaches a plateau, the third phase of re

THE TEAM APPROACH TO PATIENT CARE AND REHABILITAT

Members of the rehabilitation team are involved in setting short-te

Medical Management

General medical goals are usually straightforward. Because most p

In patients with decreased ROM in a joint, the cause of the problem

Phenol blocks or botulinum toxin injections are used to decrease sp

The technique for administering the phenol block depends on the a

Botulinum toxin is injected directly into the muscle belly. The onse

Nursing Care

Nursing goals concentrate on basic bodily needs such as nutrition,

Tracheostomy tubes are commonly used in patients with brain inju

Feeding tubes are also commonly used. If oral feeding is not antici more easily aspirated.

The ability to inhibit voiding is generally a cognitive function. Resto

Cognitive and Neuropsychological Management

The return of cognitive abilities follows the same sequence of stag

Table 13–4. Cognitive Function.

Level	Description					
I	No response	II	Generalized response	III	Localized response	IV

Adapted from Malkmus D et al: *Rehabilitation of the Head-Injured*

Memory loss and diminished cognitive function are frequently the

Speech Therapy

After traumatic brain injury, patients may have temporary or perm

Physical Therapy

Areas of concern in physical therapy include patient positioning, m

Among the factors that influence whether a patient can walk are li

In developing appropriate exercises and activities for a patient, th

Surgical Management of Residual Musculoskeletal Problems

After neurologic recovery stabilizes, surgical procedures may be in

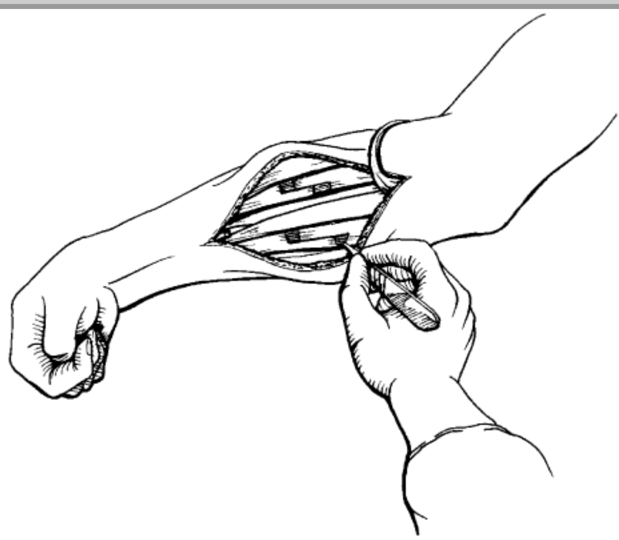
CORRECTION OF LIMB DEFORMITIES IN THE LOWER EXTRE

In functional lower limbs, surgery is most often directed at correct
A stiff-knee gait is a common deformity that causes the patient to
In nonfunctional lower limbs, surgery commonly consists of releasi

CORRECTION OF LIMB DEFORMITIES IN THE UPPER EXTREM

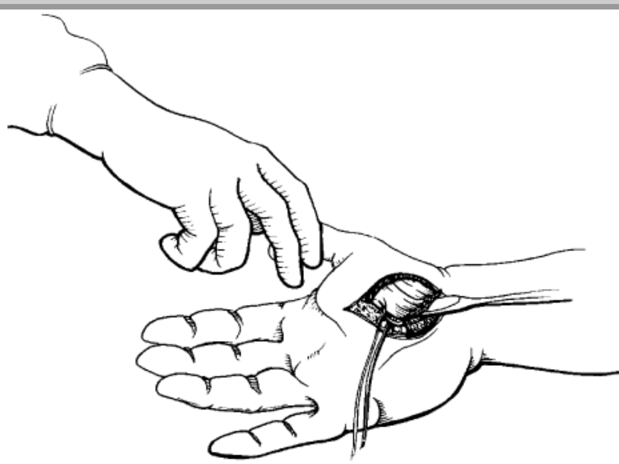
In functional upper limbs, surgery is frequently needed to correct

Figure 13–23.



Lengthening of the extrinsic finger flexors to correct the problem
(Illustration by Anthony C. Berlet. Reproduced, with permission, fr

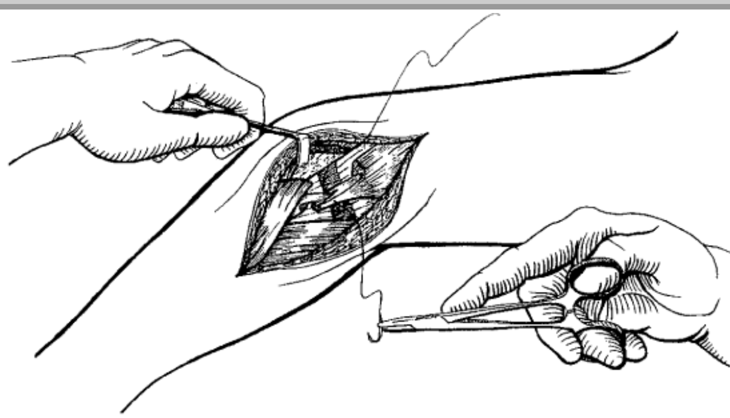
Figure 13–24.



Proximal release of the thenar muscles to correct a thumb-in-palm

(Illustration by Anthony C. Berlet. Reproduced, with permission, fr

Figure 13–25.



Lengthening of the elbow flexors to correct flexor spasticity and ir
(Illustration by Anthony C. Berlet. Reproduced, with permission, fr

In nonfunctional upper limbs, common procedures consist of releas

EXCISION OF HETEROTOPIC OSSIFICATION

Surgical measures for treatment of this problem are discussed late

OCCUPATIONAL THERAPY AND SOCIAL SERVICES

Before patients are released from the hospital or rehabilitation fac

Inpatient Rehabilitation

Changes in the rules governing inpatient rehabilitation hospitals ar

Physicians generally agree on the circumstances that justify a mec

Patients needing rehabilitative services require a hospital level of c

1. The services must be reasonable and necessary (in terms of efficacy, duration, fr
2. It must be reasonable and necessary to furnish the care on an inpatient hospital

To meet the requirements just cited, the following basic componer

1. Close medical supervision by a physician with specialized training or experience ir
2. The patient requires the 24-hour availability of a registered nurse with specialize
3. The general threshold for establishing the need for inpatient hospital rehabilitatic
4. A multidisciplinary team (usually includes at minimum a physician, rehabilitation

Banovac K, Sherman AL, Estores IM et al: Prevention and treatme

Botte MJ, Bruffey JD, Copp SN et al: Surgical reconstruction of acc

Dahners LE, Mullis BH: Effects of nonsteroidal anti-inflammatory d

Esquenazi A et al: Dynamic polyelectromyography, neurolysis, and

Gardner MJ, Ong BC, Liporace F et al: Orthopedic issues after cere

van Kuijk AA, Geurts AC, van Kuppevelt HJ: Neurogenic heterotop

HETEROTOPIC OSSIFICATION

Heterotopic ossification is commonly detected 2 months after traur

Clinical Findings

Clinically significant heterotopic ossification is seen in 20% of adult

In 27% of patients with heterotopic ossification, shoulder involvem
but significantly impedes both flexion and extension of the joint.

Management

EARLY MEASURES

Aggressive treatment of spasticity is necessary because this proble
daily, but in theory, other medications are equally effective. Physic

DEFINITIVE TREATMENT

Surgical excision is the definitive treatment for heterotopic ossifica

Banovac K, Sherman AL, Estores IM et al: Prevention and treatme

Burd TA et al: Indomethacin compared with localized irradiation fo

Dahners LE, Mullis BH: Effects of nonsteroidal anti-inflammatory d

Kaplan FS, Glaser DL, Hebela N et al: Heterotopic ossification. J Ar

van Kuijk AA, Geurts AC, van Kuppevelt HJ: Neurogenic heterotop

Viola RW, Hastings H II: Treatment of ectopic ossification about th

RHEUMATOID ARTHRITIS

Rheumatoid arthritis (RA) is a systemic disease that affects conne

Immune mechanisms are involved, as evidenced by the presence

Figure 13–26.

Chronic synovitis of the joints and extensor tendons in a patient w

The erosion of articular cartilage is greatly enhanced by the superi

Clinical Findings

RA affects synovial joints, bones, muscles, fasciae, ligaments, and

Table 13–5. American Rheumatism Association Criteri

Category	Description
Classic rheumatoid arthritis	Presence of 7 of the following findings

[a]Finding must be present for at least 6 weeks.

The clinical course of RA is variable with respect to the extent and

The multisystem nature of RA and its variable clinical pattern mak

Table 13–6. American Rheumatism Association Classi

Class	Description
I	Complete function; able to perform usual duties without har

Management

THE TEAM APPROACH TO PATIENT CARE AND TREATMENT

Optimal management requires an interdisciplinary team approach

Nursing Care and Patient Education

The liaison nurse functions as the coordinator of the team. The nu

Much of the responsibility for patient education in the daily care of

Medical and Surgical Management

The rheumatologist is commonly the team leader and in charge of
modifying antirheumatic drug (DMARDs), which can retard or prev

The recognition of TNF-α and IL-1 as central proinflammatory cytok

The orthopedic surgeon should be involved early in the course of t

In selected situations, early surgical intervention may prevent exc

Most surgical procedures are reconstructive. Because relief of pain

For further discussion of medical and surgical treatment, see the s

Physical Therapy

The physical therapist uses modalities such as heat and ultrasound

Patients with joint effusions and synovitis automatically assume pc

Muscles weakened by the concomitant myopathy need strengtheni

Occupational Therapy

The occupational therapist evaluates and instructs the patient in m

Psychological Counseling

It is not uncommon for patients or their family members to have f

Social Services

A variety of modifications in lifestyle accompany chronic illness wit

MANAGEMENT APPROACHES BASED ON THE AREA OF DISEA

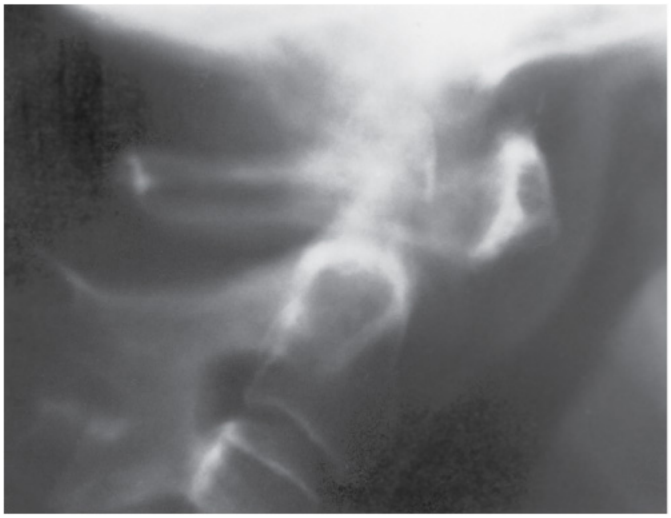
Orthopedic surgery is frequently necessary for patients with RA af

Cervical Spine

Depending on the study and diagnostic criteria, involvement of the

The first and most common form is atlantoaxial instability (Figure

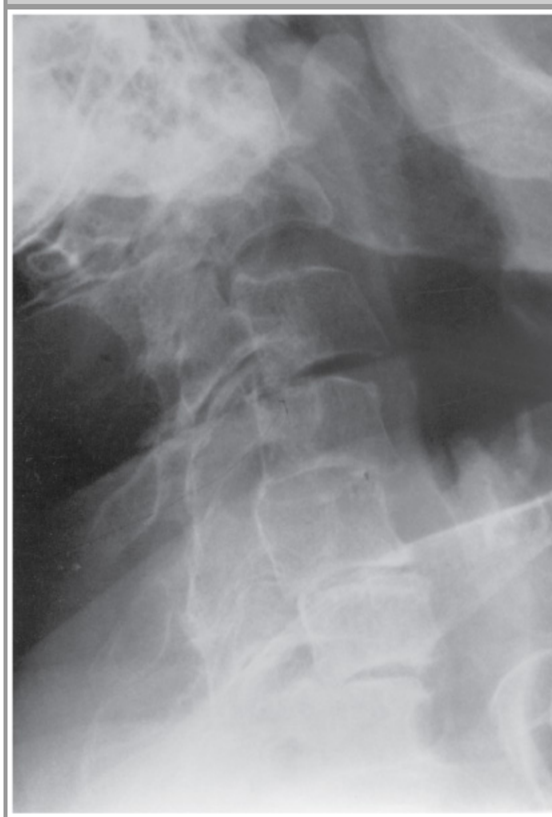
Figure 13–27.



Tomogram of the upper cervical spine, showing atlantoaxial instab

The second form of cervical spine involvement is subaxial instabilit

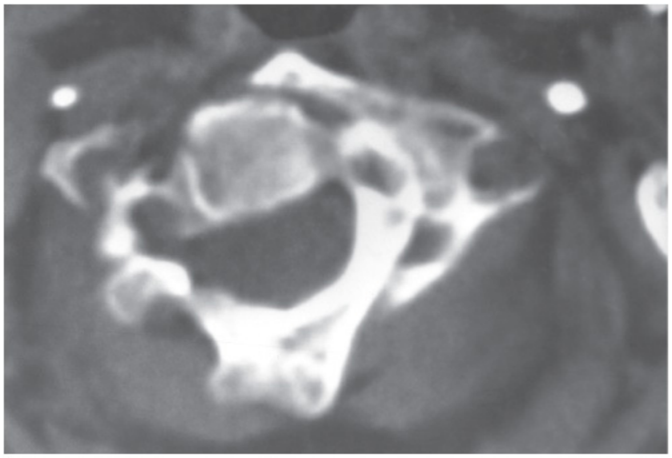
Figure 13–28.



Radiograph of the cervical spine, showing multiple levels of subaxi

The third and least common form of cervical spine involvement is s

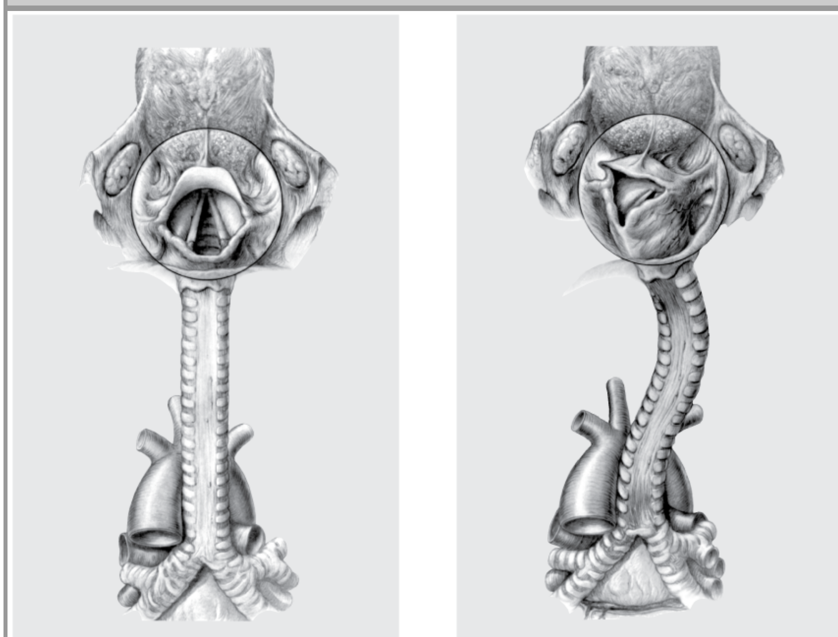
Figure 13–29.



CT scan showing rotational instability of C1 on C2 in a patient with

Orthotic supports are useful in controlling the patient's symptoms.
In patients with severe erosive disease of the cervical spine and pr

Figure 13–30.



Left: Diagram showing the normal relationship of the trachea and

(Illustrations by Ted Bloodhart. Reproduced, with permission, fron

Lower Extremities

HIPS

Total joint replacement has vastly improved the quality of life for p

KNEES

Knee pain is common and may be the result of a valgus deformity

Arthroscopic evaluation of the rheumatoid knee demonstrates the

Total knee arthroplasty is effective in restoring knee alignment anc

FEET

Forefoot involvement is common in RA. Clawtoe deformities with p

Hindfoot involvement is also common and results in a planovalgus

Upper Extremities

SHOULDERS

In patients with RA, shoulder involvement is common but is genera

Arthroscopy provides a useful tool in examining the shoulder and a

Normally, the glenohumeral joint has more motion than any other surgery of the shoulder is performed, it is important to preserve tl

The subacromial bursa is often involved with the inflammatory res

Repair of a ruptured rotator cuff is often possible and should be pe cuff is destroyed, humeral hemiarthroplasty is the preferred surgic

ELBOWS

The elbow joint consists of three separate articulations: radiocapite

Olecranon bursitis is common in patients with RA. The usual treatr

Subcutaneous rheumatoid nodules are common along the extensor

Radiocapitellar arthritis is often the predominant feature of elbow

When the joint destruction is severe, prosthetic arthroplasty is ind

WRISTS AND HANDS

In patients with RA, evaluating the wrist and hand deformities and

Tendons

Dorsal tenosynovitis is common. It is of significance because it ofte

Rupture of an extensor tendon can result from attenuation of the For more complex ruptures, tendon transfer from the wrist extens

Synovitis in the flexor tendon sheaths is characterized by crepitatio

Wrist Joints

The wrist joint is a frequent site of synovitis and may begin to sho

When the wrist becomes unstable, several choices of surgical treat

Another option is to perform a prosthetic arthroplasty of the wrist.

Fusion of the wrist joint provides a stable pain-free joint and rema

Metacarpophalangeal and Carpometacarpal Joints

Finger and wrist deformities commonly occur together in a collapsi

Ulnar deviation and volar subluxation of the fingers at the metacar

Dynamic splinting of the fingers, which maintains alignment while

Flexion of the metacarpophalangeal joint with extension of the inte

Interphalangeal Joints

Continued synovitis gradually attenuates the capsular and ligamen

Flexion deformity results from rupture or attenuation of the centra
fingers are usually selected.

Hyperextension deformities, or swan-neck deformities, can be eith

Derangements of the distal interphalangeal joints are either mallet

Abboud JA, Beredjiklian PK, Bozentka DJ: Metacarpophalangeal joi

Belt EA et al: Outcome of ankle arthrodesis performed by dowel te

Berger RA et al: Long-term follow-up of the Miller-Galante total kr

Chen AL, Joseph TN, Zuckerman JD: Rheumatoid arthritis of the s

Dionne RA et al: Analgesia and COX-2 inhibition. Clin Exp Rheuma

Gordon P et al: A 10-year prospective followup of patients with rh

Johnstone BR: Proximal interphalangeal joint surface replacement

Kauffman JI, Chen AL, Stuchin S et al: Surgical management of th

King JA, Tomaino MM: Surgical treatment of the rheumatoid thum

Nelissen RG: The impact of total joint replacement in rheumatoid a

Shen FH, Samartzis D, Jenis LG et al: Rheumatoid arthritis: Evalua

POLIOMYELITIS

Poliomyelitis is caused by an enterovirus that attacks the anterior

Classification

Four stages of poliomyelitis are recognized.

ACUTE POLIOMYELITIS

All of the anterior horn cells are attacked during the acute stage, v

A variable number of anterior horn cells survive the initial infectior

SUBACUTE POLIOMYELITIS

Anterior horn cell survival, axon sprouting, and muscle hypertroph

RESIDUAL POLIOMYELITIS

It is only after 16–24 months following onset that the ultimate ext

POSTPOLIOMYELITIS SYNDROME

Patients who had acute poliomyelitis during childhood often compla

The diagnosis of postpoliomyelitis syndrome is based on a history o

Management

ACUTE POLIOMYELITIS

When the shoulder muscles are involved, respiratory compromise

SUBACUTE POLIOMYELITIS

During the subacute stage, which may last as long as 24 months,

RESIDUAL POLIOMYELITIS

Patients with compromised function of the diaphragm can be taugl

POSTPOLIOMYELITIS SYNDROME

Treatment is directed at preserving current muscle strength and p

General management strategies consist of modifying lifestyle to pr

Specific management strategies depend on the areas of disease in

Spine

Back pain is a common complaint and usually results from postura

Paralysis of the cervical spine musculature can result in the inabilit

Scoliosis is common in patients with muscle imbalance caused by p

Lower Extremities

Full ROM of the hip and knee joints is needed for function. Contrac

A patient with flailing lower extremities can stand using crutches a
joint is used to stabilize the knee, and ankle dorsiflexion is limited

Quadriceps muscle strength is not essential for ambulation. A stror

Muscle imbalances in the foot can lead to deformity. When muscle

Equinus contracture of the ankle is a common problem and results

A cavus foot deformity causes forefoot equinus, which also limits b

The long-standing muscle imbalances, patterns of muscle substitut
fair (grade 3) strength (see Table 13–1) in the hip extensors, abdu

Upper Extremities

SHOULDERS

The shoulder is important for placing the hand in the desired posit

Preservation of shoulder strength should be a priority of treatmen
or motorized scooter should be prescribed to prevent excessive st

ELBOWS

The elbow requires sufficient flexor strength to lift an object again

WRISTS AND HANDS

Opponens paralysis is common in the hand and results in a 50% lo

Paralysis of the intrinsic muscles of the hand interferes with functi

Paralysis of the finger flexors and extensors can be overcome with

Bruno RL: Paralytic vs. "nonparalytic" polio: Distinction without a d

Chasens ER, Umlauf MG: Post-polio syndrome. Am J Nurs 2000;10

Dhillon MS, Sandhu HS: Surgical options in the management of re

Gandevia SC, Allen GM, Middleton J: Post-polio syndrome: Assess

Giori NJ, Lewallen DG: Total knee arthroplasty in limbs affected by

Klein MG et al: Changes in strength over time among polio surviv

Klein MG et al: The relationship between lower extremity strength

Sunnerhagen KS, Grimby G: Muscular effects in late polio. Acta Ph

CEREBRAL PALSY (STATIC ENCEPHALOPATHY)

Cerebral palsy is a nonprogressive and nonhereditary disorder of i

Classification

Because of the diversity of neurologic findings seen in patients wit

TYPES OF MOVEMENT DISORDER

Three types of disorder are seen.

Spastic Disorders

These are characterized by the presence of clonus and hyperactive

Dyskinetic Disorders

Among the conditions classified as dyskinetic disorders are athetos

Mixed Disorders

These usually consist of a combination of spasticity and athetosis w

PATTERNS OF NEUROLOGIC INVOLVEMENT

Monoplegia

With single-limb involvement, the disorder is usually spastic in nat

Hemiplegia

Spasticity affects the upper and lower extremities ipsilaterally. Equ

Paraplegia

In paraplegia, neurologic deficits involve only the lower extremities

Diplegia

Spastic diplegia, seen in 50–60% of cerebral palsy patients in the

Total Body Involvement

Sometimes referred to as quadriplegia, total body involvement is c

Management

Because cerebral palsy in children is discussed elsewhere (see Cha

SPECIAL CONSIDERATIONS IN ADULT PATIENTS

Musculoskeletal Problems

Long-standing deformities may be rigid. Bony deformities are com

Mobility

The patient who can sit independently has good balance and may

Ambulation can be divided into four categories: community ambula
to expect patients to expend all their energy in merely transportin

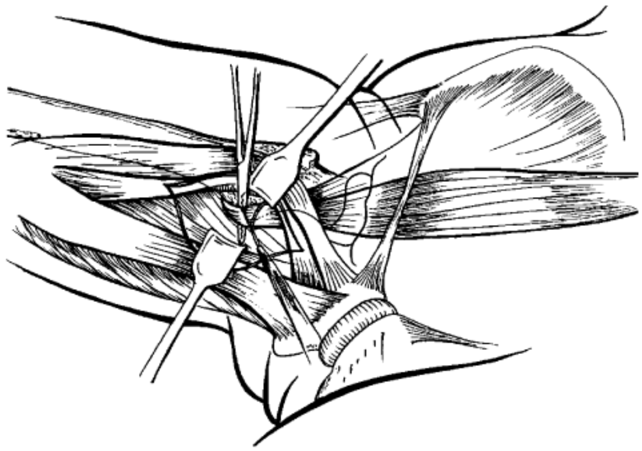
TREATMENT OF PATIENTS WITH LOWER EXTREMITY PROBLE

Hips

An adduction and internal rotation deformity of the hip is sometim

A crouch gait and lumbar lordosis are evidence of hip flexion defor

Figure 13–31.



Release of the iliopsoas tendon from its insertion on the lesser tro
(Illustration by Anthony C. Berlet. Reproduced, with permission, fr

Knees

Correction of a knee flexion deformity in a patient with a crouch ga

Feet

Equinus posturing of the ankle is common. If no fixed contracture

Equinovarus posturing of the ankle is also common. Although the a

If the anterior tibial muscle is overactive, Achilles tendon lengthen

A pes cavus deformity of the foot is occasionally seen in patients w

TREATMENT OF PATIENTS WITH UPPER EXTREMITY PROBLE

Function of the upper extremities depends on a variety of factors,

The Functional Upper Extremity

In patients with problems involving the functional hand, treatment

In some patients, release of objects from the hand is a problem. I

Transfer of a wrist flexor to a wrist extensor should be done with c

The thumb-in-palm deformity is treated by proximal release of the

The Nonfunctional Upper Extremity

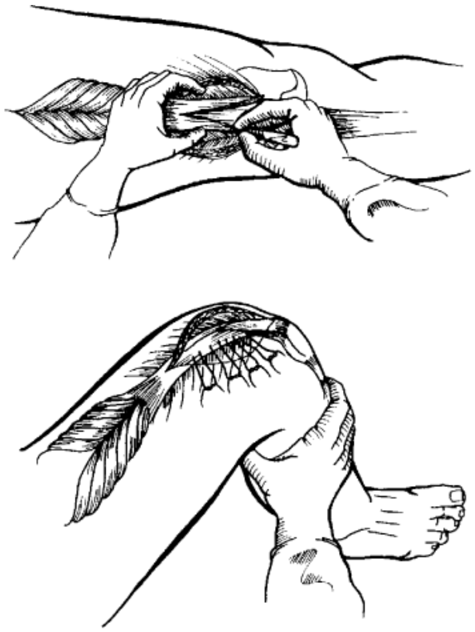
Surgery may be indicated in the nonfunctional upper extremity to
proximal release of the thenar muscles (see Figure 13–24).

TREATMENT OF PATIENTS WITH TOTAL BODY INVOLVEMENT

Patients with total body involvement are rarely functional ambulat

Occasionally, knee flexion deformities require distal hamstring rele

Figure 13–32.



The dV-Y incision (*top*) and lengthening (*bottom*) of the quadricep
(Illustration by Anthony C. Berlet. Reproduced, with permission, fr

Foot deformities in the spastic patient are extremely common and
The spine is of major concern in patients with total body involveme

Buckon CE, Thomas SS, Piatt JH Jr et al: Selective dorsal rhizotom

Johnston TE, Finson RL, McCarthy JJ et al: Use of functional electr

Koman LA: Cerebral palsy: Past, present, and future. J South Orth

Moran CG, Tourret LJ: Recent advances: Orthopaedics. BMJ 2001;

Pfister AA, Roberts AG, Taylor HM et al: Spasticity in adults living i

Sussman MD, Aiona MD: Treatment of spastic diplegia in patients

Tilton AH: Management of spasticity in children with cerebral palsy

Wren TA, Rethlefsen S, Kay RM: Prevalence of specific gait abnorm

NEUROMUSCULAR DISORDERS

The neuromuscular disorders represent a diverse group of chronic
intervention can significantly increase the functional capacity of pa

Table 13–7. Classification of the More Commonly Enc

Disorder	Inherited	Creatine Phosphokinase Level	Electromyographic Pattern	Ne Co
Muscular dystrophies				

Data compiled by Irene Gilgoff, MD, Rancho Los Amigos Medical C

Diagnosis

HISTORY AND PHYSICAL EXAMINATION

A careful genetic history is important. The clinical history and phys

MUSCLE ENZYME STUDIES

Serum levels of muscle enzymes are elevated in myopathies but n

ELECTROMYOGRAPHY AND NERVE CONDUCTION STUDIES

EMG and nerve conduction studies differentiate between primary r
gravis, the fatigue phenomenon is exhibited. In myotonia, the EM

MUSCLE BIOPSY

To gain the maximal amount of information from muscle biopsy, th

Histologically, myopathies are characterized by muscle fiber necro

Neuropathies display small, angulated muscle fibers. Bundles of at

Biopsy findings in polymyositis include prominent collections of infl

Dietz FR, Mathews KD: Update on the genetic bases of disorders w

Esquenazi A et al: Dynamic polyelectromyography, neurolysis, and

Roberts A, Evans GA: Orthopedic aspects of neuromuscular disord

Duchenne-Type Muscular Dystrophy

Duchenne-type muscular dystrophy, which is also called **pseudohy**

Clinical Findings

Early signs of disease include pseudohypertrophy of the calf, which

Weakness and contractures prevent independent ambulation in ap

Management

Efforts are made to keep patients ambulating for as many years a

Equinus contractures of the Achilles tendon occur early and are ca

Surgical intervention is directed toward the release of ambulation-

The triceps surae and tibialis posterior are the strongest muscles i

Scoliosis is common in nonambulatory patients confined to a whee

Fractures in patients with myopathies occur secondary to osteopor

Bentley G et al: The treatment of scoliosis in muscular dystrophy u

Biggar WD, Klamut HJ, Demacio PC et al: Duchenne muscular dys

Do T: Orthopedic management of the muscular dystrophies. Curr

Sussman M: Duchenne muscular dystrophy. J Am Acad Orthop Sur

Yamashita T et al: Prediction of progression of spinal deformity in

Spinal Muscular Atrophy

Spinal muscular atrophy is a neuropathic disorder in which fewer a

Approximately 20% of patients with spinal muscular atrophy are a

The goal of orthopedic intervention is to prevent collapse of the sp

Bentley G et al: The treatment of scoliosis in muscular dystrophy u

Frugier T, Nicole S, Cifuentes-Diaz C et al: The molecular bases of

Hopf CG, Eysel P: One-stage versus two-stage spinal fusion in neu

Iannaccone ST, Burghes A: Spinal muscular atrophies. Adv Neurol

Iannaccone ST, Smith SA, Simard LR: Spinal muscular atrophy. Cu

Nicole S, Diaz CC, Frugier T et al: Spinal muscular atrophy: Recen

Noordeen MH et al: Blood loss in Duchenne muscular dystrophy: V

Charcot-Marie-Tooth Disease

Charcot-Marie-Tooth disease is the most common of the hereditary
The peroneal muscles are affected early in the course of the diseas
The intrinsic minus hand deformity causes difficulty in grasping ob

Aktas S, Sussman MD: The radiological analysis of pes cavus defor

Borg K, Ericson-Gripenstedt U: Muscle biopsy abnormalities differ

Guyton GP, Mann RA: The pathogenesis and surgical management

Olney B: Treatment of the cavus foot. Deformity in the pediatric p

Smith AG: Charcot-Marie-Tooth disease. Arch Neurol 2001;58:101

Schwend RM, Drennan JC: Cavus foot deformity in children. J Am

PARKINSON DISEASE

EPIDEMIOLOGY

Parkinson disease (PD) is a progressive neurodegenerative disorde

PATHOPHYSIOLOGY

The major neuropathologic findings in PD are a loss of pigmented

HISTORY

Onset of PD is typically asymmetric, with the most common initial

PHYSICAL EXAMINATION

The three cardinal signs of PD are resting tremor, rigidity, and bra

MEDICAL CARE

The goal of medical management of PD is to provide control of sig

NEUROSURGICAL CARE

When medical management is exhausted, neurosurgical interventi

ORTHOPEDIC CARE

Treatment of orthopedic problems in patients with PD can be prob

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BURNS

More than 2 million people sustain burns of sufficient severity each

Thermal burns affect the skin most directly but can also involve th

Classification

Burn wounds are traditionally classified as first, second, or third de

First-degree burns damage only the epidermis. They cause erythe

Second-degree burns involve the epidermis and a variable amount

Third-degree burns are full-thickness injuries that damage the epi

Management

TECHNIQUES FOR MAINTAINING FUNCTIONAL POSITION

Burn scars contract and become rigid, so it is critical to maintain t

To prevent deformities of the neck and jaw in patients with burns

When the burns involve the torso, the goal is to maintain a straigh

Regardless of the location of burn wounds on the extremities, the and toe traction are useful.

Burns of the hands present special problems. Scar contracture res

SKELETAL TRACTION AND EXTERNAL SUSPENSION

In patients with circumferential burns on an extremity, the use of

Special splints are fabricated for use in the hand. The traction fran

PRESSURE DRESSINGS

Consistent pressure of 25 torr applied evenly aids in the preventio

MOBILIZATION

Early motion is desirable for burned and uninvolved extremities. S

Patients with burns of the lower extremities can begin to stand or

TREATMENT OF SPECIAL PROBLEMS

Fractures

If fractures occurred at the time of the burn, they can be treated

Osteomyelitis

Osteomyelitis is not a common complication, despite the high incid

Exposed Joints

Children and adolescents with exposed joint surfaces may retain s

Heterotopic Ossification

Periarticular bone formation is seen in 2–3% of patients with sever

Heterotopic bone can continue to form as long as open granulating

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